*Note:For full proposals, the cover page, and sections 1, 2 and 3, together should not be longer than 70 pages. All tables in these sections must be included within this limit. The minimum font size allowed is 11 points. The page size is A4, and all margins (top, bottom, left, right) should be at least 15 mm (not including any footers or headers).*

**COVER PAGE**

**Title of Proposal** ROBOHOME2.0

**List of participants**

*Participant No \* Participant organisation name Country*

1. *ITA UMIL – Coordination + Games for physical and cognitive activity and for education (gamification)*
2. *SWE OREBRO University – Intelligence (2.0 part)*
3. *SWE GIRAFF Giraff Technology – Robot + Integration*
4. *GB PLY Plymouth – HRI, behavior analysis (in collaboration mainly with PCL, SAS and MUN)*
5. *ITA SXT srl – sensors*
6. *ITA PCL Fondazione IRCCS Cà Granda Ospedale Maggiore Policlinico, Geriatric Unit, Elder psychology and clinics, GP network. Milano, Italy*
7. *ITA POLIMI Politecnico Sensors data interpretation (cellular phone data processing?). Design of instrumented objects for controlled monitoring.*
8. *SWE MUNIC, Orebro municipality. Tests in real environments, sociological aspects?*
9. *ESP BDIGITAL Community development.*
10. ESP – SAS, Evaluation and diffusion of the results. Pilot. To be confirmed
11. FRA - Korian group. Service provider.

**Table of content**

[General Objective **Error! Bookmark not defined.**](#_Toc380953992)

[Specific Objectives 6](#_Toc380953993)

[Relation to the work programme 8](#_Toc380953994)

[Concept and approach 11](#_Toc380953995)

[Ambition 19](#_Toc380953996)

[Implementation 20](#_Toc380953997)

[3.1 Work plan — Work packages, deliverables and milestones 20](#_Toc380953998)

[WP1 – Functional Specifications (PCL?) 21](#_Toc380953999)

[Task1.1 (M1-M6): Identification of Robohome stakeholders (PCL?? 22](#_Toc380954000)

[Task1.2(M3-M12): Activities scenarios design (PCL 23](#_Toc380954001)

[Task1.3(M2-M12) Identification of the functions of the Robohome Activity Center (PCL, UMIL, OREBRO…, 23](#_Toc380954002)

[WP2 - Technical specifications 27](#_Toc380954003)

[Task 2.1 (M3-M12) HRI and User Requirements Analysis (PLY, 27](#_Toc380954004)

[Task 2.2 (M3-M18) Multimodal HRI interface design (PLY, **Error! Bookmark not defined.**](#_Toc380954005)

[WP3 –Virtual Caregiver (OREBRO, ……). **Error! Bookmark not defined.**](#_Toc380954006)

[WP4 – Smart Activity Center (UMIL, ….) 33](#_Toc380954007)

[Task4.1 (M1-M12) – Design and Implementation of the Activity Center (UMIL, 35](#_Toc380954008)

[Task 4.2 (M1-M24), Multi-player infrastructure (UMIL, BDIGITAL….) 36](#_Toc380954009)

[Task4.3 (M4-M24) – Mini-games content generation (UMIL,…. 37](#_Toc380954010)

[Task4.4 (M4-M36) – Automatic narrative for education and training (UMIL, POLIMI,…. 38](#_Toc380954011)

[Task 4.5 (M7-M24) Motivation (UMIL, POLIMI, PLY,…..) 39](#_Toc380954012)

[Task 4.6 (M3-M18) Definition of calibration games for video and/or inertial systems (UMIL, 41](#_Toc380954013)

[WP5 - Monitoring 43](#_Toc380954014)

[WP6 - Community 54](#_Toc380954015)

[WP7 – Integration 61](#_Toc380954016)

[WP8 – Pilot 63](#_Toc380954017)

[WP9 – Dessemination and exploitation 69](#_Toc380954018)

[WP10 Coordination 69](#_Toc380954019)

[Task1.4(M2-M9): Identification of Robohome monitoring functions (PCL, OREBRO, POLIMI, **Error! Bookmark not defined.**](#_Toc380954020)

[Task1.5(M2-M12): Identification of Robohome virtual caregiver functions (PCL, OREBRO, POLIMI, 26](#_Toc380954021)

# ABSTRACT

ROBOHOME2.0 develops, integrates and field tests an innovative robot based assisting platform, which assists the elders at home actively promoting a healthy lifestyle. The main idea is to assemble off the shelf components in a robust and reliable way to get a low-cost system that can be deployed massively at home. The platform consists in three hierarchical levels: 1) a community of stakeholders that provides a tight connection between elders and formal and informal caregivers, and promotes socialization; 2) an intelligent virtual caregiver that proposes activities according to the elder idiosyncrasies and needs, adapting them according to the elder status on a daily basis; 3) a service level, centered on a Giraff service robot that works as an active companion. The system is complemented by a set of sensors that capture possible risks and lifestyle information and provide a controlled evaluation of the physical/cognitive capability through gesture sequences signature. A fully body-free approach is pursued to provide maximum adherence to the system. Giraff cooperates with a smart activity center to provide adapted personalized activities. The most adequate physical, cognitive and social activities will be identified and the proper mix of activities for each elder will be suggested on a daily basis to provide the maximum effectiveness. Activities will be implemented resorting as much as possible to the gamification paradigm to stimulate the maximum adherence and motivation. A pilot is designed to evaluate the effectiveness and suitability of ROBOHOME2.0, and to obtain a continuous active evaluation and refinement of the technical specifications since the beginning of the project.

**Workpackages:**

WP1 – Management

WP2 – User and technical requirements (PLY: functional specifications elicited by stakeholders and clinical partners: SAS and PCL in collaboration with MUNIC, technical offer provided by tehnological partners: UMIL, BDIGITAL, OREBRO, POLIMI, technical specifications will follow functional specifications, refinement of implementation specification throughout most of the project)

WP3 – Virtual care giver (OREBRO, ……).

WP4 – Smart activity center (UMIL, ….)

WP5 – Community (BDIGITAL, ….

WP6 – Monitoring (POLIMI, SME…..)

WP7 – Integration (GIRAFF)

WP8 – Pilot (MUN or SAS or PCL, …)

WP 9 – Dissemination (UMIL)

**1. Excellence**

# 1.1 Objectives

## ROBOHOME2.0 General Objective

In Europe, the share of people aged 65 years or over in the total population is projected to increase from 17.1% to 30.0% and the number is projected to rise from 84.6 million in 2008 to 151.5 million in 2060. Similarly the number of people aged 80 years or over is projected to almost triple from 21.8 million in 2008 to 61.4 million in 2060[[1]](#footnote-1) and the availability of nurses is already becoming an issue in the US[[2]](#footnote-2).

Physical activity, cognitive stimulation, social inclusion, balanced diet promote a lifestyle that guarantees a **slow progression of decline, thus enabling the elder to live at his home healthy for a longer time**. This is becoming a priority in Europe as recognized by the EC community: managing frailty and functional decline through targeted interventions, enhancing participation and independence, and promoting systematic-routine screening for pre-frailty are among the specific objectives of the Action Plan on “Prevention and early diagnosis of frailty and functional decline, both physical and cognitive, in older people” of the European Innovation Partnership on Active and Healthy Ageing (Bruxelles, November 6, 2012).

Physical activity, cognitive stimulation, social inclusion are highly inter-twined[[3]](#footnote-3). Regular physical exercise has been shown to be effective at maintaining and improving the overall health of elderly individuals[[4]](#footnote-4),[[5]](#footnote-5),[[6]](#footnote-6).[[7]](#footnote-7). Physical fitness is associated with higher functioning in the executive control processes[[8]](#footnote-8), correlated with less atrophy of frontal cortex regions[[9]](#footnote-9), and with improved reaction times[[10]](#footnote-10) compared with the sedentary. Social interaction, and specifically high perceived interpersonal social support, has also been shown to have a positive impact on general mental and physical wellbeing[[11]](#footnote-11), in addition to reducing the likelihood of depression[[12]](#footnote-12),[[13]](#footnote-13),[[14]](#footnote-14),[[15]](#footnote-15).

Several approaches have been proposed to address some of these aspects [PCL EXPANSION WITH QUOTATION] but their impact comes short as they are not able to address such inter-twined needs, thus providing limited potentiality for exploitation. Moreover, a high emphasis is put on wearable devices for monitoring that, at present, limit the compliance of elder people that would maintain their habitudes and attitudes unchanged [PSYCHO ISSUE – PCL].

**Main goal of ROBOHOME2.0 is to address the whole spectrum of need of an elder person, especially when falling in a fraile state, through a comprehensive holistic approach, addressing cognitive, physical and social monitoring and developing a pro-active stimulation towards a all these three components, can maximize the promotion of a healthy lifestyle that is negotiated with the elder himself. ROBOHOME2.0 shift monitoring of the elder from wearable devices to the ROBOHOM2.0 platform itself that perform, mostly transparently, through the activity center.**

We will fully leverage to recent ICT developments to design and realize and innovative platform for elder empowerment and managing aging in the most successful way for the elder himself first and for his ecosystem, by realizing a distributed hierarchical system (Figure 1).

Community of stakeholders

GP, geriatrists

Social services

Care givers

Virtual Caregiver elder 1

Virtual Caregiver elder 2

Virtual Caregiver elder N

Intelligent ambient monitoring

Giraff

Activity center

Figure 1- The Hierarchical Structure of ROBOHOM2.0

ROBOHOME2.0 has the ambition to go beyond the available prototypes and devices to achieve two accomplishments: promoting healthy lifestyle and monitoring the elder in a comprehensive and integrated way, leveraging novel ICT technology. It will assemble off the shelf components in a robust and reliable way to get a low-cost system that can be deployed massively at home. To achieve this, several steps have to be completed.

We aim at developing a modular low-cost robot-based system to assist physical training allowing 3D gaming experience integrated into a sensorized home. The system will conform to the health status and the personal needs of the single subject. The system will assure a home monitoring, both during exercises and daily living activities, in order to adapt the exercises proposed to the elder to her actual conditions, within a predefined range, and eventually to alert the caregivers, the family and the general practitioner about the changing situation. Interoperability with most of assisted living devices’ standards, such as alarms, devices for therapy adherence, remote control of home settings as well as the integration with a telemedicine platform will be considered as prior requirement. The design will aim at the user experience of a friendly control and interaction with the system. A set of multiple applicability scenarios, spanning from the old independent adult to the chronic disable person living at home will be defined. A cohort of XX end-users, care-givers and physicians, will be involved both in the definition of the requirements of the system and in testing the system. An extended evaluation will be set for each scenario within a within a living lab; the evaluation will include the acceptability by the users and their caregivers and, when applicable, also the evaluation by other actors, such as the family doctor, the physiotherapist, etc.

Characteristic of RoboHome is a tight integration of monitoring inside everyday life of the elder with no impact on him. Monitoring and activity results are used to refine the activities inside the virtual caregivers, but they produce valuable data for the remote caregiver, clinicians, and social service who may want to intervene to advice the patient and to steer the virtual caregivers. Video-communication with elder and data transfer to the virtual caregivers will be made available.

## Specific Objectives

In particular, here are the specific Objectives of RoboHome2.0:

1. **To promote elders education to healthy lifestyle, self-empowerment, and increase their perceived usefulness in the society aiming at improving quality of life of the elders and their formal and informal caregivers**
2. **Monitor and prevent frailty, age-related cognitive and physical decline and social exclusion based on a sensorized home for a non-intrusive evaluation of activities of daily living and behavior.**
3. **To develop a single user intelligent virtual caregiver able to profile the system to user interests and conditions, suggesting motivated exercises and context driven activities.**
4. **To develop a multi-user gaming platform to propose interactive training activities.**
5. **To field test a complete ecosystem, involving all stakeholders, to gather evidence of ROBOHOME2.0 benefits.**
6. **To demonstrate the cost-effectiveness of technology and develop a proper business models for the technology transfer to massive use within a sustainable healthcare system.**
7. **Non intrusive evaluation of the elder status on a daily basis.**

To address these challenges ROBOHOME2.0 will develop the following set of devoted technologies methodologies ingredients aimed to create an ecosystem to support prolonged life at home, aimed to create an ecosystem to support prolonged life at home:

1. **STAKEHOLDERS COMMUNITY.** A community that promotes socialization and exchange between elders, thus avoiding isolation and promoting healthy lifestyle. The community will provide structured knowledge and suggestions in structured domains, like diet and managing sickness and will allow to support discussion and communication between clusters of elders with similar profiles that self-organize inside the community. The community will also support multi-player gaming functionalities that will be the basis to let those elders who cannot go out socialize and also learn new acquaintances. It will also act as shared repository of cognitive activities that can be structured and returned into reports that can be made available outside the community.
2. **SERVICE ROBOT** The system will capitalize on Giraff robot[[16]](#footnote-16) that will be further extended to meet the project challenge. Giraff will be endowed with an embodied cognitive system fully interacting with the elder, the sensorized home and with the community of stakeholders.
3. **VIRTUAL CAREGIVER Design and implement a intelligent system** which analyzes the elder status and history and suggests structured and unstructured physical, cognitive and social activities to the user. It adapts the level of difficulty of the activities to current status of the user, as monitored by the sensorized home and by the interaction with the robot and the gaming system. Personalization will aim at attaining the maximal motivation, involvement, and attention of the user favoring health benefits. Adequate algorithms from machine learning domain will be used to profile the patients activities and detect early meaningful deviations from typical behavior, providing also information also to clinicians and caregivers and eventually change the overall Robothome 2.0 user scenario.
4. **HUMAN ROBOT INTERFACE Implement the most natural human-robot interaction interfaces, which** will be used for natural and simplified communication, provided according to different degrees of functional impairment of the elder. Such interfaces will be designed, developed and tested with the stakeholders for all the components developed to achieve a unitary and effective use of the system.
5. **ACTIVITY CENTER. Design and implement a personalized activity service system**, based on the gamification paradigm and fully integrated with the robot and with the community of stakeholders. The center will provide cognitive, physical and social activities and it will also support education towards healthy lifestyle, promoting knowledge and self-empowerment of the elder.
6. **SENSORIZED HOME. Identify, design and network a set of sensors that allow to detect risks and to monitor the elder status**. This will require, for instance, to instrument some of everyday life objects (e.g. the cane, the trolley, or other everyday use instruments) to derive patterns of interaction with them. A specific more complex set-up will be identified to identify the performance and dexterity of the elder in certain daily activities to early detect decline.
7. **BUSINESS MODEL. Define a sustainable business model to massively deploy Robohome2.0.** Evaluate the actual market and available services and elaborate a possible model that takes into consideration the variety of actors that can be involved: from public to commercial entities, non-profit, philanthropic and other forms of social organization. Costs and benefits will be made explicit, analyzing also hidden costs in the actual model. This will regard the whole platform as well as its constituent and will be carried out throughout the project development. A summary of the objectives and technology/methodology ingredients is summarized in Figure 2.



Figure 2 – Objectives as a function of the component / methodology identified to achieve them.

# 1.2 Relation to the work *programme*

**The call mentions the following risks for ageing population: 1) cognitive impairment, 2) frailty and 3) social exclusion.**

We address these three risks with a holistic approach that is based on three main pillars: monitoring, activities and evaluation that are not carried out in isolation, but while the elder carries out the activity of everyday life.

**How ROBOHOME2.0 will reduce the risk of cognitive impairment?**

Cognitive impairment will be addressed in a pro-active way, by proposing activities that match the actual elder competence and are negotiated with him / her. Activities (WP4), monitoring (WP5) and evaluation (WP7) are carried out on activities that can mix the three aspects at the point of need (WP3).

ROBOHOME2.0 system will include different gaming experiences modulated on the single user condition. These games will comprise pphysical exercises, training fitness programs as well as cognitive exercises such as playing cards, memory games and making puzzles, recognize the sequence of a cooking receipt etc.

**How ROBOHOME2.0 will reduce the risk of frailty?**

Frailty syndrome is the most important in the elderly population and is defined as a state of excessive vulnerability to environmental factors accompanied by a progressive decrease in the functionality of many organs and body systems. This functional loss occurs gradually, resulting in disability situations that diminish the quality of life and can even lead to death[[17]](#footnote-17).

ROBOHOME2.0 will stimulate the elder and keep her active. In addition, the scores obtained during the games along with some data derived from the sensorised home, will be used to assess the status and the level of activity of the user to monitor it and promptly register a possible physical and cognitive decline. Specific validation of these decline alert parameters will be included into the project activities. These feedback parameters will be functional to 1) adapting the system to the changing conditions of the user; 2) follow up the user status keeping the carers informed and eventually favoring appropriate and timely interventions.

**How ROBOHOME2.0 will reduce the risk of social exclusion?**

About the problem of social exclusion of the elderly, ROBOHOME2.0 will set a community of users, so that they will be able to connect each other, to make multiplayer games and also to exchange the experience of using the system. ROBOHOME2.0 intelligence will make simple suggestions to the users including solicitation to stay in touch with the relatives, the friends, etc., following the specific setting of the single user.

**How ROBOHOME2.0 will improve independence?**

ROBOHOME2.0 will assure the elder keeping active with an everyday cognitive and physical training, properly calibrated on the single user’s requirements, assuring rewarding experience and confidence of the subject in her/his capability.

In addition, ROBOHOME2.0 will help the elder in some simple but basic tasks related to independent living such as finding the keys, the glasses and the mobile phone, remembering the time for having meals, remembering the medicines to assure prescription adherence.

**How ROBOHOME2.0 will improve quality of life, that of those who care for them?**

The quality of life will be changed by the positive interaction of the user with the system , into a single user setting able to match the interests of the elder and to stimulate her/him in keeping active and connected. The carers will be helped in the care practice (prescription adherence especially for informal carers like the relatives could be not so much easier that for the elder), and they will perceived help both in the effort to keep the elder active and in monitoring her/his health status and decline.

**How ROBOHOME2.0 will improve the sustainability of the health and care system?**

ROBOHOME2.0 will allow private partners, like Korian group, to enter in the social services domain providing a continuity of the assistance provided by public bodies.

The progress of the physical decline of elderly people sometimes is abrupt, such as in case of dramatic events (stroke, falls, psychological traumas) but sometimes it is a slow progress which might be even negliged by the relatives. The lack of recognition of worsening could provoke dalyed interventions which amplify the decline itself, inducing a negative loop which impact on the requests to the health and care system. ROBOHOME2.0 project will include into the system also a validating set of activity measures (based on the games and on measures of daily activities) capable to monitor the cognitive and physical decline of the user and will communicate a periodic report to the family doctor, so to allow prompt and tuned intervention in case of worsening, slowing down the progression.

For the most severely impaired users, specific supervisions of clinical measures (blood pressure, glucose) will be included into the ROBOHOME2.0 system so to alert critical situations, so to permit anticipated discharges and limit the risks of relapses. ROBOHOME2.0 will communicate the data, when dangerous, directly to the clinicians.

**The challenge is to develop new breakthroughs for active and assisted living based on advanced ICT solutions.**

Hereafter, an analysis of the crucial ingredients of the aim of the call with respect to the ROBOHOME proposal is detailed.

**Service robotics:** The ROBOHOME project is based on a commercial off-the shelf service robot (GIRAFFE), which will be enriched with a multiplayer gaming engine and will be integrated into a system of sensorized home.

**Assisted living environment:** proper environmental sensors will be integrated into the ROBOHOME2.0 system to monitor subject behaviors and recognize situations. The data from sensors will be usedto choose what to propose to the user by the robot and also to keep a continuous monitoring of the subject’s status to alert the carers as well as the family doctors or clinicians (cf. Figure 3).

**The project should combine multi-disciplinary research involving behavioural, sociological, health and other relevant disciplines.**

- *behavioural discipline:* partner PLY has a strong background on Human Robot Interaction evaluation and will contribute to ROBOHOME2.0 from the design of the user requirements, to the design of the metrics to evaluate the user acceptance , the user experience and also the carers’ feedback. All the interfaces will be designed with this in mind to obtain a unified view of the system and maximize usability. PLY will extensively participate to the evaluation of the project with the pilot study.

- *social discipline:* social scientists from MUN and PCL will assure both in the design and in the evaluation phases that the project has a positive impact both on the social inclusion of the user and on the external society (including the family, the carers, the family doctor, the clinicians involved in the care as well as the society, in more extended sense)

- *health discipline:* two teams of clinicians (PCL and SAS) with complementary specializations (GP and geriatry) and a group f bioengineers (POLIMI) will collaborate to the project in order to set how the games and the activity acquired by the environmental data will be used to monitor the health status of the user focusing on parameters to monitor the cognitive and physical decline. Specific clinical need of the user will be integrated into the system upon request to monitor comorbidities. Physical trining is included into the game engine to reduce the most relevant risks (like falls), the burdening of mild disabilities (also cognitive) to the physical decline. For the most severe disabled, simple home-based rehabilitative treatment will be included into the game platform, reducing the days spent in hospitals and preventing relapses.

**The expected characteristics of the solution:**

- *modularity:* this is typical of robots, e.g. to be differently combined with the sensorised home and depending on single user needs

- *Cost effectiveness:* We must have in mind an acceptable final target price. This, of course, depends on what we are offering but some external feasible limits should be clearly known and considered (they could be something about 5 to 10 kEuro, but Simona is doing a sort of market research on this)

- *Reliability*: the system has to reliably acts upon a finite variety of scenarios. Note that reliability and safety will somehow be counterpart of the intelligence of the system and its automatic adaptation.

*-Adaptivity.* We should provide at a certain level, a system that can learn from users feed-backs. For instance it can learn preferred activities for users or her idiosynchrasies.

- *Flexibility:* of course flexibility could be devolved upon the onboard intelligence of the control system to adapt to changing scenarios, but a robot could be extremely risky in terms of safety and safety is another expected characteristic. We can develop the concept on a scenario based: a sort of list of scenarios can be compiled, each having a well defined configuration of the system and allowing some automatic behavior but not that much to comply with reliability and safety. The scenarios could be defined, depending on the physical condition of the user. A crucial way to address the broadest flexibility is interoperability of the system with standards, so the system is conceived to be easily operated in a bespoken complex, integrated service. Note that flexibility is required also to a range of social expectations (to be clarified).

- *applicability to realistic settings:* home setting will be the final target. To evaluate the real applicability at home of the proposed solution (which is indeed a prototype and not a commercial device) the idea would be to carry and extended (in time and number of users) evaluation within a living lab for the multiple scenarios (MUN, SAS and PCL might host these).

- *acceptability to end-users*: psychologies and sociologies will define this point. Acceptability to user should include the elderly users but also the caregivers and for the scenarios where it is applicable also other actors, such as the family doctor, the physiotherapist, etc.

To make this steps mostly effective we will spouse an approach that is based on:

- realizing a system that can be fully configurable and adaptable. Interfaces will be designed such that thay can be personalized and adapted to the current status both with the elder and with the community of the stakeholders. Similarly activities and monitoring will be adapted as much as possible to the elder profile.

- No constraint on the elder is required to allow maximal compliance.

- Off-the-shelf components will be assembled in a robust way to realize the platform, such that it can be massively deployed at elder’s home.

- Push towards a social lifestyle, although a more private way of life is taken into account for elders who are not inclined to socialization.

# 1.3 Concept and approach

• *Describe and explain the overall concept underpinning the project. Describe the main ideas, models or assumptions involved. Identify any trans-disciplinary considerations;*

*• Describe the positioning of the project e.g. where it is situated in the spectrum from ‘idea to application’, or from ‘lab to market’. Refer to Technology Readiness Levels where relevant. (See General Annex G of the work programme);*

*• Describe any national or international research and innovation activities which will be linked with the project, especially where the outputs from these will feed into the project;*

*• Describe and explain the overall approach and methodology, distinguishing, as appropriate, activities indicated in the relevant section of the work programme, e.g. for research, demonstration, piloting, first market replication, etc;*

*• Where relevant, describe how sex and/or gender analysis is taken into account in the project’s content.*

*Sex and gender refer to biological characteristics and social/cultural factors respectively. For guidance on methods of sex / gender analysis and the issues to be taken into account, please refer to* [*http://ec.europa.eu/research/science-society/gendered-innovations/index\_en.cfm*](http://ec.europa.eu/research/science-society/gendered-innovations/index_en.cfm)

Frailty, cognitive and physical decline are syndromes that progress slowly but constantly over time and the standard monitoring methods such as brief and periodic visits conducted about every 6 months, or clinical evolutions based on patient reported questionnaires are not enough to early detect meaningful changes or significant but rare events such as fall, naps or transient neurological events that sometimes are just forgotten by the elder because of their rare occurrence. A continuous monitoring of the elder during his/her daily activities can help geriatrics in promptly recognizing aging changes.

Recently an alternative approach of monitoring was proposed based on the so called “smart homes” equipped with sensors to monitor the user at home and with advanced ubiquitous and pervasive computing. Indeed remote, automated patient monitoring and diagnosis, may be very promising in advancing home care, and in enhancing patient self-care and independent living [Orwat et al 2008].

Many studies were proposed to identify the most typical activities by means of domotics (Berenguer, et al 2008; Gupta, et al 2007; Noury et al. 2009) or using body-worn sensors (Atallah, et al 2009; Logan et al 2007; Min, et al 2008; Park & Kautz, 2008). Other studies monitored the health status using sensors distributed in the house: Hagler et al proposed infrared ceiling sensors equally spaced to detect the gait speed of the elder while moving within a corridor (Hagler et al, 2010)

; Hayes et al., 2008; Kaushik, Lovell, & Celler, 2007; SAPHE, 2010; Virone, Noury, & Demongeot, 2002).

BEYOND THE STATE OF THE ART

A gamut of issues, such as personnel organization, direct and structured involvement of stakeholders and community, clinical validation of the proposed monitoring, privacy and safety concerns, or financial issues have to be faced and overcome before the real deployment of these promising systems at home. Thus, there is the need of an intensive research in this field.

We here develop innovative monitoring modality that is embedded in the usual lifestyle such that the elder does not perceive monitoring as an activity disjointed from ordinary life. This novel monitoring modality will comprise cognitive physical and social aspects all important to assess meaningful aging changes. We are going not only to monitor the user in his/her environment but in a strict collaboration between geriatrics we are here proposing a new model of both monitoring and stimulate the elder during his/her daily life. Specific context aware software will be developed based on static rules based on the initial user profiles and on dynamic rules updates based on the assessment of the user response to the exer-games and the stimuli provided by the Robohome platform and on the user behavior and typical instrumented or monitored ADL performed at home. The results achieved by this pervasive and intelligent software will be crucial to the decision making process that will comprise 1) the involvement of geriatrics in order to check, when necessary the patient condition through novel telemonitored and instrumented clinical tests and 2) the change of the user profile thus implying a change of the training program provided to the user by the Robohome platform.

The theme of elder assistance and aging well has been addressed by several research projects both under FP7 and AAL frameworks aimed at improving the quality of life of elder people, some targeting also disabled people.

The idea of having a robot that interact with an assistive environment has been explored in the **Companionable** project (<http://www.companionable.net>), where a mobile robotic companion interacts with a smart home sensorized environment with the aim of monitoring the elder against cognitive decline and stimulating cognitively him. Moreover, it can detect adverse events like falls. The **Robo M.D.** project (<http://www.innovation4welfare.eu/307/subprojects/robo-m-d.html>) was aimed specifically to detect critical situations like falling and launch an alarm. These concepts have been further developed in the **Excite** (http://www.aal-europe.eu/projects/excite/) and **Giraff+** projects (<http://www.giraffplus.eu/>), coordinated by OREBRO, in which a wider range of heterogonous signals are used to monitor the elder and to provides a pictorial representation of his/her activities that can be used to assess her/his lifestyle. Monitoring is complemented with a low-cost service robot that provides local feed-back and assists the elder. The **Robot Era** project (http:// www.robot-era.eu/robotera/), provides a complementary view providing a set of robots that assist the elder in specific functionalities of every day life like moving objects [PLY and OREBRO may comment on this]. On the other end, a few projects have explored the use of low-cost technology for support elder at home. The **Oldes** project (<http://www.oldes.eu/home.html>) is aimed to offer stimulation and remote overview to improve the quality of life of elder people, through a care platform designed to ease their life in their homes. More recently the **Wecare** AAL project (<http://www.wecare-project.eu/>) explores the social aspects in building a community to support the elders to live alone. These projects have provided a large step forwards in service robotics for assisted living but do not provide the pro-active stimulation that may be beneficial for an elder at home. Moreover, they do not address the elder needs as a whole, focusing on particular aspects.

Several projects have been based on wearable devices to monitor elders at home. The **Rosetta** project (<http://www.aal-europe.eu/projects/rosetta/>) was aimed to monitor activities of elderly persons with sensors to generate alarm when unexpected activity, like a fall, is detected and support the elderly in carrying out daily and recreational activities. Monitoring of Parkinson people is carried out similarly in the **Cupid** project (<http://www.cupid-project.eu/>) that completes monitoring with specific rehabilitation exercises. The aim of the **Interaction** project (<http://cms.interaction4stroke.eu/drupal/>) is to develop a system based on e-textile and sensors to monitor motion and force exchange between a subject and the environment and to profile his activity. Using a similar approach, the **Psyche** project (<http://www.psyche-project.org/>) has developed a monitoring system based on e-textile and portable sensing devices for the long and short term acquisition of data from screened, patients, typically affected by mood disorders to manage psychiatric illnesses. However, the need to wear sensors limits strongly the usability of these systems that are still bounded mainly inside the research domain [PCL comment on this].

A comprehensive approach has been pursued in the **Fitrehab** (<http://www.innovation4welfare.eu/287/fitrehab.html>) and the more recent **Rewire** projects (<http://www.rewire-project.eu>), coordinated by UMIL and participated also by SAS and BDIGITAL, in which monitoring and assistance were embedded inside a multi-level hierarchical platform. Moreover, Rewire has shown that assembling off-the-self components, patients discharged by the hospital, are enabled to continue exercising intensively at home, still under supervision by the clinicians.

Robohome2.0 combines the Giraff robot and the service model envisioned in the Giraff+ project with the activity center developed in the Rewire project to realize a modular system that addresses in a holistic way, the needs of superivision, evaluation and assistance of the elder at home. A unifying view of the components, the modularity of each sub-system, an effective modular personalized design of the interfaces, a transparent monitoring system, clinical assistance and smart supervision through the virtual caregiver and through the community of stakeholders are combined with the choice of off-the-shelf components and a non-intrusive approach to make such system massively deployed at elders’ homes. Moreover, a full integration of the social aspect through a community of the stakeholders and through the design of social activity will make the platform even more effective [PCL, SAS, MUN, KORIAN comments].

Besides research projects, a few companies have approached assisted living market through robotics. Giraff technology ([http://www.giraff.org/](http://www.giraff.org/?lang=en)) has developed over the year the **Giraff** robotics platform that is aimed in containing the costs on one side, and on the other side has been developed with particular attention to a good interfacing with the elder. Giraff robot has been awarded “Most Promising Innovation” of 2011 by the AAL organization. Moreover, touch screen display and Kinect 3D sensors are already provided as standard devices, that allow integrating activities smoothly and effectively.

A similar robot is **Kompai**, developed by Robosoft (<http://www.robosoft.com/robotic-solutions/healthcare/kompai/index.html> ) inside the Domeo project (<http://www.aal-domeo.eu/>) which is meant as an open robotics architecture with, presently, limited capabilities.

As shown already by research projects, these robots can have a large market appreciations if they can work as a hub to acquire, analyze elder’s activities and provide feed-back both to the elder and to the caregivers.

To achieve this we need to provide a closed loop system that provides the following functionalities: **monitoring** to acquire information from the elder and clinical status as well on his/her environment; **evaluation** of his/her situation and **assistance** to provide pro-actively a mix of activity that are suitable to the elder’s profile. Moreover, clinical testing as well as concrete help in adhering to the therapy will be provided.

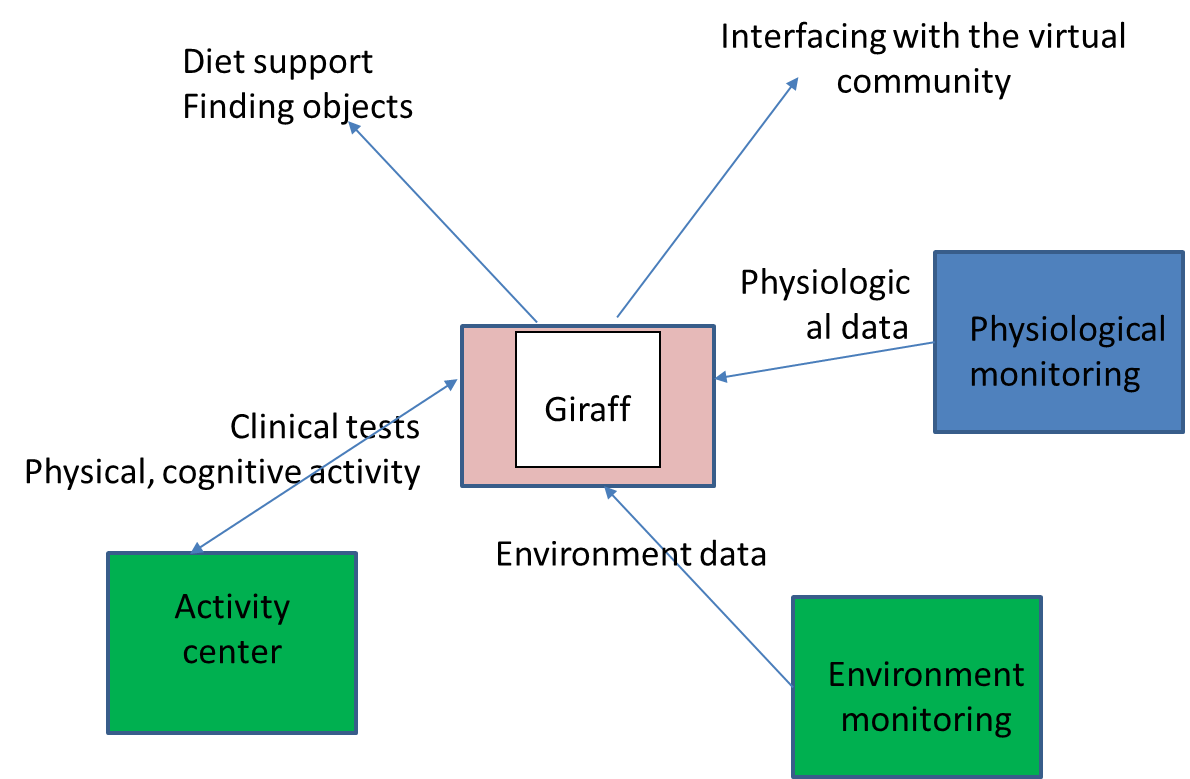


Figure 3- The different components for monitoring and assistance are shown. Evaluation takes place inside Giraff.

## Monitoring

The main element that hamper the prolonged living at home of the elder is monitoring. [PCL, SAS, MUN, KORIAN: further elaboration and references]. Monitoring have different facets that all contribute to make the elder and his caregivers feel safe and supervised at home and it is delineated in Robohome2.0 along different directions:

* ***Environment monitoring***, to guarantee safety on one side (e.g. gas alerts) and to acquire data that influence activities as well as the other monitors.
* ***Cognitive monitoring,*** to monitor the cognitive residual abilities of the elder through time and pro-actively suggests adequate interventions.
* ***Physical monitoring,*** to provide a quantitative evaluation of the motion control capabilities of the elder, especially related to maintaining balance.
* ***Clinical monitoring,*** to assess the elder’s clinical status and to manage alarm situations in due time.
* ***Social monitoring,*** to provide a qualitative evaluation of the social habitude of the elder.

**Scenario**

**“Mrs. Mary is ready for her daily exercise sessions, walks to Giraff and asks for exercising through the touch screen. Robohome2.0 shows her the daily program and at the same time it downloads from the environment sub-network the environmental data taken directly from the ambient sensors. The virtual caregiver analyzes the data and realizes that it is too hot and humid today to maintain the same level of exercise as the days before and tunes the games difficulty. It sends a message to both the elder and the caregivers and allows Mary to start her daily exercise”.**

**Scenario**

**“Mr. Cottrel is approaching Giraff for exercising. Upon termination, the virtual caregiver avatar asks him to take heart beat measurements pressing the adequate button of his Smart Phone. The virtual caregiver realizes that the heart rate is much higher than usual for the same amount of physical activity. It launches a warning to Mr Cottrel’s GP, and informs also the elder that a tele-consulting session will start soon”.**

***Environment monitoring*** has been addressed in the field of the safety at home is a domain that has been long addressed by the domotic industry: gas alarms and light alarms have long been developed as stand alone (e.g. <http://www.beghelli.it/>) or as devices that can be also integrated in a house control panel (<http://allarmiwireless.net/shop/>). Additional measurements can be added, like temperature and humidity. For instance, BDIGITAL add proposed system that integrates inside a single complex sensor temperature, humidity, luminosity and gas alert. Indeed such aspect is integrated inside Robohom2.0, using the most promising off-the-shelf devices at project start, that will provide environment parameters that can be used both for safety reasons and for tuning the system (Task ??). Such sensors will be integrated into a modular sub-network that uses the recent novel standards, like low-power Bluetooth for minimal intervention and longest battery duration. Such sub-network will be interfaced with the Virtual Caregiver inside Giraff.

***Physical monitoring.*** The progress in micro and nanotechnology and the availability of miniaturized sensors, has made available a huge range of small wearable devices devices that are used mainly in the fitness market, from simple pedometer to computerized trainers that allow measuring heart rate, calory consumption, local speed and additional parameters of the physical exercise (e.g. <http://www.polar.com/us-en/products>. Similar principles have been applied to derive products applied to clinical evaluation (http://www.gaitup.com/). These devices are usually mounted in charming cases that makes these objects fashionable and trendy. However, on one side they allow collecting limited amount of information, on the other side they require that the user wearing them.

The new generation of these devices is connected wireless through a hub that integrates different information, this hub is typically a smart phone. Fitness is still the leading market for this; for instance personalized training paths can be acquired from the web and displayed in real-time along with the actual physical data (heart beat and position) to provide to the athlete both environment and physical information (e.g. <http://sites.garmin.com/edge/>).

~~Clinicians have provided some skepticism on these devices as the compliance on the long run of a normal elder people is bounded to be low [PCL, SAS, MUN, KORIAN references].~~

***Cognitive monitoring,*** is based on evaluating the basic cognitive function: memory, reasoning, orientation [PCL, SAS, MUN, KORIAN references]. This is usually carried out through standardized tests (e.g. Mini-mental, ….).

***Clinical monitoring.*** Huge progress has been achieved in the last years for clinical monitoring. The possibility of carrying out routinary exams at home is now a reality and we will take advantage of this possibility to integrate inside Robohome2.0, clinical monitoring through off-the-shelf components.

In the very last years we are seeing a unification of monitoring for fitness and for clinical purpose. Indeed heart frequency measurement is commonly picked up by most fitness devices Although they do not provide the detailed depolarization / repolarization wave, the information provided is considered sufficient for clinicians. For instance, IMEC (<http://www2.imec.be/be_en/home.html>) has proposed wireless ECG, EMG and EEG devices that can be connected to an android phone to enable reliable long-term ambulatory monitoring of various health parameters such as cardiac performance, brain activity and muscle activity. Portable devices for sugar measurement are also available. ~~Other material to be inserted by KORIAN~~. Most recently, Samsung has revealed its S5 Smartphone that has an integrated sensor for measuring heart beat. In Robohome2.0, the most convenient sensor/system to measure a specific required clinical parameter will be implemented.

Similarly to environment sensors, clinical sensors will be integrated into a modular sub-network based on recent standards, like low-power Bluetooth. Such sub-network will be interfaced with the Virtual Caregiver inside Giraff. Multiple solutions for the same parameter, like for instance heart beat, will be considered and interfaced.

***Social monitoring,*** this is a new aspects that is becoming more and more important in a society in which the elder is often left alone [PCL, SAS, MUN, KORIAN references]. Although an automatic identification of all the possible activities is beyond reach, we will identify some activities that have a social role, like doing cooperative activities through Robohome2.0 (see assistance section). Social monitoring will be carried out also through telephone conversations. In this domain the frequency and duration of the calls as well as an analysis of the pitch and pace can provide information on the actual elder social inclination and mood as well as their change over time[[18]](#footnote-18). Additional social monitoring is provided by logging structured activities (e.g. teaching at a third age University, giving courses, going to theatre, concerts) that can be registered through a digital diary made available by Giraff to the caregivers.

## Evaluation

One of the main issues is an objective clinical evaluation of the status. Specific tests are routinary used by clinicans to assess the cognitive (e.g. mini-menthal test, ~~Tinelli)~~ or physical status (TUG- Time UP and go test, Berg-balance, Morse Scale ). ~~In the routinary clinical procedure, these tests have to be carried out in the presence of a clinician and are quite time consuming as they required the elder to commute to the clinician and to both elder and clinicians time to perform the test. These tests are required to provide and an objective picture of the physical / cognitive status of the patient.~~

Besides this, an adequate profiling of the elder in terms of his/her expected activity is required. This will be identified at start with the help of relatives, caregivers and clincians and will strongly depend on the elder hydiosyncrasis and inclinations. It will be the starting point to promote a fully collaboration between the service provider and the community of the stakeholders (GP, relatives, social services) and the elder. [PCL, OREBRO, KORIAN, SAS]. Clinical profiling will also be carried out through specific tests. This will provide a profiling of the elder at the entty point of Giraff. All the elements will be continuously tracked and updated with the feed-back provided by the transparent monitoring and the clinical spot tests provided as well as by additional information provided by stakeholders.

## Assistance

Assistance is extensively based on Gamification in Robohome2.0. PCL elders and gaming. Gaming will be provided by a gaming centre that will be fully integrated inside the epCARE infrastructure, thus providing valuable data to the clinicians for tuning the therapy and advising the patient.

**Exercising:** Structured exercise training is a commonly prescribed for many typical morbidity of elders, like heart failure, chronic lung disease, and arthritis as well as for general physical condition. PCL comment. Therefore**, the elder will be required to perform exercises to support her health and cognitive status**. In order to achieve this goal, the Virtual Caregiver will introduce and guide the patient through the exercises. Given that much care should be put in making these exercises at the proper level of difficulties and games attractive in order to achieve a strong treatment adherence, **controlled statistics will be massively introduced in terms of Bayesian network and graphical models in general to provide at each instant of time, a proper challenge level inside the game, taking into account all the information available to the virtual caregiver**.

**Gaming also allows accomplishing cognitive training**, and in particular training of memory and cognition. Simple exercises, linked to daily lifestyle actions can be designed, like for instance puzzle games with images of elder’s best life moments (e.g. a vacation, a journey) or memory games. Card games will also be supported as these provide a mean for natural socialization.

Indeed most activities will be enabled in a social context where each elder can see live all the other elders that are played with him, enabling also speech communication through distributed audio-video streaming. To his aim, standard support through Skype API or through Google Talk will be explored.

In this respect, exercising is completely intertwined to socialization and education.

Serious games are introduce not only to guide physical or cognitive activities but **can be also used to educate and inform the elders**. This is the role of serious games implemented in vocational training, of which the most popular is possibly the flight simulator. However, vocational training based in Virtual Reality has extended to other fields like business (negotiation skills), construction, mining, sports, education and so forth. It has been also applied in the clinical domain, in which surgeon training has become common practice. Serious games can provide a strong support on vocational training and **we will take this novel perspective to games to educate and motivate the elders to be compliant with their lifestyle**. Very recently a first attempt in this direction is represented by badblood, which is aimed generally to educate healthy people on the most dangerous illnesses.

Such educational games can be easily embedded in the social dimension. In fact, experiences with applications oriented towards promoting active lifestyles on seniors highlight the importance of social motivational instruments to overcome the barriers of acceptance in older adults. Indeed social dimension is one of the pillar of Robohome2.0 and it is widely adopted to support activities.

Diet will be part of the functionalities that can help the elder to keep healthy.

**Scenario.**

**Ann has invited her daughter and nephews but she does not know what to cook. She calls Giraff and select the kitchen button on the display: a set of recipies, compatible with her diet regimen, are displayed, organized along a few dimensions like time of cooking and complexity. She chooses a RICETTA and a list of ingredients is displayed on Giraff monitor and sent to her android phone as an SMS. Ann prepared then the dinner with the help of the instructions displayed by Giraff one step at a time. Her dinner was a success. She was very happy and gives this feed-back to Giraff, that changes the recipies order, ranking higher the successful recipie.**

One of the issues that plagues elders life is not finding objects of common use like the phone, the keys or the eyeglasses.

**Scenario.**

**Jill is ready to go out to meet with her fried Jane, but she cannot find her keys. She calls Giaraff that starts searching for them, and realizes that they are in the sitting room close to the sofa. Jill approaches the sofa and find that the keys had slipped under the cushion of the sofa. She is very grateful to Giraff and can get out immediately to be on time.**

## Robot interaction

The Virtual Caregiver will represent the main interface element between the Giraff robot and the elder and particular care will be put in its design and development.

Given the growing number of human-robot interaction systems for the elderly, assistive robots for disabled children, and robot use in educational context, there has been a growing interest in the design of effective interfaces to support human-robot communication.

One key feature of the multimodal interface will be the integration of the user’s explicit and implicit feedback, as in any assistive, cooperative, or interaction-based tasks, user feedback is critical to task performance (Broz et al. 2013). The most commonly used form of explicit feedback for interactive service robots consists of providing information to the user directly in the form of language, possibly with accompanying visual information (Li & Wrede 2007). As for implicit feedback, Breazeal et al. (2005) demonstrated that the use of implicit communication by a robot could improve task performance and robustness to errors. Implicit feedback can be based on the user’s motion and gestures, her gaze.

Proper performance of actions is key to alert others of our intentions and of the desired outcome of our actions. Humans use a wide range of paralinguistic cues to signal intention. Eye gaze, preparatory gestures, body language, etcetera are used to signal actions and goals. Robots that operate in public settings (e.g. homes and care homes) can be safer and more effective at performing work if they are designed with similarly human-readable behaviours (Breazeal et al., 2005). Unfortunately, care robots are severely limited in this respect. Their appearance does not evoke anthropomorphisation and their behaviour, alluded to earlier, is not conductive for human-robot interaction. An important aspect of the ROBOHOME2.0 project is studying how behaviour can be tailored so naive users can use behavioural cues to form an understanding of the beliefs, intentions, goals and abilities of the robot. The challenge is to make the robot’s thought processes external and thus observable. There are promising studies that show that principles from animation, such as anticipation and follow-through, can be used to achieve this goal (Takayama et al., 2011). ROBOHOME2.0 will develop multimodal HRI interfaces, integrating speech, touch interfaces and implicit feedback mechanisms.

## Beyond the state of the art

### Monitoring

We will use a completely modular approach for environment monitoring for which we will realize a sub-network based on most recent standards, like low-power Bluetooth to integrate any device that shows its utility for environment monitoring. Such sub-system will then be integrated inside the Virtual Caregiver through the Giraff Hub and it will be seen as a complex peripherical in a computer system.

Clinical and environment data will be acquired by two-subnetworks that will share similarities. They will represent a middleware that allows integrating the required devices, thus realizing a **modular monitoring system** that can be **tailored** to the needs of the individual elder. Unified interfaces for the control of these sub-networks from smart phone and from Giraff virtual caregivers will be developed, thus implementing technology equivalence. Similarly the most convenient device will be used to monitor specific parameter, will be used.

Our strong effort will be do made physical and cognitive monitor transparent to the user. We will realize physical **transparent monitors**, through the realization of low-power general modules that provide pressure and movement information and can be inserted inside everyday use objects. This will allow to acquire the elder natural behavior throughout his daily activity without splitting the monitoring stage from the ordinary life stage.

**Transparent cognitive monitoring** will be carried out through a selected set of specific spot questions and answers or mini-games (e.g. puzzles, Simon or other memory games) that will be administered at random during the day (e.g. before switching on the TV).

Monitoring data will be acquired by the virtual caregiver that will analyze and use them for determining a few parameters that are associated to the monitored aspects, typically stability of posture. **The development of methods to derive clinical meaningful clinical information, both for the physical and for the cognitive side, from these data will be also investigated inside Robohome2.0.**

### Evaluation

In parallel Robohome2.0 will develop a **ICT based version of typical clinical tests** identified by clinicians (e.g. Berg-balance or Mini-mental) will be defined, developed and validated. This would allow a re mote screening of the elder at home.

Monitoring data will be acquired by the virtual caregiver that will analyze and use them for determining a few parameters that are associated to the monitored aspects, typically stability of posture. **The development of methods to derive clinical meaningful clinical information, both for the physical and for the cognitive side, from these data will be also investigated inside Robohome2.0.**

This same information will be used by the virtual caregiver to evaluate the elder and to tune the activity proposed to the elder on one side and to warn the caregivers on the other, in case of deviations from the actual parameters value. We will use [OREBRO: POSSIBLE NOVEL TECHNIQUES FOR THIS].

**Scenario**

**“Robohome2.0 realizes that Janes has answered the wrong month of the year in the last times. It warns Jane’s GP and relatives. Meanwhile cognitive activities is increased in the mix of activities suggested by the virtual caregivers and more riddles and puzzles are proposed during the day. At the same time, the virtual caregiver along with Jane’s sons push her towards resuming playing cards regularly with her friends, at least through Giraff. Indeed Jane after a while did not answer wrong any more to Giraff spot questions.”**

### Assistance

We will explore here the use of serious games, not only to guide them into activities, but also to **teach the patients on their own therapy program and educate them on the effect, symptoms and results of taking their therapy and adhering to the lifestyle set.** To enforce compliance, the elders should be protagonist of his own health management. For this reason, the elder should negotizate his/her lifestyle with her caregivers, he/she should learn about the effect of the different medicaments ad the effect of the various activities so that he can better appreciate them and take them on a regular basis. This would fully implement the concept of **elder empowerment**. Such approach will also explore an innovative way to create educational stories that can be updated and provide always different scenarios to the user. Variability in this process can be obtained by using stochastic finite state automata that have been extensively explored to generate procedural stories. (Task xxx).

The establishment of common goals that have to be obtained through the collaboration with the elder community and/or with his/her relatives will be the basis for **the adoption of social inclusion drivers, which will represent an incentive for game adherence on seniors**. In particular, in Robohome2.0 we will explore how the increase of knowledge in therapy, illnessese and lifestyle (through gaming and social interaction) and the overall increase in the compliance to the cure can be used for increasing the reputation inside the on-line community (Task xxx) and the trust in the Robohome2.0 caregiver, increasing therefore the patient‘s motivation to education, compliance and exercising.

Cognitive games will also target diet aspects and some of the game may be related to preparing virtually a meal inside a virtual kitchen, as was suggested in the FITREHAB project. Such recipies can be matched to the elder’s diet and therefore can be linked also to education, suggesting to the elders also new recipes and new diet at match with his/her health status.

The overall **highly modular approach** followed allows a large freedom in setting up a proper mix of social, physical and cognitive activities of the elder.

ICT technology has been explored also to get transparenly track of specific objects, typically glasses and keys. We will explore the use of differencial power measured by Giraff to direct it towards the maximum of the signal and therefore locate the area in which keys can be easily found. SXT specify possible technology and solutions.

### Robot interaction

Given the crucial need to design an integrated user-centred robot system supporting long-term interaction with the user, the project will put strong emphasis on the following issues:

(i) Long-term interaction and acceptance: current HRI systems tend to be based on single-session interaction. In robot assistive scenarios, where the same user interacts with a robotic companion for multiple sessions, it is important to include a memory system that keeps track of the history of interaction and support subsequent tasks in a predictive way, in accordance with the predicted user’s behavior and expectations (Belpaeme et al. 2013). Indeed such history of interaction is available to the caregiver as quantitative and quality feed-back by the activity center.

(ii) Matching of perceived and actual ability: acceptance of robots is strongly influenced by the discrepancy between perceived ability and actual ability of the robot. Matching user expectations can be achieved through either physical design of the robot (e.g. a strong looking robot will be expected to be able to lift objects and people, if in reality this expectation is not fulfilled this has a negative impact) or through setting correct expectations in users by the people introducing the robot. Indeed the Giraff robot has been designed to maximize its compliance with the elders.

(iii) Readability: users should be able to read the robot’s “cognitive processes”. Humans are finely tuned to cues and signals communicating our actions and intentions in inter-human interaction, but these cues are generally lacking from robots and this hampers natural HRI (Takayama et al., 2011). ROBOHOME2.0 will study how the behaviour of the robot can be generated to provide feedback and signal intentions and goals.

(iv) Responsiveness: typical performance of a robot involves a considerable amount of processing (for example for automated speech recognition and natural language interaction), which inevitably leads to perceivable delays. As such during processing the robot seems to be inactive. Conversational fillers and back-channel feedback can be used to create the illusion of responsiveness, which is highly influential on acceptability. ROBOHOME2.0 will study how users respond to varying perception of responsiveness.

None of the above mentioned qualities can be considered in isolation: long-term interaction and acceptance, readability, responsiveness and matching of perceived and actual ability all impact on each other. As such it is impossible to develop one quality while neglecting the others. Our research and development on the HRI aspects will focus on incrementally improving these HRI qualities through implementing the latest insights in the field of HRI and field testing with naive users.

Moreover, for the design of mimic and linguistic communication capabilities in the assistive robot, the same integrative approach will be used , and to acquire mimic and linguistic capabilities.

DISCARD NEXT TEXT

Monitoring deals also with a supervision of the cognitive status of the elder. Cognitive decline monitoring is required to understand the capability of the elder to live at home, possible helps that are needed and critical situations. This is carried out mostly in a transparent way by ROBOHOME2.0 that will monitor through its activity center the cognitive orientation and capability of the elder. Physical status is also a critical issue as falls and consequent fracture drive the elder faster towards an overall decline that will limit his independency. ROBOHOME2.0, provides a transparent continuos monitor thorugh everyday objects, like his/her ~~cane~~ that do provide valiable data on her stability. ~~The two aspects are intertwined and ???~~

~~Social monitoring is also important and a profiling of the social activity of the elder partly transparently and partly through interaction is carried out…~~

~~Clinical monitoring is very important as well. Drug compliance, assessment can be carried out.~~

~~ICT allows going one step further, being pro-active in making the elder living longer at home. Focus will be mainly on providing socialization to avoid depression and . A set of activities. Thse can be carried out alone for people not inclined…~~

~~The supervision of the system at home is carried out through an adequate robot, that works not only as a companion, but also providing to the elder an active role in different aspects. Provides suggestions, diets, activities, tests… becoming a virtual caregiver. It will be designed in a modular way, such as to be expandable to other activities.~~

~~However, these robots are mainly meant as companion robots, with limited capabilities with respect to the needs of lifestyle.~~

~~Paro, a touch-sensitive companion robot is based on this concept.~~

Assistive robots for independent living are a particular category as they require not only the capacity to work on a given activity but to acquire, analyze and manage a host of heterogenous information to provide adequate feed-back at the right point. This requires a strong work of testing and feed-back that involves sociology and psychological to develop adequate models of behavaiour suggestion.

Motivation of using Giraff plus:

* Costs.
* Advanced navigation and integration of 3D sensoring that can be used also track human activities.
* Good Gui desing.
* Semi-autonomous navigation.
* Scalability and flexibility

…….

Clear pathway to the market exhists as Giraff Technology has already licensed the robot [GIRAFF TECHNOLOGIES AIMS AND PLANS]. This is a friendly service robot, ….

The project capitalizes on the results of the project: FITRHAB and REWIRE on the part of gamification and EXCITE and GIRAFFPLUS for the part of service robots.

One of the results of REWIRE has been IGER, that is …. Description.

GIRAFFPLUS has produced the Giraff robot, that ….

RoboHome communication will be based on most used standards, like for instance SSH communication for secure communication, or ?? The community will be based on ???. In general all software used will be built as much as possible on components released under GPL license. Semantic and interoperability standards will be defined and permeate the system as much as possible. For instance we will store the monitoring data into a local data-base that provides standard access at many different levels.

REFERENCES

Broz F., Di Nuovo A., Belpaeme T., Cangelosi A. (2013). Multimodal Robot Feedback for Eldercare. Workshop at IEEE RO-MAN IEEE International Symposium on Robots and Human Interactive Communications

Breazeal, C. C.Kidd, A.Thomaz, G.Hoffman, and M.Berlin, “Effects of nonverbal communication on efficiency and robustness in human- robot teamwork,” in Intelligent Robots and Systems, 2005. (IROS 2005). 2005 IEEE/RSJ International Conference on, aug. 2005, pp. 708 – 713.

Li S. and B. Wrede, “Why and how to model multi-modal interaction for a mobile robot companion,” in AAAI Spring Symposium: Interac- tion Challenges for Intelligent Assistants, 2007, pp. 72–79.

Takayama, L., Dooley, D. and Ju, W. (2011). Expressing thought: Improving robot readability with animation principles. Proceedings of the IEEE/ACM International Conference on Human-Robot Interaction.

ADDITIONAL REFERENCE

Belpaeme, T., Baxter, P., Read, R., Wood, R., Cuayáhuitl, H., Kiefer, B., Racioppa, S., Kruijff-Korbayová, I., Athanasopoulos, G., Enescu, V., Looije, R., Neerincx, M., Demiris, Y., Ros-Espinoza, R., Beck, A., Cañamero, L., Hiolle, A., Lewis, M., Baroni, I., Nalin, M., Cosi, P., Paci, G., Tesser, F., Sommavilla, G. & Humbert, R. (2012) Multimodal Child-Robot Interaction: Building Social Bonds. Journal of Human-Robot Interaction, 1(2), 33-53.

FROM HERE TO THE END OF THE SECTION HAS TO BE INSERTED A SUMMARY OF THE CONTENT OF THE DIFFERENT WPs STRESSING NOVELTY AND INTERDEPENDENCES.

As a result all the issues that determine a lifestyle of the elder have been addressed according to the following table (Figure 3):

|  |  |  |  |
| --- | --- | --- | --- |
|  | Monitoring | Assistance | Evaluation |
| Physical | Analisys of interaction with the elder support (e.g. cane) or instrumented objects (e.g. balls, dolls) | Specific exercises that address physical weakness | Community competition or cooperation in the activities |
| Cognitive | Analysis of activities and answers to spot questions | Cognitive training through puzzle, memory or card games | Community competition or cooperation in the activities |
| Social | Analysis of social activity from diary and of cellular phone calls | Card games, story telling | Community based activity |
| Clinical | Novel validated tests through the activity center and monitored everyday objects. | Not applies | Supervision by clinicians |
| Diet | Not applies | Proposal of diet and shopping lists | Supervision by caregivers |

Figure 4 - Table containing the different dimensions of the elder life: physical, cognitive, social, clinical and diet and how do we envisage to monitor, stimulate and evaluate them.

Conclusion + scenarios still missing here.

Gender and ethical issues should be paid due attention.”

# 1.4 Ambition

*• Describe the advance your proposal would provide beyond the state-of-the-art, and the extent the proposed work is ambitious. Your answer could refer to the ground-breaking nature of the objectives, concepts involved, issues and problems to be addressed, and approaches and methods to be used.*

*• Describe the innovation potential which the proposal represents. Where relevant, refer to products and services already available on the market. Please refer to the results of any patent search carried out.*

TO BE FILLED

Our aim is to move elder far from just watching TV passively. We dream a society in which all the people can feel an active and useful part and not simply a higher weight as they increase their age. The collection of memories, the bank of time, the suggestions to youngers are all elements that would contribute to a less eager and more giving society.

Patent Search

Patent on smart drug dispenser:

[<http://www.google.com.tr/patents/US8588964>].

Patent EPFL on profiling physical activity.

Patent UMIL on IGER

# 3. Implementation

# 3.1 Work plan — Work packages, deliverables and milestones

Please provide the following:

• brief presentation of the overall structure of the work plan;

timing of the different work packages and their components (Gantt chart or similar);

• detailed work description, i.e.:

o a description of each work package (table 3.1a);

o a list of work packages (table 3.1b);

o a list of major deliverables (table 3.1c);

• graphical presentation of the components showing how they inter-relate (Pert

chart or similar).

*Give full details. Base your account on the logical structure of the project and the stages in which it is to be carried out. Include details of the resources to be allocated to each work package. The number of work packages should be proportionate to the scale and complexity of the project. You should give enough detail in each work package to justify the proposed resources to be allocated and also quantified information so that progress can be monitored, including by the Commission.*

*You are advised to include a distinct work package on ‘management’ (see section 3.2) and to give due visibility in the work plan to ‘dissemination and exploitation’ and ‘communication activities’, either with distinct tasks or distinct work packages.*

*You will be required to include an updated (or confirmed) ‘plan for the dissemination and exploitation of results’ in both the periodic and final reports. (This does not apply to topics where a draft plan was not required.) This should include a record of activities related to dissemination and exploitation that have been undertaken and those still planned. A report of completed and planned communication activities will also be required.*

TO BE FILLED

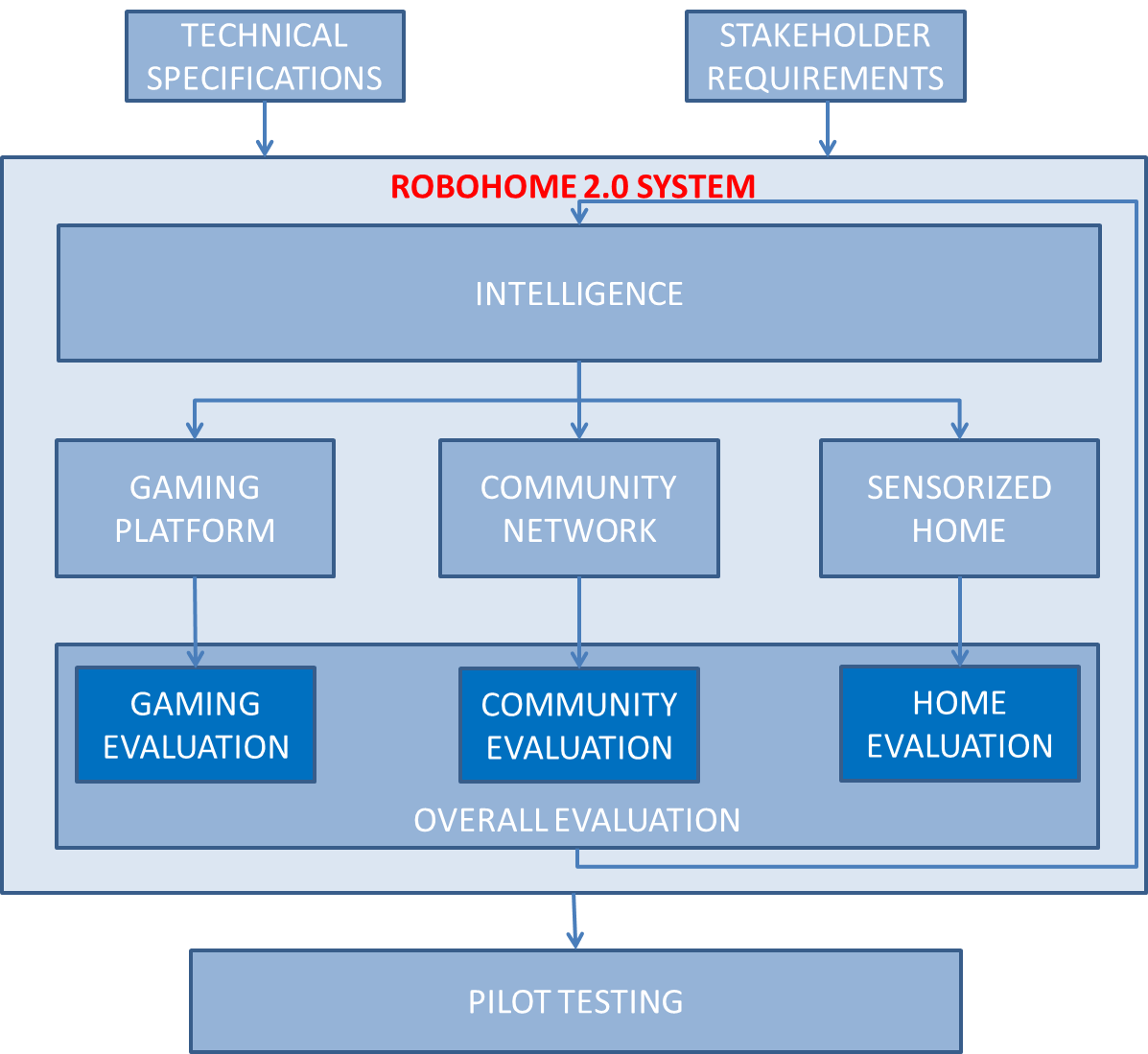


Figure 5 - Development of RoboHome2.0

## WP1 – Functional Specifications (PCL, )

**Objectives:**

• To identify users, stakeholders and scenarios of the ROBOHOME system;

• To identify user requirements of the platform as a whole and specifically for each module (activity center, monitoring, community). In particular for the community, specifications for each group of users: clincians, caregivers, elders, informal caregivers will be defined.

• To design and identify clinical tests to assess cognitive and physical decline that can be carried out by service robots.

**Beyond the state of the art:**

* Identification of tele-monitored clinical tests, both cognitive and physical, suitable to be validated clinically, that can be performed by the elder at home

User specifications and functional requirements will be gathered in this WP and written in a comprehensive technical report. The document will set the main constraints for the future development of the ROBOHOME2.0 system modules.

**Description of Work**

The major effort of Robohome2.0 in the first few months will be to clarify the scope and implications of the project to drive the development in the most effective direction. In particular the bi-directional translational research approach[[19]](#footnote-19) facilitating the communication between clinical teams, that will bring the instances and requirements of stakeholders, and the technical teams, that will portray the possibilities offered by technology, to come up with a shared view on how the Robohome platform should be.To this aim we will start from the elder and other Robohome users needs and move towards technology specifications addressed by WP3 and then to implementation carried out in WP4, WP5, WP6, integration in WP7 and testing in WP8.

Inclusion criteria (which elder)

Fraility areas

Lifestyle goals

Exer-Games

Monitoring

Technology

The progress towards identifying the functional and technological requirements of Robohome.

In particular, a major effort of Robohome first few months will be clarify the scope and implications of the project’s research goals to drive the development in the most effective direction. In particular the bi-directional translational research approach[[20]](#footnote-20) will be followed facilitating the communication between clinical teams, that will bring the instances and requirements of stakeholders, and the technical teams, that will portray the possibilities offered by the technology on which the project is based , to come up with a shared view on how the Robohome platform should be. This will lead the development in two main directions: definition of the platform requirements and components design and implementation.

To achieve this, meetings in the clinical site will be organized in the first months of the project. During these meetings the technology on which the project is based will be shown live and discussed as well as videos and mock-ups of the components of Robohome. Clinicians, on their site, will illustrate some of the features and possibility currently offered by the social services to support elders at home in the different countries, stressing the weak and strong points of the current system. In parallel, the most important features will be assessed by interviewing directly stakeholders with a functional prototype of the system, through adequate focus groups.

The task will combine the use of questionnaires to reach a larger group of potential users in the different countries of the ROBOHOME2.0 partners’ sites. In addition, individual interviews and focus-group sessions will be conducted to investigate specific design interaction issues in more depth. These methodologies will lead to the definition of the user requirements, the design of the metrics to evaluate the user experience, acceptance of the robot, and also the carers’ feedback.

User specifications and functional requirements will be gathered in this WP and written in a comprehensive technical report. The document will set the main constraints for the future development of the Robohome system modules.

## Task1.1 (M1-M6): Identification of Robohome stakeholders (OREBRO, PCL, UMIL,

Possible Robohome group of users will be identified. These might have a typical technological role, like managing the community, supporting the system or a functional role, like clinicians, social assistant, psychologists, relative and so forth. For each of these categories a clear role for Robohome will be identified and their possible function identified. Accordingly the relationship between them is outlined. Unified Modeling Language (UML) and conceptual maps[[21]](#footnote-21), [[22]](#footnote-22), [[23]](#footnote-23) can be used for instance to clarify such processes and roles.

Inclusion and exclusion criteria will be clearly defined for the pilot (WP8) on the basis of physical and mental conditions, their availability and willingness and, finally, on their living environment. In particular, compliance with technology has to be appreciated. Particular issues to be assessed are: Lower limbs motor function ability, upper limbs motor function ability, mental function capabilities, willingness and availability to use the system, availability of caregivers and families.

Frail elders will be preferentially enrolled as they are the people who, without any assistance, have the higher risk of degeneration. As a result, highly focused interventions will be defined especially for:

1. Elders who show the initial symptons of Alzheimer desease or other neurodegenerative illnessese as well as evolutional depression. Commonly documented depression interventions indicate that cognitive behaviour therapy, cognitive stimulation and psychoeducation delivered are effective in reducing symptoms of depression. Such intervention can be delivered also from remotely[[24]](#footnote-24).
2. Elders who have developed stability problems and need assistance to move (e.g. through cane). For these elders a continuous evaluation of the trade-off between independent walking and wheel-chair should be always be monitored.
3. An active social life is one of the determinants of maintaining good cognitive capabilities for prolonged time. The stimulation given by interaction with pairs provide implicitly the kind of stimulation.
4. Elders who need to control a specific desease over time, like hypertension, diabetes, COPD, Heart problems and so forth. ICT has made the control of these deseases possible at home [[25]](#footnote-25), [[26]](#footnote-26). Still most of these systems are tele-operated. Samples (e.g. blood, pressure or sugar samples) are taken by the elder remotely under the remote supervision of the clinicians. Very recently, few systems have made such measurements possible autonomously, life for instance . Moreover, the measurements should be integrated inside a more general system, like ROBOHOME2.0, that keeps the patient motivated, informed and monitored.
5. Diet is complementary to all the aforementioned issues as it allows to keep the elder health for prolonged time.

Elder will be profiled along five main dimensions: physical, cognitive, clinical, social activities and diet habitude. For each of these five classes the requirement minimal monitoring and evaluation function will be defined. Moreover, a degree of intensity of activities is identified. Fuzzy sets[[27]](#footnote-27) will be explored to suitably transform the structured knowledge of the caregivers, relatives and clinicians into a digital form that can be effectively managed by the virtual caregiver to monitor and assist the elder. His idiosincrasis will be also collected in an organized way for instance using category maps. Moreover, a proper set of interfaces will be customized according to elder idiosyncrasies and profile.

The selection of the end users will be based on the same procedures already experimented in Giraff+ and REWIRE project. Elders will be performed according to the following steps:

1. Pre-selection of users and first contacts with elder associations. In particular, OUTLINE PROCEDURES IN SPAIN, ITALY and SWEDEN.
2. Identification of 20-30 potential end users.
3. First personal interviews in order to establish their availability and willingness to participate in the project.

A plan (including insurance cover) for emergency situations that might occur during the pilot study will be designed. This last effort will be carried out in collaboration with the Ethical Review Board of the project.

## Task1.2(M2-M12) Identification of the functions of the Robohome Activity Center (PCL, UMIL, OREBRO…,

Within this task the functions to be supplied by the Robohome game center will be identified always considering easyness to use, acceptability and user involvement has the main requirements . All of the identified functionalities have to include physical and cognitive exer-games, for promoting social activity and to support a compliant diet will be identified and defined.

Particular care will be made in defining functionalities that are considered most effective by stakeholders and by elder themselves as suggested by the results of the meetings carried out early in the project, during which mockups, videos and real demos will be carried out on the technology offer and possible developments.

As far as physical activity is concerned, a wide range of exercises can be proposed to improve selectively control, coordination or strength. Exercises that are most important to keep a lifestyle will be selected according to current geriatric practice[[28]](#footnote-28), [QUOTES]. A similar approach will be followed for the cognitive training[[29]](#footnote-29), for which the most suitable activities will be selected.

## Task1.3(M3-M12): Activities scenarios design (UMIL,

The task will take care of the design of scenarios for activities by means of the ROBOHOME stakeholders, including the elders themselves, with the support of the technical teams. Possible physical, cognitive and social activities will be identified. Such step is fundamental to maximize the design of the exer-games that will implement these activities as it will allow to design gameplay the maximize the capture of all the exercise aspects[[30]](#footnote-30).

Depending of the type, each physical and cognitive activity scenario should include information among the following:

* A set of possible virtual environment that can be suitable for the largest elder population to contain all the exer-games developed for exercising and tutoring.
* A set of possible exercises required.
* The parameters that determine their difficulty and some possible adaptation mechanisms inside the exercises. A general approach has been recently proposed[[31]](#footnote-31) that is based on Bayesian optimization and it is shown it effectiveness. Such an approach is particularly suitable to insert any information a-priori related to knowledge based estimate of the proper level of difficulty and therefore it can be particularly suitable in ROBOHOME2.0. Moreover, it has the advantage of being already implemented inside the IGER game engine made available to the project.
* The parameters to monitor to evaluate the elder’s performance quality in terms of intensity and time, and of correctness
* The modality of the activity: personal or within a group.
* The possible constraints on the design associated to elder characteristics, for instance elements size and contrast; avatar anthropometic measurements. Particular care will be put in the **definition of a proper cognitive load** of the exer-games scenario and the gameplay, associated to the different groups of elders identified such that each exer-game will automatically adapt to the actual user.
* Explicit definition of all the elements that can concur to motivation. An effective and balanced reward system will be defined as well as several possible ways of defining levels of difficulty of the exercises in front of the elder residual capabilities.
* Exercises that can be carried out through the everyday activities will also be identified and monitoring of these activities will be implemented in WP5 to derive a feed-back on their quality and intensity.
* The need of additional feed-backs, besides the visual one, will be investigated and possiblye additional components required to implement additional cues and reward mechanisms (e.g. loud speakers) will be defined.

Groups of possible diets will be also identified in this task.

## Task1.4(M2-M9): Identification of Robohome clinical monitoring (PCL, OREBRO, POLIMI,

The clinical monitoring of physical and cognitive frailties will be performed by means of:

a) Clinical tests carried out at-home by the elder himself guided by the Robohome system.

b) Novel pervasive clinical tests included randomly in the user scenario.

a) The most used cognitive and physical tests that can be easily performed by the elder himself/herself at home will be identified. The cognitive clinical tests used will be ???[PCL may further elaborate on this]. For instance the QMCI test, recently developed [PCL may further elaborate on this]. Concerning physical tests, the best clinical test to evaluate physical decline will be ??? [PCL may further elaborate on this].

The interactive version of these already validated tests will be assisted by the Robohome system. Robohome will remind the user not only when he/she has to perform the clinical test but it will also guide him/her step by step. during test execution. These tests can be or tele-monitored by the GP when needed or performed in front of Robohome system to store the video or filled in by the user using Robohome2.0 in order to store the scores. An example would be to create an **interactive version of the Mini-mental state test**[[32]](#footnote-32)in which theanswers from the elder will be collected and automatically scored. When score drops below a given threshold an alarm will be sent to the reference GP and to the caregivers. Another example would be to implement the interactive **Berg balance Scale test**[[33]](#footnote-33) in which Robohome will ask the user to carry out in front of Robohome video all the movements required by the clinical test, compute automatically the associated partial and total scores.

b) A novel approach in clinical monitoring will be to implement pervasive clinical tests

The idea is to insert randomly during the activities proposed daily to the user and performed with the Robohome assistance some questions, correspondent to simple cognitive tests, and some physical exercises and to record the obtained answer or movement with a specific score. These simple and short tests have to be identified by geriatrics because they have to be clinically meaningful and thus useful to assess the user cognitive and physical condition.

Figure ?XX? reports an example of these pervasive tests.

**“SCENARIO: During day 1 the user starts his/her assisted activities with activity 1 (exer-game puzzle) then he watched a TV program and at the end of it Robohome asked him “Joe what day is tomorrow?” Joe as to reply and Robohome stores the answer. Then the activities keep going with the defined program and at the end of the day Robohome asks to the user to perform 3 consecutive sit to stand tasks using the sofa (because the sofa is sensorized with a pressure pillow) and thus the results of the movements are stored. Every day a similar planning is carried out with different simple cognitive tests and exercises”.**

This pervasive cognitive and physical tests will be scored daily and weekly and then after a proper data analysis it will be possible to extract important informations about the user condition and its changes over time.

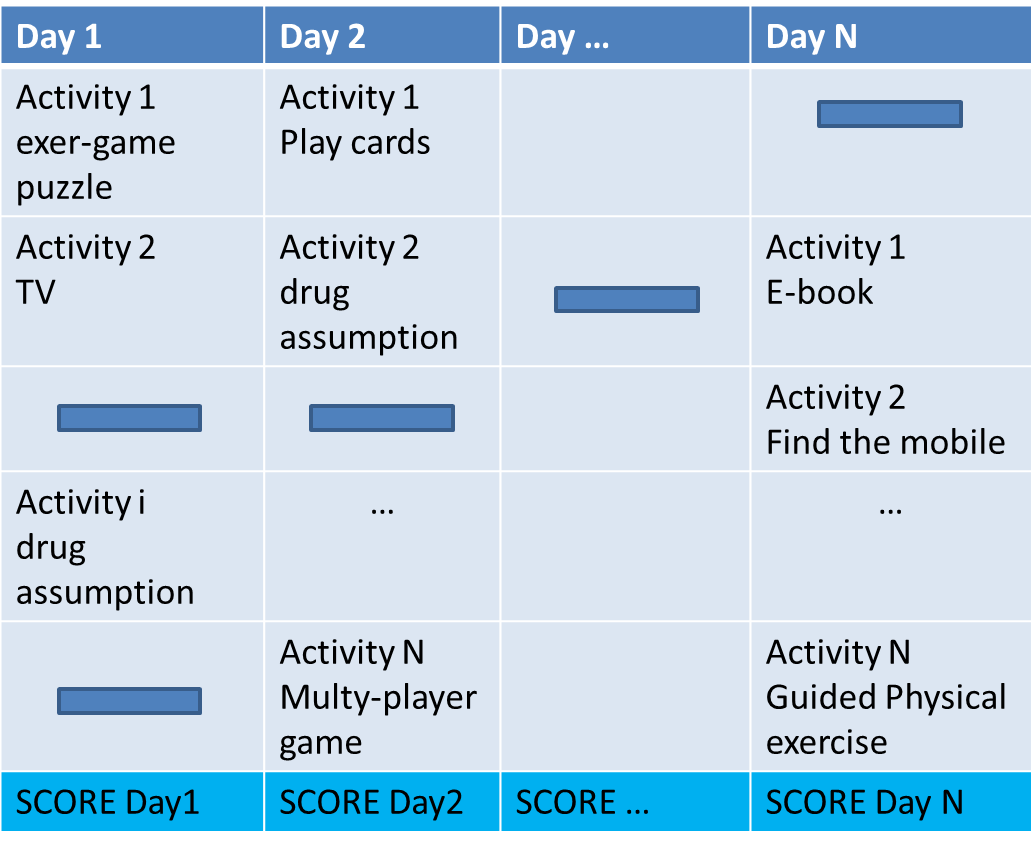


Figure 6 - A possible user scenario for the pervasive clinical tests. These tests are indicated with blue boxes randomly inserted in the daily schedule of the user activities assisted by Robohome2.0

## Task1.5(M2-M9): Identification functions for system monitoring (POLIMI, PCL...)

Monitoring is fundamental to trust the elder to stay home for a prolonged period of time also when facing with objective frailty. To this aim Robohome will carefully address monitoring specifications and come up with a set of defined functions that will address frailty and critical elements for most elders. Monitoring will mainly address physical and cognitive frailities through clinical tests carried out at-home by the elder himself.

1. MONITORING COGNITIVE AND PHYSICAL EXERCISES PERFORMED WITHIN THE ACTIVITY GAME CENTER

The activities offered by Robohome 2.0 and defined in Task 1.2 and 1.3 will be monitored. These can be for instance the time required to complete a “memory” game or a puzzle or a physical exer-game, the score, the average number of points lost in card games, etc.

1. MONITORING PHYSICAL ACTIVITY BY MEANS OF INSTRUMENTED OBJECTS

This physical activities will be monitored by means of sensors mounted on objects typically used by the elder so that the monitoring will be transparent to him. A few objects that can be of use for a wide variety of elder population will be defined in this task. These objects will be used both during the physical exercises performed by the user within the activity game center (WP4) and during specific clinical tests (WP3). They will also be used during everyday life, like for instance the supporting cane, thus garthering information both indoor and outdoor.

1. MONITORING THE USER BY MEANS OF ENVIRONMENT SENSORS

The Robohome system will monitor and store data about the main activities carried out by the user during the day such us the number of hours of sleep, regularity of meals and drinks, number of times the user goes to the toilet. All these data will be helpful to monitor the user habits and behaviors and to understand how and how much his/her condition is changing over time.

1. MONITORING SOCIAL INTERACTION

Monitoring functions of social aspects will also been defined with the idea to come with a rough picture of the elder isolation, that can be linked to depression or disorders mood. Such picture will be made at the beginning, with the help of interviews with relatives and caregivers and deviation from the usual social profile will be monitored. The social monitoring will be carried out mainly through a simple week dairy that the caregiver can compile. An interactive version of such a diary again guided by the Robohome system can be provided . Additional simple information can be derived from the profiling of the telephone calls and the analysis of the social activities performed with the user smartphone. Finally, the monitoring of the multi-player activities and games can enrich the social monitoring (see WP2 and WP4).

1. MONITOR HEALTH CONDITION

Another important user requirements will be to monitor specific parameters to assess the health condition such as the blood pressure, the heart rate, or, in case of patients with diabetes mellitus or pre-diabetes conditions, the glucose concentration. It would be very important to integrate alert systems advising the GP when the parameter exceeds certain upper and lower thresholds. Such tests will be part of the clinical profiling.

1. OFFER SERVICES TO PROMOTE INDEPENDENT LIVING

An important feature of the Robohome system will be also the integration of some services to facilitate and promote independent living. Some examples are: an intelligent and novel system to manage the location of specific objects in the house; some smart alerts to advice the caregiver or the GP when needed and a novel system to assure the prescription adherence of the user.

## Task 1.6 (M3-M12) HRI and User Requirements Analysis (PLY,

This task will provide the user requirements for the ROBOHOME2.0 to facilitate natural interaction between the robot and the users. This will inform the design of the interaction features, the HRI multimodal interface, and the design and analyses of the experimental sessions. Full configuration and adaptation of the interface to elder status and lifestyle will be taken into account.

Possible evaluation models will be based on TAM questionnaires developed in the last years aimed to assess the impact of the technology[[34]](#footnote-34), [[35]](#footnote-35). TAM builds the prediction of individual adoption and use of a technology on two main beliefs that affect the behavioral intention of the individuals: (i) the perceived usefulness, defined as “the extent to which a person believes that using a technology will enhance his or her job performance”; and (ii) the perceived ease of use, defined as “the degree to which a person believes that using a technology will be free of effort”. that focus on perceived usefulness and ease of use of the technology.

## Task1.6(M2-M12): Identification of Robohome virtual caregiver functions (OREBRO, POLIMI,

The caregiver will supervise and monitor the elder lifestyle and advise him. Therefore, the following functionalities have to be defined:

• Modality of prescription of the activities. The involvement of all stakeholders, including the elder, in the definition of lifestyle goals, the definition of a-priori information on elders idiosyncrasies, and effective feed-back to the elder to increase his intrinsic motivation is already a routine in RSA structures where elders can be recovered. One of the goals of Robohome is to move this holistic integral approach to the elder living at home, for which the continuous presence of specialized operators that enforce the program cannot be guaranteed. Such role can be partially taken up by the community of stakeholders but a clear definition of functionalities is required.

* Association of the mix of activities to the elder profiling carried out in Task 1.1.

• Functionalities required by the clinical tests defined in Task 1.4.

## Task 1.7 (M3-M12) Functional requirements of Community services (KORIAN, PCL, BDIGITAL, …

Within this task the functions to be supplied by the ROBOHOME community will be identified. Taking into account the possible actors which will be participating in the usage of the ROBOHOME platform, the user requirements will be defined.

In particular, the relationship between the care-givers and the clincians and the other stake-holders will be identified. Functions required to provide monitoring, evaluation and activities in a personalized ways, adapted to the elder status will be identified with a tight cooperation between technological and clinical partners.

## WP2 - Technical specifications (PLY, …

**Objectives:**

* To identify the devices and components of the ROBOHOME platform that best suits the project in terms of reliability, costs, availability and the overall technical specifications of the ROBOHOME platform;
* To design the main HRI to maximize compliance and effectiveness.
* To design the evaluation tests of the system components and of the whole platform.

**Beyond the state of the art**

Interfaces that can be easily configured to the different elders profiles and activity and monitoing needs will be designed along with mechanisms to adapt the interfaces to eleder current status.

**Description of WP**

WP2 has the role of defining the technical specifications of the ROBOHOME2.0 platform and of its components to comply with the functional specifications set in WP1. A strict coordination with activities in WP1 is needed and will be guaranteed by the PC. OREBRO will set up the ROBOHOME2.0 platform at the different stages of completeness produced in WP3, WP4, WP5 and WP6. This pre-prototype platform will be tested with different types of stakeholders: therapists, clinicians, caregivers and elders themselves. In particular the same model used in GIRAFF+ proposal will be assumed and the partners MON and SAS have been involved on purpose.

The technical specifications of the sensors that will be integrated in the Robohome platform in order to monitor the functions identified in Task 1.3 will be defined. From the technological point of view, the development of an effective monitoring system relies on a good integration of available devices and applications with specifically developed ones. Thus, the available off-the-shelf devices and the best components that have to be assembled to produce reliable and accurate customized sensors will be selected. The modality of use and recharge of the customized sensors will all be considered in this task.

All of the sensors have to suit the project in terms of reliability and must be low cost. They have to be based on two main design principles: they must be non-intrusive and easy to use. The idea is to sensorize the environment and the objects and not the user and to adopt sensors that do not require any collaboration from the user (transparent sensors).

**Tasks**

## Task 2.1 (M2-M9). Identification of the technical functions for monitoring and activities (PLY, POLIMI, UMIL, …..

The specification and identification of the off-the-shelf components that have to be assembled to produce a reliable and accurate sensing embedded in objects of everyday life, according to specifications set in Task 1.3, will be carried out. Pressure range, motion amplitude, additional constraints, modality of use and recharging will all be considered inside this task. Possible modules that can be reused in different objects will be considered. A few objects that can be of use for a wide variery of elder population will be defined.

Similarly, the specifications of the off-the-shelf components that will be used to track elder motion while exercising will be also identified. Motion amplitude, body segments tracked should be carefully identified and modular and scalable implementation solutions have to be identified such that the platform can adapts to the user and not-viceversa according to the specifications set in WP1.

## Task 2.2 (M2-M9). Identification of the technical functions of the activity center (PLY, UMIL, …..

This task will define the main software functions that will be contained inside the virtual graphical engine :

• Definition of the software components according to OpenSoftware paradigms and taking in mind modularity and interoperability of different software modules. Software like Panda3D, Ogre, H3D that come with GPL

licenses or similar licenses will be considered and compared with Unity3D, which is a cross-platform game engine.

• Definition of input/output software modules. This is particularly critical as technical equivalence will be enforced inside the project and current output will be chosen by the virtual therapist according to the situation.

• Definition of graphics/video functionalities to be implemented to address all the exercises and modalities defined in WP2. These can be for instance, video or augmented reality multi-playing, first / third person gaming and 2.5D silhouette rendering.

## Task 2.3 (M3-M12) HRI and User Requirements Analysis (PLY,

This task will provide the user requirements for the ROBOHOME2.0 to facilitate natural interaction between the robot and the users. This task will concern the design of the multimodal HRI interface to allow the user to integrate the facility of the Giraff robot and the integrated smart environment systems and the virtual caregiver module. The interface will combine various interaction modalities as speech, touch screen.

Focus will be placed on interface facilities to manage the user’s explicit and implicit feedback, as we havepreviously shown[[36]](#footnote-36), user feedback is critical to task performance in any assistive, cooperative, or interaction-based robot systems. Such interface will also be able to track the user’s gestures when this is in front of Giraff and it will be used in combination with a speech dialog system to facilitate interaction. On the other hand, the interface will provide speech-based feedback to ask questions and to solve pragmatic ambiguities.

This will inform the design of the interaction features, the HRI multimodal interface, and the design and analyses of the experimental sessions. The task will combine the use of questionnaires to reach a larger group of potential users in the different countries of the ROBOHOME2.0 partners’ sites. In addition, individual interviews and focus-group sessions will be conducted to investigate specific design interaction issues in more depth. These methodologies will lead to the definition of the user requirements, the design of the metrics to evaluate the user experience, acceptance of the robot, and also the carers’ feedback.

## Task 2.4 (M7-M18). Design of system testing (PLY, POLIMI, UMIL,

Testing will proceed in two directions: technical testing and functional testing.

A set of tests and experiments will be designed for testing the functionality and of each component and define their specifications. Evluation and validation will be performed by the stakeholders that will rate, for instance through Likert scales, the compliance and effectiveness of the realized components according to the specifications set in WP2. Particular care on the easiness of use will be reserved.

Possible evaluation models will be based on TAM questionnaires developed in the last years aimed to assess the impact of the technology[[37]](#footnote-37), [[38]](#footnote-38). TAM builds the prediction of individual adoption and use of a technology on two main beliefs that affect the behavioral intention of the individuals: (i) the perceived usefulness, defined as “the extent to which a person believes that using a technology will enhance his or her job performance”; and (ii) the perceived ease of use, defined as “the degree to which a person believes that using a technology will be free of effort”. that focus on perceived usefulness and ease of use of the technology.

Tests and experiments to verify the proper communication between the components and will also be developed, to assess accuracy, resolution and reliability of each component.

## WP3 –Virtual Caregiver (OREBRO, ……).

**OBJECTIVES**

- To develop tele-monitored clinical tests to be performed by the user at home by using Robohome components.

- To develop and validate cognitive and physical pervasive tests

- To implement novel algorithms to infer changes in the user condition from the whole information gathered by the sensorized home and the activity center.

- To update the user profile according to detected user condition

**Beyond the state of the art**

* Monitoring is carried out on heterogenous information coming from activities, monitoring, clinical, social and ambient data. Similarly a mix of activities will be suggested according the same information.
* Develop HRI the maximize variability to increase compliance on one side, and on the other side provide a feed-back, whose emotional/visual aspect, is shaped by the history, type and quality of adherence of the elders to the lifestyle plan.

**Description of WP**

The design of the virtual caregiver will address to main areas. The first area is its appearance to the elder to maximize motivation and effectiveness. In this area we will explore fully configurable and adaptive interfaces.

The second area is the supervision of the elder’s activities. This second area will require to filter information from system monitoring to pass processed information to the caregivers and GPs on one side, on the other side this information will be used to tune the activities and monitoring.

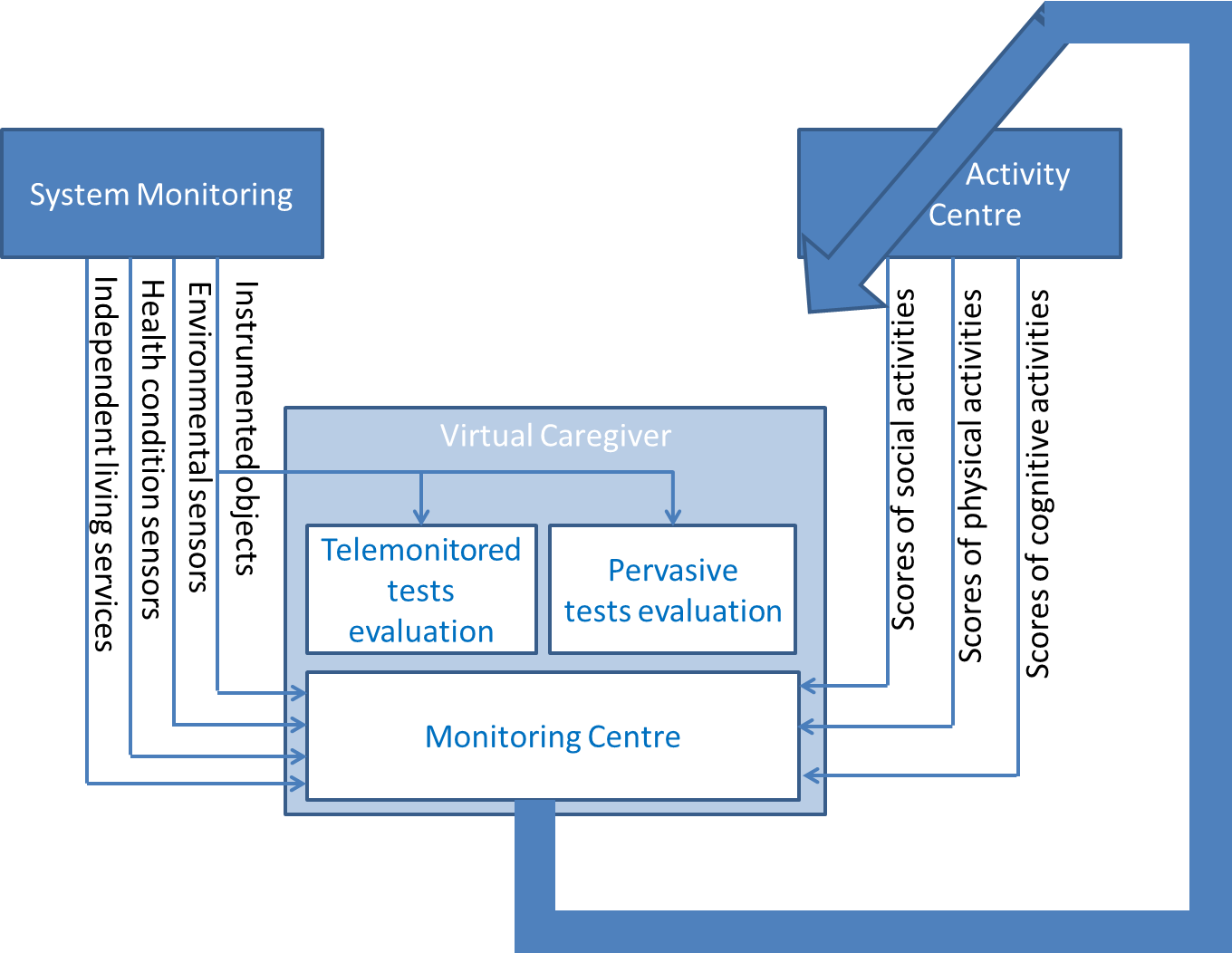


Figure 7 - The continuous analysis of all of the gathered information will be performed by the Virtual Caregiver through the monitoring centre and will allow the personalization of the user scenarios managed by RoboHome2.0 intelligence.

Monitoring input can be supposed:

**Social activities:**

* Diary of activities (e.g. teaching at University of third age, tea once a weak, concert one every two weeks, friends visit twice a week so forth).
* Telephone calls. Duration and numbers called. Analysis of pitch can be evaluated for cognitive decline.
* Video-calls through Giraff to caregivers.
* Cards or other social activities played through Robohome.
* Interaction with the community (to be better defined).

**Cognitive activities:**

Memory games output (time / success)

Puzzle games (time / success)

Results on specific tests (e.g Mini-mental) spread over several days.

**Physical activities:**

Balance exercises

Arm movement exercises

Balance and hand support exercise.

Results on specific tests.

**Diet**

Adherence to recipies suggested by Giraff.

## Task 3.1 (M3-M18) Multimodal HRI interface design (PLY,

The interfaces with the elder will be implemented and fully tested. In particular, several different basic configurations modalities will be proposed to the end users and evaluated. Speech and gesture interfacing through the Kinect device of Giraff will be fully exploited. These social signals will be used by the interface and speech dialog system to facilitate interaction. On the other hand, the interface will provide speech-based feedback to and to ask questions to solve pragmatic ambiguities.

**We will give one step further and we will design all the interfaces and the robot itself to maximize the degree of compliance of the robot with the elder.** The basic mechanisms that will allow interface to be easily configured to the elders activity and monitoring needs will be designed along with mechanisms to adapt the interfaces to eleder current status.

Particular care will be put in the **design of the virtual caregiver**. A continuos feed-back to the elder is one of the fundamental elements to keep her engaged [REFERENCES]. Several approaches to this have been proposed. REVIEW. Particular care will be put in designing a virtual caregiver avatar, such that it does not fall in the so called “**uncanny valley**”[[39]](#footnote-39). Its aspect will be stilyzed so as the subject clearly understands that the avatar is a humanoid being, but does not really pretend to be a human being.

In the Wii-fit system, an animated virtual balance board is used to guide the user through exercises and give him a feed-back. In the REWIRE project, users can choose among several possible virtual therapist avatar, according to their idiosynchrasis: some preferred a puppet, to stress the game nature of the interaction, while others felt more reassured seeing on the screen an avatar resembling a doctor[[40]](#footnote-40) [QUOTE]. In both cases, the Virtual Therapist represents an embodiment of the therapist and it is equipped with 3D face and lips animations and text-to-speech technology to make interaction more real.

|  |  |  |
| --- | --- | --- |
| hannah | piggy | C:\AlbertoW\Eudora\Embedded\1d6e6b.png |
| (a) | (b) | (c) |

Figure 8 -The Virtual Therapists used in the IGER system: a) a humanoid avatar, Hannah, b) a mascot, Piggy, and e) a real therapist.

## Task 3.2 (M3-M18) Behavior analysis (PLY, PCL, SAS, MUN, POLIMI,….)

This task will be responsible for the behavioural analyses of the HRI experiments. This will be primarily based on standard analyses of the user’s behavior (gaze direction, gestures, speech) through video coding methodologies. The analyses will also follow the developed in Task 2.2. On HRI and user requirements. In addition, a set of controlled experiments will be carried out with the explicit manipulation of targeted conditions (e.g. speech-only interaction vs. speech+touch interface) to evaluate different features and functionalities of the interface and of other

Main way of communication of the virtual caregiver will be through speech combined with simplified animation[[41]](#footnote-41). Desired features can be the clarity of language exposure and pitch / characteristic of the voice reproduced by the virtual caregiver some variability and even surprise elements in the feed-back[[42]](#footnote-42) [Mataric]. We will also aim to provide to the elder some possibilities of personalization.

## Task 3.3 (M3-M30) Identification of mix of activities (OREBRO,

One of the characteristics of Robohome2.0 is to develop a collaborative intelligence, upon which a continuous interaction between stakeholders and the system is obtained.

A mix of activities of the four classes can be required to age well. Possible mix of activities will be defined, according to the personal goal of the elders, compliance, idiosyncrasies that will all contribute to steer the mix towards the most effective one, thus achieving complete elder empowerment as he will main actor in the final decision. Self-determination is considered one of the main factors to increase intrinsic motivation and therefore the adherence to healthy lifestyle[[43]](#footnote-43), [[44]](#footnote-44).

The virtual caregiver will be able to suggest to the caregivers and clinicians a possible suitable mix of activities. This can be represented, for instance, through a fuzzy expert system, whose output is continuously updated with the feed-back from the elder adherence to the lifestyle prescribed such that the optimal mapping from the elder profiling (input) and the mix of activity (output) is continuously tuned this increasing the knowledge of the virtual caregiver on this topic.

Artificial Intelligence techniques will be used o identify clusters activities in terms of intensity and challenge levels along the physical, cognitive, social dimension. One possibility is to resort to fuzzy clustering systems that allow some overlap between the clusters obtained.

The virtual caregiver collects all the sensors and behavioral data and extracts a picture of the current psycho-physical state of the elder. This information can be compared with past history and used to define a mix of activities that are most suitable to the elder. When large deviations occur, warnings can be sent to the caregivers and / or to the GPs.

We may envision a structure for which human intervention can be minimal. This could still be required, for instance, some general themes upon which to develop activities can be provided on a regular basis by the system manages. Indeed a direct video communication is guaranteed between GPs and the elder in case a consultation is needed and between remote relatives and the elder.

For instance, at due time, RoboHome2.0 will inform the elder through the virtual caregiver that she has to take a given pill and that the corresponding drawer has been unlocked. The virtual caregiver will transmit this information to the patient with the best channel available, taking into account the elder preferences and the status of the devices (e.g. it can be through an SMS or video message on cell phone, through Giraff monitor or through TVscreen). A model based on computational intelligence (e.g. reinforcement learning) will be used to make the virtual caregiver learn the best option for that elder.

**SCENARIO: Anna is calling her friend less often in the last week. Giraff (ROBOHOME) identifies that Anna has to be suggested more social activities and suggests her more social activities, suggesting playing cards, give calls to Michela or Mary, who has not heard about since a long time, or to go with her friend to the violin concert of her nephew to which she was invited.**

## Task 3.4 (M9-M24) Virtual caregiver and social monitoring (OREBRO, POLIMI, ….)

Two are the elements that will be specifically implemented to monitor social activity. The first one will be a profiling of telephone calls in terms of number calls and duration. It will allow monitoring the intensity of relationship with the pairs through the phone. Similarly the interaction through the community will also be measured and profiled. Overall these two measures will allow to derive one measure of socialization.

This will be combined with a diary of activities that can be combined asynchronous by a relative, the elder himself or a caregiver in a digital form inside the caregiver. A list of typical activities will be made available and the user can introduce the specific activities (teaching to groups, concerts, theatre,…) from the list and comment upon it through speech interface, using speech to text conversion.

## Task 3.5 (M7-M24) Data analysis to profile the elder condition (POLIMI, PCL, SAS, OREBRO, UNIMI, )

All the data acquired by the sensorized network and all of the scores obtained by the activity center will go to the monitoring center. A proper data analysis to compute the actual user condition and to compare it with the last user condition available will be performed. The data monitoring center have to:

1) Identify indicators of physical and cognitive decline:

- how many times the Robohome reminded the user to take peels before obtaining compliance.

- how many times a day the user used the object locator (forgetfulness)

- how many pre-defined instrumented ADL where performed and how long do these tasks take.

- gait speed during indoor movements in the house.

2) Assign weights to the decline indicators. These weight will be personalized to the user scenario and based on geriatrics experience in frailty evaluation.

3) Create probabilistic rules to infer cognitive and physical improvement or deterioration of the user profile.

The correlation between indicators computed from the information gathered by the sensorized home and typical tests of a geriatric comprehensive assessment will be assessed to create rules for detecting significant changes in the user profile. When a change is detected the tele-monitored tests al used to assess the user condition and eventually the user scenario is updated.

4) Produce as outputs:

- Alarms to formal or informal caregivers when needed

- New activity program adapted to the new user condition that has to be transimitted to the activity centre

## Task 3.6 (M4-M12) Elders profiling (OREBRO, PCL, SAS,

A second grouping is required to identify clusters of elder people with a similar profile in terms of idiosyncrasys, to better tune the activities proposed. Such profiles are further refined through the feed-back produced while executing the activities so that the most enjoyed activities can be proposed more often.

A profiling of the elder is obtained and the best match between the activity made available in the gamification center and the profile will be spawned. The profile will be used also to configure the activities to maximize the enjoyment of the elder.

## WP4 – Smart Activity Center (UMIL, ….)

**Objectives:**

* Realize the Smart activity Center with full functionalities and the communication infrastructure with the virtual caregiver;
* Design, implement exercises that can be adapted to the physical and cognitive status of the elder;
* Cross-calibration of video / intertial / graphics and other devices.
* Long lasting games through automatic narration, and maximum motivation
* Use generic everyday physical objects as trackers.

**Description of WP**

**Objectives:**

* Realize the Smart activity Center with full functionalities and the communication infrastructure with the virtual caregiver;
* Design, implement exercises that can be adapted to the physical and cognitive status of the elder;
* Cross-calibration of video / intertial / graphics and other devices.
* Long lasting games through automatic narration, and maximum motivation
* Use generic everyday physical objects as trackers.

**Description of WP**

The smart activity center provides a wide variety of activities, personalized by the virtual caregiver, to the elder. The activities suggested in terms of exergames are aimed to exercise physical / cognitive aspects and to promote social activity, promoting a healthier lifestyle. The activities will be negotiated with patient empowerment strategies, such as negotiation of the lifestyle, goals of activities, and feedback from monitoring and exercising themselves and the caregiver is informed on the resulting general goals.

The Smart activity center is heavily based on **gamification**. Gamification involves the use of game design and game mechanics for a purpose other than entertainment[[45]](#footnote-45). Gamification techniques strive to leverage people's natural desires for competition, achievement, status, self-expression, altruism, and closure[[46]](#footnote-46).

In a single-player settting, gamification concerns designing gameplay such that the user feels rewarded when accomplishing a task. Intrinsically, this can mean adding a game on top of the exercise, providing a goal and meaningful gameplay, as well as feedback, Extrinsically, to this aim, various and targeted reward systems can be devised, for instance: points or coins gained, achievements and levels reached certified by virtual badges, improving in completing a game (e.g. a puzzle). Such rewards can be shown by a progress bar [ADD REFERENCS – cf. Wikipedia] and spent inside a community of players, showing relative achievements through ranking or leader boards [ADD REFERENCES].

In a multi-player setting, gamification can be implemented through direct or indirect competition, or through collaboration. Indirect competition follows the use of scores, virtual badges and achievements, when they are integrated into a social engine. Direct competition can be implemented by providing multi-player play, so that two people can directly compete in a race, sport or even mini-game. This is implemented in many online games, especially sports and shooter games. Such virtual competition is considered extremely challenging and it allows athletes from different parts of the world to compete and compare their performances [REFERNCES NEEDED]. At last, collaborative games can be played with multiple people, all pursuing the same goal. This allows less harsh, not competitive activities to be performed in a social manner. In all these cases, a proper challenge level is required to allow users to enjoy gaming and achieve effective gamification. If too challenging player would give up soon, while if the task is too easy the game becomes boring and uninteresting soon.

All these elements contribute to enter the player in a state of flow[[47]](#footnote-47). Flow theory is widely accepted as guiding principle by the game design community. In particular, it states that when the physical and cognitive skills of the user are matched by the level of challenge posed by the game, the user enters a state of complete focus and immersion in which it loses track of time. Gaming alternates moments of difficulty and moments of easiness of play. The benefit of the flow state is that the user becomes completely focused on the game and everything else vanishes. Studies also show that physical pain is also reduced when flow state is reached[[48]](#footnote-48).

In the latest years, gamification has been gaining a lot of interest from very diverse fields and it can thus be found everywhere[[49]](#footnote-49): from car fueling systems to ATMs, to environmental campaigns, to workplaces around the world. At this speed, every aspect of our lives will likely be affected by gamification in the near future[[50]](#footnote-50).

Gamification has received a strong push by the novel tracking devices, like the Nintendo Wiimote Controller and Balance Board, the Sony Move, and the Microsoft Kinect, that have revolutionized the way people play video games, making interaction much more intuitive. It was soon recognized[[51]](#footnote-51) that **these devices allow the acquisition of motion and interaction data of good quality that be useful in many domains**. Two of these are indeed fitness and rehabilitation. In particular Wii-Fit[[52]](#footnote-52) proposes a series of exercises for increasing balance and strength guided from the Nintendo Wii balance board with rich graphics and some elementary evaluation.

Alongside, powerful games engines have been made available recently under open source license, or with limited costs (e.g. Unity or Panda3D). This, paired with the rise of mobile gaming, has opened the game development process to smaller teams, who can no sit beside the big corporations, complementing their offer. On the other side, it **has allowed the incorporation of novel ideas coming from the research fields into new or existing video-games with less technological effort than before.**

The application of serious games to improve health is currently a very active research area.

Several EU projects, mainly targeted to rehabilitation, are based on the concept of stimulating and motivating the people with games. The REWIRE project is developing, integrating and field testing an innovative rehabilitation platform based on video-games that allow patients who have been discharged from hospital to continue intensive rehabilitation at home. In the SCRIPT project, games are combined with small robots and are aimed at guiding patients in the rehabilitation of wrist and hand functions. Also should be mentioned the project H\_CAD, which was aimed to rehabilitate cognitive dysfunctions was carried out through tasks used in occupational therapy inside a controlled environment. In the EU project Backhome, how to provide cognitive rehabilitation tasks to people with severe disabilities is investigated. Currently, three categories of cognitive games have been taken into account: perception; attention and concentration; and memory. It is beyond the scope of BackHome to develop, validate, and illustrate clinical outcomes, however the intention is to validate the efficacy and stability of the proposed solution within a future evaluation. CUPID is aimed to Parkinson patients and in particular it develops an approach in which specific exer-games are …… The RGS system is aimed at upper arm and develops a game aimed at guiding the arm in 3D space. However, few of these projects go beyond basic graphics and gameplay resulting into exer-games of little attraction as they lack addressing good game design guidelines. Moreover, they have limited configuration capability and adaptation as well as monitoring is not provided. Moreover, the repetitive nature of their game machanics make them not fit for prolonged exercising. The IGER (Intelligent Game Engine for Rehabilitation) game engine[[53]](#footnote-53), developed inside the REWIRE project, is a remarkable exception. **IGER constitutes a new generation game engine that provides in an integrated and coordinated way, several high level functionalities**: IGER integrates methods of computational intelligence for users’ monitoring and adaptation, providing the required elements to make exercising at home feasible and robust. IGER games are fully configurable so that they can be tailored by the clinicians to the users needs and exercising goals, and they are continuously adapted in real-time to the user’s performance through a Bayesian framework that updates game parameters to provide an adequate difficulty level while keeping the elders within the therapeutic constraints specified by the clinicians. The gameplay is continuously monitored using a fuzzy system (leveraging for instance the therapists’ knowledge) to avoid wrong postures or wrong movements, which would make exercising more harmful than useful. A novel color coding feed-back is used to inform the user in real-time on wrong movements. IGER also integrates a personalized avatar that advises the user and guides him through the exercising sessions. Controlled randomization of assets, targets, voice feed-back avatar choice, and facial animation are all aimed to increase compliance with the therapy[[54]](#footnote-54). Finally, several input devices can be interfaced to IGER thanks to its specific input abstraction middleware. Besides this, from videogames, IGER has borrowed the concept of game engine: a set of tools that, on one end, make the games run on the machine they are designed for and, on the other end, help the developer in creating games that share the same features. Therefore, IGER has allowed a fast prototyping of new games, reusing the gaming functionalities that been developed for previous games. IGER offers therefore a good starting point to RoboHome.

The use of the IGER system, made available for Robohome, will made the implementation of the exer-games sufficiently fast to be accomplished inside the framework of the project. For instance a total of 17 exer-games have been designed and implemented inside the REWIRE project in one year of development. Given the experience of UMIL, an even larger number of games is expected to be developed.

A proper set of activities that counteract social, physical and social decline will be defined. The most promising activities will be selected for implementation. At least four activities for each domain will be defined for the implementation.

**Beyond the state of the art.**

* LOD in the game scenario
* Automatic story generation inside a given theme.
* Addressing long-term motivation.
* Multi-device gaming, making everyday objects game trackers.

## Task4.1 (M1-M12) – Design and Implementation of the Activity Center (UMIL,

Activity center will be built around the **gamification** concept and therefore its main component will be a general purpose game engine. Aim of this task is to realize a game engine with all the functionalities required to realize mini-games that can guide the elders through social, cognitive and physical activities defined in WP2 as well as to run mini-games that are aimed to educate and advice them. Basic functionality will comprehend loading scenes and avatars, input data acquisition from trackers, collision detection, rendering, and animation. To make the activity center the most compliant as possible, full configuration and adaptation will be made available as well as supervising of elder activity and real-time feed-back through an adequate avatar that acts as a virtual trainer.

Such platform will be built starting from the IGER game engine[[55]](#footnote-55), developed for the REWIRE project, extending its architecture to address elder people with different profiles and to provide a mix of heterogeneous activities. The capability of IGER to accommodate many different tracking devices, through its input middleware, will be fully explored here to provide the best guidance in the different activities.

The activity center will be designed to address a large variety of activities, according to specifications set forth in WP2 and WP3. The center will be realized in subsequent steps, incorporating via via new features. A first prototype with basic mechanisms will be developed early in the project, starting from the IGER system[[56]](#footnote-56). It will allow loading scenes and avatars, collision detection, rendering, animation capabilities and acquisition from several devices. Real demos and videos will be fully exploited in WP2, in Task xxx, for tuning the functional specifications.

Most accepted standards for data storage and transmission will be used (e.g. XML for definition of activities and configuration, quaternions for motion representation).

**Patient interfacing based on Natural User Interface, defined in WP2, will be developed**, such that activities will be played in the most natural way, without needing to hold or wear additional devices. Functionalities developed for Task4.1 could be re-used to fully develop gesture interfacing and open source voice recognition software, like the Microsoft voice recognition based on Kinect audio input, will also be explored.

In this task, we will explore the different visualization possibilities offered by modern ICT technology. We aim, in particular, at introducing the concept of **device equivalence** in the home field. This is a concept well known in the technology domain[[57]](#footnote-57),[[58]](#footnote-58), and it will be fully exploited here to define the compliance to the patient of the different display. These can be: Giraff display, computers, laptops, tablets, digital frames, cellular phones, TV screen and so forth and the output will be formatted and displayed to the current device that will be chosen by the Virtual Care Giver as most suitable for a particular activity / message.

We will fully take advantage of the IGER middleware, called IDRA ( ) to support a large variety of tracker devices. Such layer will allow to easily integrate and **use as trackers the everyday objects instrumented** developed in WP5.

***SCENARIO. Maria has started to use a cane, with whom she feels more comfortable. However she is still stable enough and the caregiver identifies postural exer-games useful to maintain a good postural control for prolonged time. It suggests to Maria to play games like the arcade game“Whac-A-Mole[[59]](#footnote-59)” in which she has to smash a virtual mole coming out the virtual floor displayed in front of her. Indeed such exer-games was fun but allows also Mary improve in managing her cane.***

## Task 4.2 (M1-M24), Multi-player infrastructure (UMIL, BDIGITAL….)

This is a mainly technological task aimed in maximinizing the sense of presence when more elder people are doing activity together. To this aim we will provide two different settings. The first setting will be based on multi-video streaming, in which the video captured in multiple sites is shown in the same display window. Such setting can be used to support social activities. For instance these video can, for instance, capture a group of elder that are playing the same card game, each in his own house. All the elders will see theirselves and the other pairs in different windows on the screen. Card played will be shown in the middle of the screen mixing virtual elements with multiple videos. We will analyze the most suitable technology to realize this. At present, SkypeVideo APIs seem particularly suitable for this as they allow point to point video streaming, that can be manageable for a few elders playing together. BDIGITAL CAN PUT HERE ITS VIEW. Merging video streams with virtual scene will take place at visualization time, resorting to alpha shading as shown in the Duckneglect system[[60]](#footnote-60): a silhouette with the virtual scene, a card virtual carpet in this case, is created and this is used as a binary transparency mask, substituting to the current content of the viewport outside the silhouette area with the videos[[61]](#footnote-61).

Similarly the same platform will be used to do physical exercises in a group, while still being each elder at his own home. In this case, a virtual trainer will lead the exercises showing what to do in the center of the screen, and the different elders will see all the other pairs doing the exercises.

Such setting will promote also discussion and speech between the elders themselves and will promote socialization.

**SCENARIO**

***Michela leaves in Milano. She is feeling lazy and a bit less social in the last days and is moving less time as shown by more time spent on the sofa, watching TV and the average decrease of telephone conversations. The virtual caregiver approaches her and, with nice voice, remembers that she was a dancer when she was young and that some exercise would indeed helpful to her. The Virtual Caregiver suggests also her that at 3pm in the afternoon there is a live virtual session of dancing for a group of people of her capability. Lucille is sceptic, but when the Virtual Care Giver remember her this appointment just after lunch, she decides to try. With her surprise, she sees in the group a old co-dancer of her, Lenita, living now in Orebro. They are happy to make dance movements together and, at the end, they could restore the old friendhship and since then they started meeting not only for the exerises, but also through video communication thorugh Robohome2.0 platform. Eventually their nephews met each other and could travel to Italy and to Sweden in summertime, enlarging the social dimension of their whole family. Michela and Lenita were very happy of this.***

In the second form, the multi-player platform will support some collaborative work. We will explore for instance this through puzzle games that can be made cooperatively. In this case, in addition to see on the screen the virtual table with some of the puzzle tiles in place and the video of the other pairs playing Robohome2.0 will also track elder gestures to select virtual pieces not yet positioned, rotate and put them in place. This will be carried out through gesture recognition associated for instance to the 3D camera of Giraff, using for instance the FAAST library[[62]](#footnote-62) or the new SDK for Kinect2.0 that will be commercially available late this year. With this set-up , we aim to realizing a collaborative, goal oriented activity that can have a cognitive and social value.

Most of the work will be completed in the first year of the project (D4.1). We leave open the possibility of few refinements that could be implemented in the second year of the project, according to the technology offer that will be made available (D4.3).

## Task4.3 (M4-M24) – Mini-games content generation (UMIL,….

We will begin from two starting points: the identified profiles of the elders and the associated mix of activities (WP3) and the identification of suitable frameworks that can be familiar for the particular elder, like for instance a classical environment of a fairy tale or a virtual Olympic competition or a travel around the world. Such **personalized environments will constitute the containers inside which the activities will be accommodated** and it will be identified with the elder and his caregivers in a collaborative way.

We will then define a set of activities in the form of mini-episodes. These can be for instance solving a puzzle, playing a memory game, physical exercising or learning the interaction between the drugs he takes and the avoidance of the decline associated with aging.

A set of mini-games will be developed upon these activities and the specifications set in WP2, that will provide the boundaries inside which the games have to be developed[[63]](#footnote-63). A meaningful gameplay will be designed and implemented to guide the elders through the desired exercises; in particular, clear interaction and feed-back with reasonable lasting effects, enjoyable environment, music, sound, rich graphics will be adopted according to the rules of good game design[[64]](#footnote-64). Open software will be possibly used developing the center on frameworks like Panda3D or Unity, the latter would make easier to implement technological equivalence, as it already supports multiple devices.

Moreover, the set of parameters required for monitoring the elder will be defined in WP2 and logged throughout the activities.

All mini-games will be fully configurable in terms of difficulty of gameplay, such that they match the elder capability.

Games will not be adaptable only in their gameplay, but an additional innovative feature will explore inside Robohome2.0, namely the introduction of the **level of detail** **(LOD) in the game design**. LOD is a technique well known in the graphics domain, to decrease the “complexity of a 3D object representation as it moves away from the viewer or according other metrics such as object importance, viewpoint-relative speed or position [Wikipedia]”. Several techniques have been developed to create objects of lower complexity iteratively applying simple transforms to the objects at the highest complexity[[65]](#footnote-65).

A common effect of aging is decline of cognitive processing capability and, in particular, in spatial cognition[[66]](#footnote-66), [[67]](#footnote-67). This is well known in neurology, where after stroke, only simple and clear stimuli are allowed, and video-games targeted to acute patients have a real simple and basic graphics [QUOTE]. Therefore, fining the proper level of detail allows increasing the likeness of the scene and therefore the attraction. To achieve this, some mini-games will be realized according to these principle. Providing a high LOD version, with lots of details, enrichments and animated assets on one end, and a low LOD version, in which essential elements will be present in the scene. Several intermediate versions will also be provided. Evaluation of the best resolution will be carried out throughout the project.

In particular, **physical exer-games** will be mainly based on the exer-games developed inside the REWIRE project. An important step forward will be the addition of exercising with a caregiver either remotely or inside the house. In these situations the elder stands in front of Giraff with the Kinect sensor aiming at her. Alternatively, taking advantage of the device equivalence, she can use the TV monitor to have the game displayed and play in front of it. In this case Giraff will accommodate besides the TV using its Kinect to survey elder motion in front of the TV. The elder will see on the monitor the virtual caregiver introducing the exer-games and starts exercising following the gameplay.

We will explore a novel set of exercises in which the elder has not to interact directly with the virtual objects, like in most of the exer-games, but she has to realize movements to produce gestures that can be complementary to those of the virtual caregiver. Such **imitative games** increase largely the cognitive value of the exercises. For instance, she can play to “morra cinese” with her. Such game requires arm movements but also reasoning on which can be the best next action. Imitation is thought to have an important role also towards socialization[[68]](#footnote-68).

**SCENARIO: Robert gait is becoming slower and less stable. Giraff identifies that Robert needs to move more and identifies exercises for balance and posture as the best remedy. It proposes to him a set of exer-games to be played for a quarter of an hour for at least two weeks. It also shows to Robert the picture of all the other elders inside the Robohome community that has entered in the same program. The idea of a group of new people with whom Robert can compare turned out really motivating for him who start exercising regularly without missing a day. His caregiver and GP were extremely happy of this as they believe this would keep him far from needing a wheel-chair for longer time.**

**Cognitive activities** will be based mainly on touch screen interaction. A set of suitable exer-games, identified in WP2 and WP3 will be designed and implemented. Some of them could be puzzle, Simon game or memory games like memory. Content will be generated automatically according to the elder idiosynchrasis. For instance, puzzle games can be based on pictures uploaded by the elders, possibly regarding happy times with children and nephews. Memory tests may be related to diet, and be delivered as recipies for the preferred cake of the elder’s housband and so forth.

Some games already diffused like ruzzle can be incorporated inside training, promoting the use of games already distributed by the open source community.

Some of these activities can be played in a competitive or cooperative way. For instance, memory games can be played with other elder connected through Giraff community.

Some activities can also be provided for simple assessing purporse. For instance, when switching on the TV the virtual caregive may ask randomly the typical questions used in mini-mental tests, like the current day, season, month, the name of daughter or son and so forth.

**Social activities.** Card games are most popular among the eldest. They combine three important aspects: cognitive stimulation (memory, strategy), social interaction and competition with pairs. It is not always possible for the elders to get together in a physical place to play, and RoboHome2.0 can help the elder in this activity providing a virtual environment to play together. Robohome2.0 will take advantage of multi-player support and video interaction to provide a real-time video-stream of all the elder in a group inside the same display window, so that each elder sees the other as he was present in the room. A virtual table will be represented with the cards played, the cards on the table, the card virtual deck and the cards in the hand of each elder.

**SCENARIO: Anna is listless today. She is invited by the smart caregiver to contact her friends for a card game. Anna starts playing with Emma, Michela and Lina but Emma realizes that Anna is slower than usual to play her card and she is not at her best level. Emma herself leaves a message to her virtual caregiver that transmits the gentle message to Anna’s relatives.**

## Task 4.4 (M4-M36) – Automatic narrative for education and training (UMIL, POLIMI,….

The activity center will also provide education of the elder fully exploring the novel trends in gamification. We will begin from two starting points. The identified profile of the elder and the associated lifestyle program, and the identification of a suitable framework that can be familiar for the elder, like for instance a classical environment of a fairy tale or a virtual Olympic competition or a travel around the world. Such environments will constitute the containers inside which the activities will be accommodated.

We will explore the possibility of **developing automatically a narration** that can sustain the activities required by a healthy lifestyle for prolonged time[[69]](#footnote-69). The story will assume, possibly the form of a tale, and chain different mini-episodes. We will fully explore the morphology analysis of fairy tales developed by the Russian school[[70]](#footnote-70), that has identified elements common to all fairy tales, like for instance the presence of an agonist and an antagonist, the fight, the elation and so forth. We will analyse the most interesting elements and we will extract few of them in order to be casted into a set of characters. These elements can be combined to **automatically create mini-stories** by defining a set of attributes of each element and matching them to the attributes exposed by other elements and situations.

We will do automatically defining a finite state machine that describes the possible choices at the end of each episode, similarly to[[71]](#footnote-71) and develop a reinforcement learning approach to identify the best next episode. This can be obtained efficiently resorting to optimization through graph cut. Such approach has already successfully explored by our group in chaining long animation sequences[[72]](#footnote-72), to choose in real-time which would be the best next animation sequence in real-time, optimizing an adequate cost function.

Here we will extend this approach defining a cost function that describes how best each mini-episode fits the current narration point and the story in general[[73]](#footnote-73), in terms of **coherence and consistency** introducing explicitly into the cost function also the motivation elements according to **the flow theory** first defined by Mihaly Csikszentmihalyi[[74]](#footnote-74). Flow theory is widely accepted as guiding principle by the game design community. In particular, it states that when the skills of the user are matched by the level of challenge posed by the game, the user enters a state of complete focus and immersion in which it loses track of time. Gaming alternates moments of difficulty and moments of easiness of play. The benefit of the flow state is that the user becomes completely focused on the game and everything else vanishes. Studies also show that physical pain is also reduced when flow state is reached[[75]](#footnote-75). To achieve this, the mini-games chosen will allow increasing / decreasing the challenge of the patient such as driving him towards a flow state. A feed-back from the elder in terms of likeness will be used to tune the emotional value of each episode so that the most story most interesting to the elder can be created. This feed-back from activities will be gathered in an informal way by both the game center through Q&A provided by the virtual caregiver and through Giraff through touch screen interaction that provides a reacher feed-back. Such feed-back can go from simple “I like” in form of smily or other symbolic feed-back to more structured feed-back in the form of multiple answer and so forth.

This approach will be common to exercising and education, where in education there will not be specific activity, but tutoring material will be provided according to elder lifestyle goal and present behavior.

At the same time we will explore also a more traditional approach to education like the one followed in the “badblood” game[[76]](#footnote-76) that is based on a classical structured knowledge.

## Task 4.5 (M7-M24) Motivation (UMIL, POLIMI, PLY,…..)

Motivation is indeed at the heart of maintaining a healthy lifestyle. There are two forms of motivation: intrinsic, that comes from inside the elder, and extrinsic that comes from the external world. Robohome2.0 will work to increase both intrinsic motivation, by making the actual tasks more compelling and fun to perform, and extrinsic motivation, promoting promoting healthy activities, diet and socialization. However, the simple proposal of activities is not sufficient, we have to present and propose them such that maximum compliance and enjoyment can be achieved, and this is the main tenet of any gamification process. In this process, it should be clearly have in mind that external gamification is usually less effective than the intrinsic one for long-term compliance and behavioral changes[[77]](#footnote-77), [[78]](#footnote-78). To maximize the impact of extrinsic motivation, we aim to increase the gamification level inside the game engine by layering the game engine and introducing additional gamification issues related to the virtual community support and the profiling of the elder. This will take fully advantage of IGER being a game engine and therefore able to build the game from assets that can be loaded at run-time according to elder idiosynchrasies, such that the elder himself can choose and shape the appearance of the games that guide his activities. This is traditionally a key factor to increase intrinsic motivation[[79]](#footnote-79), [[80]](#footnote-80).

Different layers of gamification are placed inside the activity center, in order to address all aspects of motivation: intrinsic and extrinsic, short-term and long-term.At the basic layer are the *exergames* themselves, physical and cognitive exercises are hidden under the hood of compelling and fun mini-games. ‘*Make a step to the right’* may be a valid therapeutic balance and posture exercise, but if it is translated as *‘catch the fruit with the basket on your head before it falls’* or ‘move that shell on the bucket’ may be more enjoyable, while still retaining its validity. We couple the exercise goal to a fun gameplay goal, tailored to the elder and to the general theme set, letting the elder performing the exercise inside a virtual environment inside which, music, playful sound effects and hand-painted 3D graphics all contribute to attractiveness of the game. Intrinsic motivation is thus reinforced by the enjoyable experience of play. The theme of the games can be adapted also from the feed-back of the elders themselves who rate the exercise experience at the end of each session. This rating is used inside the Virtual Caregiver to tune the exercise difficulty or even to automatically change the game theme according to an evolution paradigm widely explored in [QUOTE] and described in WP3.

The exergames represent only a first gamification aspect, however. We will also provide short-term extrinsic motivation under the form of verbal praise from the Virtual Caregiver Avatar that is constantly monitoring the patient, giving advice on the exercises and praising her when she performs her exercises correctly. Short-term extrinsic motivation is also empowered by additional gaming-like solutions: points and high-scores, colorful and meaningful feedbacks and personalized content, according to elder profile.

Long-term motivation represents a major issue when activity prolonged in time is required: games may get old soon and lose their appeal after a period of a few days of repetitive play, and the kind words may not be enough to keep the patient engaged for months. We will tackle this by developing a *‘****bigger game’* container**, inside which locate the different individual exergames, transforming the single exercises into small bricks that build the big game’s actual, slower, gameplay. as the ‘bigger game’ can be composed of a casual, not particularly challenging game, so that it can be played with little effort, similar to successful casual games such as FarmVille[[81]](#footnote-81). We will fully take advantage for this of the community support and allow elders to play the bigger game with pairs in a cooperative or competitive way. A common them that supports both tutoring and activity will be possibly adopted.

To support **games that can have a prolonged life** we will explore different techniques that allow realizing plots and scenes that are never equal one to the other.

We will work at two levels. We will introduce **controlled variability inside the scenes and elements** associated to the same mini-games, similarly to what described in[[82]](#footnote-82) where the exer-game user has always to perform a visual scanning task, but at each session, scenarios and objects are varied such that the users perceives playing a different game, but in fact, he is guided to do the same number of movements in the different direction.

We will go beyond classical finite state machines framework introducing stochastic finite state machines allows to introduce a **controlled variability** in the temporal dimension choosing the next mini-episodes according to statistical distributions. We will fully explore here **Finite State Machines[[83]](#footnote-83)** to allow game variability in the transition from one state to the other to complete a given task. This allows managing complex interactions with limited computation effort. They will allow **to create variants of the game that would never tire the patients.** Although many issue arise when many characters and many machines interact among them, to maintain a player engaged and have a rich game play in virtual reality games, the challenge is to maintain the subject engaged with simple environments, simple games to repeat these tasks over and over again without distressing. This same model will allows monitoring the elder’s choices during the game and tune the game play to force the elder to execute also the less chosen actions. **This would be a tool that allows** **maintaining a game balanced also in front of stochastical variability and avoid abituation.** In this case optimization will work shifting the probability distribution of choosing a next episode, still retaining all the possible choices with lower probabilities. As shown in[[84]](#footnote-84) the prediction of the average number of episodes after which the same episodes is played again can be estimated.

The approach of Robohome explores therefore an innovative way to create educational stories that can be updated and provide always different scenarios to the user, thus supporting long time interaction. Final result will be a story that can have the maximum impact on the elder.

In the last year of Robohome2.0 we will also explore how to create narration taking advantage of the community of elders, at that time well established, extending the mechanisms that chain the episodes beyond the single player to create a story that is written by multiple elders that share the same lifestyle and goals, thus promoting socialization also inside the tutoring and exercising activity.

**SCENARIO**

***Therese has never liked the mountains. In his youth times she always liked to go to Porto Palo beach in Sardinia. This information is inserted in her inclinations in the environment category. The game center addresses it and, whenever it possible, chooses scenarios and games assets related to the sea-side. For instance for the memory games a sea-side scenario with shells is provided[[85]](#footnote-85).***

## Task 4.6 (M3-M18) Definition of calibration games for video and/or inertial systems (UMIL,

This task is aimed to developing all the methods that allow fusing tracking data obtained from different sources. These methods will be based on games and therefore we will explore games also for calibration the platform. A high accuracy calibration will be carried out by the service provider before delivering the system, but fine tuning of the calibration is required on the field and should be as simple as possible to cope with limited abilities of the elder and his caregivers and work in a general environment. This is required for instance to register the motion data acquired from the instrumented objects with the graphics or with the video data. Ad hoc calibration objects that can be integrated in the room furniture will be studied. Automatic spatial registration of the tracker with the graphical engine will be carried out.

We will also explore a cheap immersive Augmented Reality setting in which the elder see himself immersed in a virtual world while doing activities in it. To this aim the silhouette of the elder has to be isolated from an incoming video stream and pasted inside a virtual environment. Interaction with the virtual environment should be detected to create real-time interaction. Such installation was explored by UMIL inside the Duckneglect project[[86]](#footnote-86), in which patients reported an incredibly high sense of immersion (cf. Figure 8), provided that no appreciable delay is introduced. We want to extend this in Robohome2.0, but introducing this modality whenever the activity allows it, that is it is compatible with a mirror view, the silhouette of the elder is used as his avatar instead of a synthetic one. These can be for instance, imitation games, physical exercises that requires lateral motion and limited frontal motion, cognitive games and so forth.



Figure 9 - Silhouette extraction and integration inside a Virtual Environment

However, a clean silhouette could be obtained from 2D cameras only with controlled background, and this is beyond the use inside a common house. Kinect has raised the expectation of a robust foreground segregation, but this was not the case as Kinect SDK1.8 does not produce a clean silhouette and few attempts to improve it, turned out to be not completely satisfactory[[87]](#footnote-87). Several approaches have been proposed to improve calibration, embedding the estimate of the calibration parameters inside a larger problem of structure from motion[[88]](#footnote-88). However, the complexity of these approaches is not compatible with real-time as a delay of 70ms is introduced; moreover, their complexity requires high end computers that are not compatible with autonomous robots. Kinect 2.0, commercially available late this year, promises to have a batter foreground separation and its SDK will be integrated inside the game center. If not, we will develop a robust silhouette subtraction, building upon[[89]](#footnote-89), introducing in the segmentation process also the information that is derived from RGB images to smooth the gradient orthogonal to the silhouette.

**Deliverables**

Deliverable 4.1 – A first nucleus of physical and cognitive games + silhouette tracking. A first user manual will be provided M12.

Deliverable 4.2 – The full system for education. M18.

Deliverable 4.3 – The full smart activity center with the final reference manual, user manual and installation manual. M30.

## WP5 – Monitoring (POLIMI,…)

**OBJECTIVES**

**-** Systemdevelopment of unobtrusive customized monitoring devices;

**-** Development of the integrated sensorized home

**DESCRIPTION OF WORK**

RoboHome2.0 will provide a set of customized and off-the-shelf very low cost devices and tools to monitor the elder behavior at home and his physical and cognitive condition. All of the sensors will be designed and selected following the user and functional monitoring requirements (Task 1.5) and the technical specifications identified in Task 2.1. For each of the sensors different technological solutions will be studied. The developed sensors and sensorised devices will be also used to execute, at home, clinical tests by means of telemonitored validated tests and new pervasive clinical tests as defined in Task 1.4.

All the sensors will be integrated in the sensorized home (system monitoring system) and a comprehensive middleware will be implemented allowing the communication between the system monitoring system and the virtual caregiver. The definition of user scenarios (WP1) will be necessary to identify the set of sensors to be selected by each user profile. The modularity approach of the monitoring system will assure the flexibility and adaptability to different users and scenario.

The implemented middleware will provide to the virtual caregiver (WP3) the updated information about the parameters required to monitor the single user so to allow the personalization of the user profile according to the actual user condition.

**BEYOND THE STATE OF THE ART**

- Development of an innovative monitoring modality that is embedded in the usual lifestyle such that the elder does not perceive monitoring as an activity disjointed from ordinary life.

- Development of innovative services to promote independent living: a) novel service to remind drug administration and to monitor prescription adherence); b) alarms directly sent to the GP or caregiver when needed; c) novel service to track typical daily life objects and allow the user to find them.

**TASKS**

## Task5.1 (M6-M15) Development of sensors for physical monitoring (SXT, POLIMI,…. )

Both to monitor the physical performance during the exer-games proposed by the Robohome Activity center (see WP4) and during the physical clinical test proposed (see tasks 1.4 and WP3), different objects of daily life will be instrumented to monitor the user interaction with them. The objects to be instrumented will be defined in Task 1.5 Possible miniaturized modules that can be reused in different objects will be considered.

By means of inertial sensors integrated in the handle of cane for instance, it could be possible to analyze changes in movements, or specific behavior and or pattern modifications. MEMS technologies are now a stable and cost effective solutions: 3D, smart accelerometer and gyroscopes are wide diffused in game consoles and automotive systems. Many different models are available. The really compact design of such transducers (as low as 2x2x1 mm3) that allow to perform different kind of measure at really low power consumption.

With the aid of modern tactile sensing technology, it will be possible to measure the pressure or the force applied to different kind of handles, in order to infer data related to the clamping force and direction, for example.

Both inertial and tactile sensors can be connected or embedded with wireless modules, such as low power Bluetooth® modules (e.g. class 4.0) in order to create really low power, compact and flexible systems.

These modules will be realized with two modalities:

- The first will be a real-time transmission of the data and will be used for the activities integrated in the exer-gamees. For instance the cane can become a tracker inside one of the exer-games developed in WP4 so that for instance the elder has to climb a mountain by raising the cane and lowering it in specific positions. The movement in terms of velocity and pressure profile can provide very important information to evaluate the stability and control capability of the elder.

- The second modality will allow the on-board storing of the data related to an entire day (e.g. use of the cane in a stroll in the park and so forth). These data will be downloaded automatically when the cane is put on rest. For this aim, an approach similar to that of Giraffe and of Sony AIBOs will be used [ ]. During the rest condition, through wireless charge or standard charge technologies will be possible to recharge the systems. The new Bluetooth® Smart Technologies [http://www.bluetooth.com/Pages/Bluetooth-Smart.aspx] will be able to create extremely low power, standard transmission. Such wireless solutions are already compatible with emerging wireless charge technologies that can make really easy and safe the usage from elderly people.

A similar setting can be inserted in the handle of a pot and measure the interaction when cooking. The information from these devices can be collected directly through Robohome2.0, that will get close to them when they are being used, that is when variation in the transmission power or in the pressure measured is registered by the device.

This task will end with a technical and functional testing.

## Task5.2 (M3-M15) Development of sensors for environment and social monitoring (BDITIGAL, OREBDO, POLIMI, SXT …)

Given the fast pace of developing in domotic applications, ROBOHOME2.0 will realize an architecture that will be as open and standard as possible to incorporate easily new applications / components that are made available. At the same time, Robohome2.0 will integrate standard off-the-shelf components to monitor environment and social habits.

The Robohome platform will offer a set of environmental sensors that allows integrating monitoring of elder habit as well as his safety at home. Such sensors will allow launching an alarm or informing the caregiver upon the criticality of the alarm.

The final set of sensors that is required in ROBOHOME will be be the output of Task 1.??. These can be for instance,

* Presence sensors to check the level of mobility of the user in the day
* Cushion pressure sensor to understand how long the elder is sitting.
* TV monitoring (how much is on and the elder is sitting in front of it).
* Gas alarms
* Temperature and humidity sensor
* We can use, for instance, z-wave sensors to control presence, temperature, humidity, gas and smoke alarms and then send the information through a Rasperry micro-server to the virtual avatar where ambient monitor can be combined with monitors from other devices to adapt activity and possibly raise alarms. Different priority in the acquired information will be casted: gas alarms will raise a high level alarm with no delay while temperature and humidity may be acquired and processed with delay.

A profiling of the phone conversation of the elder will be carried out in terms of duration and called numbers. We will also carry out a pitch analysis with the aim of identifying possible consistent changes of emotional status that can be carried out, for instance, through time window Fourier analysis or cepstrum analysis of audio signal. Such information might be an early warning of emotional and cognitive changes that are indeed associated with some degenerative cognitive illnesesse.

The task will end with a technical and functional testing.

## Task 5.3 (M1-M15) Development of sensors for clinical monitoring (UMIL, SXT, SAS, PCL, … )

To monitor the health condition by means of the typical parameter identified in Task 1.5 (e.g., blood pressure, heart rate and glucose concentration ...) a detailed analysis of the state of the art and of the device already available in the market at project start will be carried out as this is a field evolving at an extremely fast pace. A possibility would be to select off-the-shelf OEM modules (e.g. <http://www.medlab.eu/english/modules/> , <http://www.casmed.com/files/documents/OEM_SellRev00.pdf> ). These cost-optimized and miniaturized modules can offer accurate measures meeting all of the medical equipment safety and quality standards and can be simply integrated in the final Robohome platfrm. The modules will be specifically selected according to the scenarios and user clinical needs. These modules can be directly mounted on Robohome 2.0 without using any wearable solution and would allow the elder to take required samples with the assistance and instruections of Robohome. In case of problems, the tele-assistance of a clinican (e.g. a GP) from remote will be made available. This will be required especially in the first period of use.

The task will end with a technical and functional testing.

## Task 5.4 (M6-M15) Development of sensors to promote independent living (SXT, POLIMI,

An important service offered by Robohome 2.0 will be the selection of sensors specifically focused to the promotion of independent living for the elders. This will be based on locating and identifying critical objects as specified in Task 1. and on assisiting the elder with the therapy as defined in Task 1. .

Robohome will provide the location of everyday objects (eyeglasses, keys, mobile phone, and cane). To this aim different already existent sensors to assist tracking of everyday objects will be investigated. There are new emerging solutions based on sticks or key ring [https://www.sticknfind.com/, http://www.thetileapp.com/] to be used with specific Apps, but elderly people has to find by themselves the objects and, moreover, the mobile phone has not to be lost. The Phone can be located through GPS signal, but usually GPS signal cannot be received at home

Also RFID technologies already are used for tagging objects. However, RFID tags devices require a reader to be placed inside all the rooms, with a high impact on the house, whilst new Bluetooth technologies (v 4.0) will allow to extend the range of detection, even with reduced power consumption.

Possible effective solutions, aimed at reaching a good standardization and integration with Giraffe, could be the same Bluetooth technologies used for the sensors. The alternative is to use also an active reading devices based on active tagging. To this aim a miniaturized localization device will be developed for keys and glasses. This will be based on low power Bluetooth and is hosted in a small lodge inside the frame. This system will strictly collaborate with Robohome 2.0.Drug dispenser.

A cooperative system in drug distribution will be developed in the form of a drug dispenser. This will be constituted of a set of drawer, each with an electromagnetic lock will be controlled remotely by the virtual caregiver. Only the right drawer is open at the time in which the elder should take prescribed pills. This approach requires that a caregiver fills the drawers at the beginning of a week, but it then guarantees that pills are not taken more than once or forgiven. At due time the virtual caregiver warns the elder through all the devices available, Giraffe, cellular phone, TV and so forth and it renew the memo every given period, until the drawer is not opened and pills are extracted [<http://www.google.com.tr/patents/US8588964>].

The task will end with a technical and functional testing.

## Task 5.x Sensors for environment monitoring

In such a system, while gas alert needs to send immediately a signal to the server for further action (besides launching an alarm), temperature and light sensors can transfer data through polling from the server.

**DELIVERABLES**

D51 Design and development of customized monitoring devices (prototype and test report) (M15)

D52 Sensorized home integration (M18)

MONITOR THE USER ENVIRONMENT

MONITOR HEALTH CONDITION

To monitor the health condition by means of the typical parameter identified in Task 1.3 (e.g.,blood pressure, heart rate and glucose concentration ...) low cost devices already available in the market that complies with all the medical equipment safety and quality standards are required (EN 1060-1, EN 1060-3, EN 1060-4 and ISO 8106).

Measurement ranges for adults should be: systolic pressure: 25 - 280 mmHg; diastolic pressure : 10 - 220 mmHg; mean pressure: 15 - 260 mmHg; pulse rate: 30 – 240 bpm.

SERVICES TO PROMOTE INDEPENDENT LIVING

Another important service offered by Robohome 2.0 will be the selection of sensors specifically focused to the promotion of independent living for the elders.

The sensorized home will be equipped with safety devices (such as gas alert) able to call the caregiver when necessary.

Concerning sensors to locate everyday objects (eyeglasses, keys, mobile phone, and cane) technical specification of the chosen technology, range of transmission, power consumption will be identified. This system will exploit the Robohome ability to navigate in the house [reference to Giraff]

To monitor prescription adherence an automatic system driven by the Robohome platform will be developed. It has to remind the user the drug assumption, allow only the correct assumption and eventually check the compliance.

MONITORING COGNITIVE ACTIVITIES AND SOCIAL INTERACTIONS

Cognitive interaction can be monitored by the log carried out by the activity monitor on cognitive tests (see WP3 and WP4 for more details).

MIDDLEWARE TECHNICAL SPECIFICATIONS

In this task, the technical specifications for the middleware that has to manage the whole sensors have to be defined. The middleware has to store and update all the monitoring parameters and has to assure a continuous communication with the virtual caregiver that remind the user when to use a specific sensor or service. Thus, technical specifications on the communication protocols to be adopted by the sensor network will be identified in order to comply with the ones of the whole Robohome platform.

All the technical monitoring requirements will be gathered in a comprehensive technical report. This document will set the main constraints for the future development of the sensorized home. A risk analysis will be provided based on a three stage approach, the Risk Identification, the Risk Assessment and the Mitigation Plans.

RoboHome2.0 will provide a set of off-the-shelf very low cost devices and tools to monitor the elder behavior at home and his status. This will allow a personalized monitoring and intervention that are managed by RoboHome2.0 intelligence in WP2. A few devices that measure typical information required, like blood pressure or heart rate will also be integrated (WOULD IT BE POSSIBLE WIHTOUT CONTACT, THORUGH A CELLULARE PHONE?) inside a middleware that will provide to the intelligence the updated information on the required parameters. The most suitable standards will be identified.

These devices will have most different transmission capabilities and cabling the entire house cannot be feasible. A structure based on WiFi transmission will be the most reasonable. . It could be based on a Hub or concentrator that integrates for instance a Raspberry card with a set of USB ports and a WiFi transmitted to the Intelligence.

Other devices that can be integrated can be:

* Gas alert
* Drawer that opens selectively and provides the right amount of pills at the right time
* Cushion pressure sensor to understand how long is the elder is sitting.
* TV monitoring (how much is on and the elder is sitting in front of it).
* Cellular phone conversations length. Pitch analysis.

We have to consider that the elder can be not alone at home. Shall we put some WiFi tracking device on the other people in the room?

Fundamental: control of the TV through Giraff. Modified remote control that can be driven by Giraff besides by the elder.

**From PCL:**

In monitoring it would be good to insert:

* SLEEP. Number of hours of sleep and its regularity (elders have often a disordered sleep for bad habitudes, included ipnotic medicaments, that are sconsigliato).
* FOOD. Quantity and regularity of meals (often elders eat small amounts of food and are disordered. They eat at wrong hours, assume too much sugar, ….
* DRINK. Both as quantity of liquids (problem of lack of thearsty stimulus) and as quantity of alcohol (this is underestimated but it is a large problem).
* BATHROOM. Number of times that the elder goes to the bathroom to evacuate.

Besides these standard devices, we would like to have:

* A general way to instrument everyday life objects like: cane (e.g. consider http://www.medgadget.com/2013/12/isowalk-a-smart-cane-that-adapts-to-its-user.html) or a trolley, that would provide force and motion information. In case, we could also try to instrument handles but it would be more difficult.
* Processing to detect stability in walking, especially with the instrumented cane (I GUESS THAT THIS COULD BE PATENTED).

Therefore RoboHome allows a telemonitoring capability of the elder at home, that can provide to caregivers the information to adopt preventive strategies for the patient, and send to the virtual therapist information that guide its behavior, closing the loop with the elder and with its behavior.

With the diffusion of wearable device, some of the standard tests for cognitive or physical decline have been proposed to be instrumented. EPFL has proposed an instrumented way to carry out the Berg Balance test, typically used to assess the equilibrium of neurological / post-stroke patients. Description of the test. We will define here possible standardized tests that could be implemented inside RoboHome2.0 using the devices and or the robot. For instance the QMCI test, recently developed [PCL may further elaborate on this].

The relationship between parameters that can be monitored with ROBOHOME2.0 and the following typical tests of a geriatric comprehensive assessment will be evaluated:

* Mini Mental State Examination (MMSE)
* Katz index (basic activities of daily living - ADL) and Lawton Scale (instrumental activities of daily living - IADL)
* Chair Stand test

Integration of clinical measuring devices can be required. If we can integrate apps would be much better. We may buy applications if needed, we do not need companies. Among the clinical parameters to monitor (+ alert system) we would suggest:

* blood pressure with alert system when the parameter passes certain upper and lower thresholds
* heart rate with an alert when the parameter passes certain upper and lower thresholds
* integration of glucose monitoring in case of patients with diabetes mellitus or pre-diabetes condition, with an alert when the parameter passes certain upper and lower thresholds
* reminder for assumption of pharmacotherapy with a system to track the response to the reminder/ the accomplishment of the task (possible???)
* falls??? (Is it possible to detect a fall?)

The idea would be always that the elder does not have to wear anything. He can use devices for measurements.

We have to consider gender issues.

**SME section**

From the technological point of view, the development of an effective monitoring system relies on a good integration of available devices and applications with specifically developed ones.

Sensors and electronics miniaturization has made possible devices that could not been imagined few years ago. Recently apps for Smart-phone that can measure heart rate have been developed [HOW CAN WE MEASURE PRESSURE?]. These are among the clinicial measures that are most required by elder people. Other measures will be identified in WP2, could be for instance oxygen saturation or specific results of exams like […] for glucose concentration in the boold. Such system would allow to integrate into the monitoring network most of the clinicial parameters that have been identified, using measurements that have been validated and are commercially available.

Other aspects are equally important to monitor fraility. Among these, the patters of physical and cognitive interaction with the world is equally important. Cognitive interaction can be derived by the log carried out by the activity monitor on cognitive tests as shown in WP4. We here develop innovative monitoring modality that is embedded in the usual lifestyle such that the elder does not perceive monitoring as an activity disjointed from ordinary life.

Monitoring has to be targeted to physical activity in general, but also to fine motor activity.

To this aim we will instrument objects of daily life that will be identified in WP2. These can be for instance the cane using to support walking or the trolley. Handle of pans, handle of doors or fridge or other typical objects will be considered as well. To this aim, we will design and develop miniaturized modules that can be embedded inside such device [FIGURE of the CANE or of the PAN] and can sense the pressure in the handle position and the movement of the object itself. [STX DESCRIBE TECHNOLOGY FOR INERTIAL TRACKING + PRESSURE]. These modules will be realized with two modalities. The first will be a real-time transmittion of the data and will be used for activities. For instance the cane can become a tracker inside a mini-game in which the elder has to climb a mountain by raising the cane and lowering it in specific positions. The movement in terms of velocity and pressure profile can provide very important information to evaluate the stability and control capability of the elder. In a second modality, the device can store in an on-board memory the data related to an entire day (e.g. use of the cane in a stroll in the park and so forth). These data will be downloaded automatically when the cane is put on rest. For this aim, an approach similar to that of Giraff and of Sony AIBOs will be used [ ]. Induction charging. Bluetooth transfer. At the same time particular care to power saving will be considered and recharging thorugh induction fully explored for many devices.

A similar setting can be inserted in the handle of a pot and measure the interaction when cooking. The information from these devices can be collected directly through Giraff, that will get close to them when they are being used, that is when variation in the transmission power or in the pressure measured is registered by the device.

Additional novel devices could be considered. For instance Nike insole.

All these data will go to the monitoring center that will analyze these data and transfer to Virtual caregiver required semantic information on the elder status. [POLI: how?].

We will go one step further and use these same devices as possible devices to execute, at home, standard evaluation tests like for instance, Berg-Balance test [Ref: Berg KO, Wood-Dauphinee SL, Williams JT, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. Physiotherapy Canada 1989;41:304-311.] or Mini Mental State Examination [Ref: Folstein MF, Folstein SE, McHugh PR. Journal of Psuchiatric Research 1975;12:189-98]. Validation of these tests will be carried out as integral part of the project.

Additional devices will be collected through standard sensors like, gas alarm or fridge open. Pressure sensor combined to TV remote controller can be used to monitor how long an elder is sitting down watching TV. A set of these devices will be deployed and information collected.

Other devices will be considered like foot plantars, like the ones developed by Nike or the more sophisticated ones by Moticon that allow recording the pressure and the motion of a foot over 24 hours.

Cellular phone information from intertial sensors will be used to detect the movement quantity of the elder throughout the day [REF LITERATURE].

The minimal set of sensors that will be considered as fundamental in WP2 will be fully developed and integrated in WP8 inside RoboHome 2.0.

Another element in monitoring is related to location of objects of common use, typically glasses, keys and phone. Phone can be located through GPS signal [APP or other instruments]. Possible solutions to locate the keys and the glasses could be based on RF-ID sensors. However, these requires a reader to be placed inside all the rooms with a high impact on the house. The alternative is to use active reading devices based on active tagging. To this aim a miniaturized localization device will be developed for keys and glasses. This will be based on low power Bluetooth and is hosted in a small lodge inside the frame. This system collaborates strictly with Giraff.

**Scenario**

**Jessica does not find her keys, call Giraffs and asks for the keys. Giraff activates and ask to the virtual caregiver help. This logs the actual power of the signal from the keys and guides Giraff towards an increase of the signal. Giraff starts moving to the right towards the sitting room, that is prioritized in the list of the rooms in the house. It then moves towards the dining room and registers and increase in the signal and moves in that room until it gets close to a drawer on the top of which sits the glasses. Giraff calls then the elder to get the glasses.**

Standardization of input devices.

The solution envisaged here is based on populating a data base stored inside the Virtual caregiver, that is able to store the detailed data for a fixed amount of time. History lumped data will be identified and send back to the community along with data that summarise the monitoring, exercising activity of the elder day by day. Such approach allows to use the most hetereogenous input and make them available through standardized data base queries (SQL).

Lastly a cooperative system in drug distribution will be developed in the form of a drug dispenser. This will be constituted of a set of drawer, each with an electro-magnetic lock + a led and will be controlled remotely by the virtual caregiver. Only the right drawer is open at the time in which the elder should take prescribed pills. This approach requires that a caregiver fills the drawers at the beginning of a week, but it then guarantees that pills are not taken more than onece or forgiven. At due time the virtual caregiver warns the elder through all the devices available, Giraff, cellular phone, TV and so forth and it renew the memo every given period, until the drawer is not opened and pills are extracted [<http://www.google.com.tr/patents/US8588964>].

Maximum use of Wifi connection, typically Bluetooth connection, will be considered for the development and to have the minimum impact of the elder’s home. Local modules for transmission will be considered and Giraff’s itself will work as collector.

Task xx. Identification of available sensors.

**WP5 - Monitoring**

**OBJECTIVES**

**-** HW development of unobtrusive customized monitoring devices;

**-** Development of the integrated sensorized home

- Extraction of user actual condition from the whole information gathered by the sensorized home

**DESCRIPTION OF WORK**

RoboHome2.0 will provide a set of customized and off-the-shelf very low cost devices and tools to monitor the elder behavior at home and his physical and cognitive condition. A few medical devices that measure typical information, like blood pressure or heart rate will also be integrated in the sensor network. The analysis of all of the gathered information will allow the personalization of the user scenarios that are managed by RoboHome2.0 intelligence in WP2.

The developed devices will be also used to execute, at home, standard evaluation tests like for instance, Berg-Balance test or mini-mental test [Quote]. Validation of these tests will be carried out as integral part of the project.

1. **What to measure? (POLIMI, PCL, SXT)**
   1. Sensors for monitoring:
      1. Monitoring daily activities and behavior:
         * Sensors to check the level of mobility of the user in the day
         * Cushion pressure sensor to understand how long the elder is sitting.
         * TV monitoring (how much is on and the elder is sitting in front of it).
         * Cellular phone conversations length. Pitch analysis.
      2. Monitoring exercises performance:
         * Instrumented aids (cane, walker, or tripode, etc) to measure the level of assistance during posture movement training exercises execution.
      3. Monitoring health condition
         * Few off-the-shelf very low cost medical devices to measure typical information, like blood pressure or heart rate will also be selected
   2. Sensors for promoting independent living:
      * + Simple sensors to assist tracking of everyday objects (eyeglasses, keys, mobile phone, and cane)
        + Automatic drawer for drug delivery to facilitate prescription adherence
        + Safety devices (such as gas alert)
   3. Sensors personalization: add/remove the sensors depending on single user (an initial set of sensorized objects will be selected on identified relevant scenarios)
2. **HW development of customized sensors (SXT)**
   1. Principle of HW design:
      1. Beyond wearability: Non intrusive sensors-> the environment is sensorized but not the subject
      2. Beyond easiness of use: transparent sensors -> the sensors do not require any collaboration from the user
   2. HW development (describe technological solutions for these specific devices)
      1. instrumented aids and daily life objects
      2. Sensors to track objects
      3. drug dispenser
   3. Technical and functional testing

Describe how to do it

1. **How to integrate information from the network of sensors? (SXT)**

The network of sensors will be integrated in a middleware that will provide to the intelligence the updated information on the required parameters. The most suitable standards will be identified and used to facilitate interoperability. All of the selected and developed devices will have most different transmission capabilities and cabling the entire house cannot be feasible. A structure based on WiFi transmission will be the most reasonable. It could be based on a Hub or concentrator that integrates for instance a Raspberry card with a set of USB ports and a WiFi transmitted to the Intelligence.

1. **how to use this information to profile the users condition and behavior? (POLIMI, PCL, OREBRO UNI)**
   1. Pilot tests on ROBOHOME2.0 specific measures will be realized in order to correlate them to gold standards clinical scales. This pilot will be run all along the project duration (after the set of requirements and the definition of the focused measures) and not just in the final evaluation of the integrated system, so to assure significant sample sizes.
   2. Machine learning algorithms will be used to fuse the whole sensors information in order to extract an overall picture of the subject current condition. The current user condition, will be transferred to the virtual caregiver.

DELIVERABLES

Design and development of customized monitoring devices (prototype and test report)

Sensorized home integration

STATE OF THE ART AND BEYOND (TO BE MOVED IN THE APPROPIATE SECTION)

1)SENSORIZED HOME (SXT+BDIGITAL)

sensors; network; integration of the sensorized home into the Robohome2.0 platform

**THE SoA section and WP (SXT)**

Modern technologies already allow to create smarts domotics systems in normal home, mainly dedicated at home automation and entertainment.

In the field of the monitoring systems for independent living many studies has been published [movement analysis, fall detection… ] with different technologies, but they are still far from representing a daily usable, cost-effective solutions, with lack in the integration.

Commercial in-home monitoring systems, designed for elder-care application, are still a frontier that need to be explored. Commercial systems usually are only alarms or presence-detector systems (Philips lifeline, Medical guardian, TeleSalvalavita Beghelli ..] and rely on the elderly people’s relatives.

From the technological point of view, the development of an effective monitoring system relies on a good integration of available devices and applications with specifically developed ones.

Sensors and electronics miniaturization has made possible devices that could not been imagined few years ago. Recently apps for Smart-phone that can measure heart rate have been developed, and also easy-to-use blood pressure monitor already exists both for smartphone and iPhone devices. These are among the clinical measures that are most required by elder people. Other measures will be identified in WP2, could be for instance oxygen saturation or specific results of exams like […] for glucose concentration in the blood. Such system would allow to integrate into the monitoring network most of the clinical parameters that have been identified, using measurements that have been validated and are commercially available.

Other aspects are equally important to monitor fraility. Among these, the patterns of physical and cognitive interaction with the world is equally important. Cognitive interaction can be derived by the log carried out by the activity monitor on cognitive tests as shown in WP4. We here develop innovative monitoring modality that is embedded in the usual lifestyle such that the elder does not perceive monitoring as an activity disjointed from ordinary life.

Monitoring has to be targeted to physical activity in general, but also to fine motor activity.

MONITORING HEALTH CONDITION

On Giraffe we can integrate an easy-to-use, ergonomic system to measure blood pressure and heart rate, without using any wearable solution.

INSTRUMENTED OBJECTS

To this aim we will instrument objects of daily life that will be identified in WP2. These can be for instance the cane using to support walking or the trolley. Handle of pans or cutlery (eating is a more common practice than cooking for elderly people), handle of doors or fridge or other typical objects will be considered as well. To this aim, we will design and develop miniaturized modules that can be embedded inside such device [FIGURE of the CANE or of the PAN] and can sense the pressure in the handle position and the movement of the object itself..

Trough inertial sensors integrated in the handle of cane for instance, could be possible to analyze changing in movements, or specific behavior and or pattern modifications.

MEMS technologies are now a stable and cost effective solution: 3D, smart accelerometer and gyroscopes are wide diffused in game consoles and automotive systems. Many different models are available. The really compact design of such transducers (as low as 2x2x1 mm3) that allow to perform different kind of measure at really low power consumption.

Whit the aid of modern tactile sensing technology, will be possible to measure the pressure or the force applied to different kind of handles, in order to infer data related to the clamping force and direction, for example.

Both families can be connected or embedded with wireless modules, such as low power Bluetooth® modules (e.g. class 4.0) in order to create really low power, compact and flexible systems.

These modules will be realized with two modalities. The first will be a real-time transmission of the data and will be used for activities. For instance the cane can become a tracker inside a mini-game in which the elder has to climb a mountain by raising the cane and lowering it in specific positions. The movement in terms of velocity and pressure profile can provide very important information to evaluate the stability and control capability of the elder. In a second modality, the device can store in on-board the data related to an entire day (e.g. use of the cane in a stroll in the park and so forth). These data will be downloaded automatically when the cane is put on rest. For this aim, an approach similar to that of Giraffe and of Sony AIBOs will be used [ ]. During the rest condition, through wireless charge or standard charge technologies will be possible to recharge the systems. The new Bluetooth® Smart Technologies [http://www.bluetooth.com/Pages/Bluetooth-Smart.aspx] will be able to create extremely low power, standard transmission. Such wireless solutions are already compatible with emerging wireless charge technologies that can make really easy and safe the usage from elderly people.

A similar setting can be inserted in the handle of a pot and measure the interaction when cooking. The information from these devices can be collected directly through Giraffe, that will get close to them when they are being used, that is when variation in the transmission power or in the pressure measured is registered by the device.

TRACKING OF OBJECTS

Another element in monitoring is related to location of objects of common use at home, typically glasses, keys and phone. There are new emerging solutions based on sticks or key ring [https://www.sticknfind.com/, http://www.thetileapp.com/] to be used with specific Apps, but elderly people has to find by themselves the objects and, moreover, the mobile phone has not to be lost. The Phone can be located through GPS signal, but usually GPS signal can’t be received at home. Possible effective solutions, aimed at reaching a good standardization and integration with Giraffe, could be the same Bluetooth technologies used for the sensors. Also RFID technologies already are used for tagging objects. However, RFID tags devices require a reader to be placed inside all the rooms, with a high impact on the house, whilst new Bluetooth technologies (v 4.0) will allow to extend the range of detection, even with reduced power consumption. The alternative is to use also an active reading devices based on active tagging. To this aim a miniaturized localization device will be developed for keys and glasses. This will be based on low power Bluetooth and is hosted in a small lodge inside the frame. This system collaborates strictly with Giraffe.

Standardization of input devices.

The solution envisaged here is based on populating a data base stored inside the Virtual caregiver, that is able to store the detailed data for a fixed amount of time. History lumped data will be identified and send back to the community along with data that summarise the monitoring, exercising activity of the elder day by day. Such approach allows to use the most heterogenous input and make them available through standardized data base queries (SQL).

DRUG DELIVERY

Lastly a cooperative system in drug distribution will be developed in the form of a drug dispenser. This will be constituted of a set of drawer, each with an electromagnetic lock will be controlled remotely by the virtual caregiver. Only the right drawer is open at the time in which the elder should take prescribed pills. This approach requires that a caregiver fills the drawers at the beginning of a week, but it then guarantees that pills are not taken more than once or forgiven. At due time the virtual caregiver warns the elder through all the devices available, Giraffe, cellular phone, TV and so forth and it renew the memo every given period, until the drawer is not opened and pills are extracted [<http://www.google.com.tr/patents/US8588964>].

Additional devices will be collected through standard sensors like, gas alarm or fridge open. Pressure sensor combined to TV remote controller can be used to monitor how long an elder is sitting down watching TV. A set of these devices will be deployed and information collected.

Other devices will be considered like foot plantars, like the ones developed by Nike or the more sophisticated ones by Moticon that allow recording the pressure and the motion of a foot over 24 hours.

Cellular phone information from intertial sensors will be used to detect the movement quantity of the elder throughout the day [REF LITERATURE].

The minimal set of sensors that will be considered as fundamental in WP2 will be fully developed and integrated in WP8 inside RoboHome 2.0.

**NOTES TO WRITE THE SoA section and WP (SXT)**

From the technological point of view, the development of an effective monitoring system relies on a good integration of available devices and applications with specifically developed ones.

Sensors and electronics miniaturization has made possible devices that could not been imagined few years ago. Recently apps for Smart-phone that can measure heart rate have been developed [HOW CAN WE MEASURE PRESSURE?]. These are among the clinical measures that are most required by elder people. Other measures will be identified in WP2, could be for instance oxygen saturation or specific results of exams like […] for glucose concentration in the blood. Such system would allow to integrate into the monitoring network most of the clinical parameters that have been identified, using measurements that have been validated and are commercially available.

Other aspects are equally important to monitor fraility. Among these, the patterns of physical and cognitive interaction with the world is equally important. Cognitive interaction can be derived by the log carried out by the activity monitor on cognitive tests as shown in WP4. We here develop innovative monitoring modality that is embedded in the usual lifestyle such that the elder does not perceive monitoring as an activity disjointed from ordinary life.

Monitoring has to be targeted to physical activity in general, but also to fine motor activity.

INSTRUMENTED OBJECTS

To this aim we will instrument objects of daily life that will be identified in WP2. These can be for instance the cane using to support walking or the trolley. Handle of pans, handle of doors or fridge or other typical objects will be considered as well. To this aim, we will design and develop miniaturized modules that can be embedded inside such device [FIGURE of the CANE or of the PAN] and can sense the pressure in the handle position and the movement of the object itself. [SXT DESCRIBE TECHNOLOGY FOR INERTIAL TRACKING + PRESSURE]. These modules will be realized with two modalities. The first will be a real-time transmission of the data and will be used for activities. For instance the cane can become a tracker inside a mini-game in which the elder has to climb a mountain by raising the cane and lowering it in specific positions. The movement in terms of velocity and pressure profile can provide very important information to evaluate the stability and control capability of the elder. In a second modality, the device can store in an on-board memory the data related to an entire day (e.g. use of the cane in a stroll in the park and so forth). These data will be downloaded automatically when the cane is put on rest. For this aim, an approach similar to that of Giraff and of Sony AIBOs will be used [ ]. Induction charging. Bluetooth transfer. At the same time particular care to power saving will be considered and recharging through induction fully explored for many devices.

A similar setting can be inserted in the handle of a pot and measure the interaction when cooking. The information from these devices can be collected directly through Giraff, that will get close to them when they are being used, that is when variation in the transmission power or in the pressure measured is registered by the device.

TRACKING OF OBJECTS

Another element in monitoring is related to location of objects of common use, typically glasses, keys and phone. Phone can be located through GPS signal [APP or other instruments]. Possible solutions to locate the keys and the glasses could be based on RF-ID sensors. However, these requires a reader to be placed inside all the rooms with a high impact on the house. The alternative is to use active reading devices based on active tagging. To this aim a miniaturized localization device will be developed for keys and glasses. This will be based on low power Bluetooth and is hosted in a small lodge inside the frame. This system collaborates strictly with Giraff.

Standardization of input devices.

The solution envisaged here is based on populating a data base stored inside the Virtual caregiver, that is able to store the detailed data for a fixed amount of time. History lumped data will be identified and send back to the community along with data that summarise the monitoring, exercising activity of the elder day by day. Such approach allows to use the most heterogenous input and make them available through standardized data base queries (SQL).

DRUG DELIVERY

Lastly a cooperative system in drug distribution will be developed in the form of a drug dispenser. This will be constituted of a set of drawer, each with an electro-magnetic lock + a led and will be controlled remotely by the virtual caregiver. Only the right drawer is open at the time in which the elder should take prescribed pills. This approach requires that a caregiver fills the drawers at the beginning of a week, but it then guarantees that pills are not taken more than once or forgiven. At due time the virtual caregiver warns the elder through all the devices available, Giraff, cellular phone, TV and so forth and it renew the memo every given period, until the drawer is not opened and pills are extracted [<http://www.google.com.tr/patents/US8588964>].

Additional devices will be collected through standard sensors like, gas alarm or fridge open. Pressure sensor combined to TV remote controller can be used to monitor how long an elder is sitting down watching TV. A set of these devices will be deployed and information collected.

Other devices will be considered like foot plantars, like the ones developed by Nike or the more sophisticated ones by Moticon that allow recording the pressure and the motion of a foot over 24 hours.

Cellular phone information from intertial sensors will be used to detect the movement quantity of the elder throughout the day [REF LITERATURE].

The minimal set of sensors that will be considered as fundamental in WP2 will be fully developed and integrated in WP8 inside RoboHome 2.0.

2) MONITORING INFORMATION FUSION (POLIMI)

## WP6 - Community

The establishment of common goals associated to the activities, that have to be achieved also through the collaboration with other stakeholders inside the on-line community will be the basis for promoting social inclusion drivers, which, in turns, will represent an incentive for compliance adherence by patients.

The virtual community would offer both a social and a healthcare support to the elder, and what is virtually surrounding the elder can be translated into an actual intervention.

- Social support, through an internet connection (or through a phone line, or what?):

* + to put the elder in contact with relatives and friends, to avoid isolation, to allow social activities, to increase the opportunities of a reciprocal monitoring
  + to allow the elder to easily access services and facilities (e.g. order food and other goods with home delivery, book ambulance/taxi for transportations)
  + to allow the elder to be informed of social and cultural initiatives that he/she can still attend and enjoy (for example undertaken by associations to which the elder can be subscribed)

- Healthcare support, through preferential pathways to produce necessary sanitary interventions. For this purpose the community around each elder will include one or more reference caregivers, the family physician, the geriatrician.

The socio-sanitary interventions will be mediated, at first, by the remote video communication capability of Giraff that will put in contact the elder with the person she needs. Interventions can be required by caregivers, by the elder themselves or by the RoboHome intelligence that monitors elder activites and continually communicates with the stakeholders. According to preset priorities, different types of alerts will trigger a different pathway. The sanitary interventions eventually delivered can include tele-visits, home-visits, and direct calls to emergency services.

The members of the virtual community around each elder will be established at the beginning of the experience to be engaged in the deliverable socio-sanitary actions. Further members can be added throughout the RoboHome2.0 life.

**The community will have therefore a very active role in ROBOHOME2.0.**

The system will be designed to build trust among the stakeholders and between them and the elder.

The virtual caregiver will also try to browse through the community to identify which would be the elders who might match the elder profile best and try to make new connection creating new sub-groups of the community.

The establishment of common goals that have to be obtained through the collaboration with the elder’s proper ecosystem. This can be the basis for **the adoption of social inclusion drivers, which will represent an incentive for game adherence on seniors**. Reputation, which emerges in the interaction between the members of a community[[90]](#footnote-90), can be a key factor.

In particular, in RoboHome we will explore how the increase of knowledge in lifestyle, possible connection with illness and decline (through gaming and social interaction) and the overall increase in the compliance to the cure can be used for increasing the reputation inside the on-line community and the trust in the RoboHome system, increasing therefore the patient‘s motivation to education, compliance and exercising.

The interaction between gaming and the community will be explored inside the field of social reputation, that emerges in the interaction between the members of a community . In particur, in epCare we will explore how the increase of knowledge in therapy and illness (through gaming and social interaction) and the overall increase in the compliance to the cure can be used for increasing the reputation inside the on-line community and the trust in the epCare system, increasing therefore the patient’s motivation to education, compliance and exercising.

The ROBOHOME project aims to bring together all the major players through a unique community (see Figure X). As defined above ROBOHOME will be formed by three types of user groups:

* **Formal caregivers** – such users will be formed by the clinical staff which will be located in the hospital
* **Informal caregivers** – such users will be formed by family and carers of old people
* **Elderly people** – this is the target users of the community and will be formed by the people which have a GIRAFF robot at home

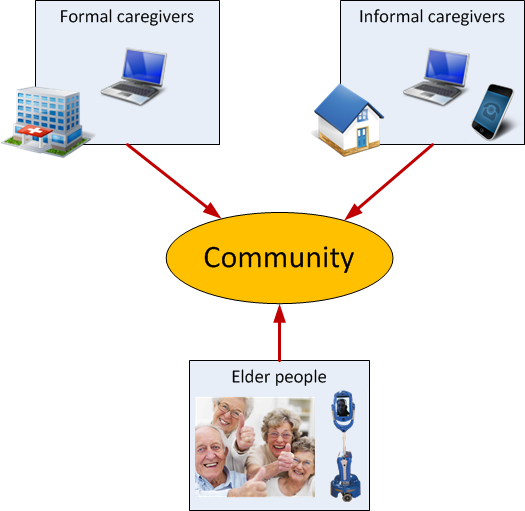


Figure 10 High level community architecture

Through the community the users will be able to interact between them, monitor activities, share information, etc. The community will have different purposes for each type of user. To accomplish this, a number of features will be developed to meet the needs of each user. Without any doubt, the most important user around which all of these features will be developed is elderly people. In this way the community is intended as a tool of motivation, adherence and cognitive and physical stimulation.

**Objective:**

Implement and integrate a social platform based on web technologies which will provide services to unify all actors involved within this system.

Possible services that will be developed will be sorted as follows (TO BE DEFINED…):

* **Elders:** 
  + Score ranking
  + Online users list 🡪 chat
  + News
  + Forum
  + Achievements (depends on the system usage)
  + Physical achievements
  + Help,
  + Calendar
  + Recommendation section (formal caregivers can suggest them to realize some tasks)
  + Videoconference
  + Organize social events with other elderly users
  + Contactme button (to contact with Informal caregivers, family, etc.)
  + VoIP calls
  + Shopping list (used for memory stimulation, e.g. elderly can select the products needed and Informal caregivers will see that information on their side, this way Informal caregivers will know what the cared person needs)
  + Generic information (e.g. weather)
  + Books and movies recommendation
  + Birthday reminders (family, friends, other elderly users)
  + Medical reminders (sent by formal caregivers)
  + Educational videos (e.g. cooking courses)
* **Formal caregivers:**
  + Alerts
  + Medical reminders management for elderly
  + Recommendations for elderly
  + Calendar management
  + News management
  + Forum
  + Videoconference
  + Elderly monitoring (e.g. number of connections/day, played games, sensors information 🡪 sleeping time, presence info, etc.)
* **Informal caregivers:**
  + Alerts
  + Smartphone application with notifications (e.g. Contactme, shopping list, alerts)
  + Calendar management
  + News
  + Forum
  + Videoconference
  + Elderly monitoring (e.g. number of connections/day)
  + Drinking water reminder
  + Food recommendation
  + Videomessage
  + Autosending messages (e.g. every morning, evening)

**State of the art**

The success of virtual communities is due to a great diversity of factors. For instance, as studied by Leimeister et al.[[91]](#footnote-91), relevant factors are focus on one target group, continuous community-controlling, definition of sources of revenue as a starting condition for building a virtual community. BDIGITAL has already been explored the use of virtual community to educate and motivate patients in several research projects. Inside the project REWIRE, a social community has been developed that allows patients and clinicians to chat using this portal, being the latter able to schedule such chats through a web application. This constitutes a good way of promoting shared clinician-patient decisions. Patients will be also able to fill in questionnaires related to clinical scales. That social community provides also further useful features such as forum, news, achievements.

In particular, STATE OF THE ART OF VIRTUAL COMMUNITY.

.

**Beyond the state of the art**

RoboHome2.0 capitalizes on this community and extends it to provide a complete support of the elder at home in his physical / psychological and social behavior.

RoboHome2.0 aims at designing a set of interventions through the robots to support the elder throughout his life. The type of these interventions will be identified and profiled at project start according to the typical elder sub-populations (POLICLINICO) and will regard the social and health sphere. The socio-sanitary interventions will be mediated, at first, by the remote video communication capability of Giraff that will put in contact the elder with the person she needs.

Interventions can be required by caregivers, by the elder themselves or by the RoboHome intelligence that monitors elder activites and continually communicates with the stakeholders.

**SCENARIO**

**Sophie usually plays card with her friends at least three times a week through RoboHome, but RoboHome realizes that she has not played in the last two weeks although she was at home and no particular illness was diagnosed. A warning to Sophie’s daughter is sent by RoboHome, and she organizes her schedule to pay a visit to her mother. After insisting, she learnt that a very good friends of her just passed away, and that her mother just need to be reassured. After this visit, and a few others, Sophie restarted her active social life and to play cards with her friends, even with more joy.**

**SCENARIO**

**Catherin lately is behaving strangely. She start shouting a bit too much and to be nervous and less patinets with people. RoboHome2.0 detects a change in the moving pattern with a faster motion of her cane and less pauses. Her son also has the impression of something changing but, at first, he did not pay attention to that. After RoboHome warning, he consults with her mother’s GP and schedules a tele-visit with a geriatrist who talked with her mother at home. Unfortunately, was the beginning of a Dementia syndrome, but at least he was prepared to tackle them. He was sent to consulening and prepared to tackle the difficult future.**

The community will support the collaboration between the different stakeholders. Different stakeholders (parents, clinicians, social assistant), will be able to define a general goal of the activities mix and suggest their input to the virtual caregiver that will adapt this input to its internal state of the evaluation of the patient, for instance using a Bayesian inference model. From the infrastructure point of view, such collaboration will be supported also through a video-conference / messaging system to increase communication support between patients and his network.

## Task 6.x (M3-M24) Clinical Station interface design (BDIGITAL, PLY,

A flexible GUI will be created to allow the different stakeholders to interact in an effective manner with other stakeholders and with the elder in ROBOHOME2.0. The interface will be designed to provide support to the elder in an empathetic and supportive manner.

In this task we will design the interface usability tests that will be based on verbal reporting and structured questionnaires compiled with all stakeholders. Community interfaces will be designed incrementally. A first mock with identified functionalities will be provided at M6 and refined afterwards with the feed-back of all the stakeholders mediated by SAS, PCL, MUNICIP and KORIAN. A new interface constituted of mock-up and real functionalities will be delivered every three month and questionnaires will be possibly updated.

## Task 6.x (M3-M18) Structuring the community (UMIL, BDIGITAL )

Through the community, the patients will access structured knowledge provided by the stakeholders and new knowledge can be created through the interaction among users, increasing the trust in RoboHome. To this aim, free and informed discussions between community members will be supported. The RoboHome social platform will also provide a continuous osmosis with the most popular social networks [REF]. Through conversation in the community, socialization and externalization of knowledge [REF] will take place. This, along with the increase of knowledge on the lifestyle, its benefit and the risks of aging and the degree of compliance of the elder measured by the Virtual Caregiver, will be used to compute the elder reputation inside the community this exploring a novel hybrid method to build reputation. In RoboHome2.0, the reputation system will therefore also empower cooperation as well as competition to increase elders‘ motivation and therefore be part of the gamification process associated to lifestyle adherence [REF].

The community will allow also self-organising a network of social ties among stakeholders, defined by symmetric or asymmetric relationships and will allow deriving self-organising clusters [REF] that can be used to refine patients profiling.

Educational games can also be easily embedded in the social dimension. In fact, experiences with applications oriented towards promoting active lifestyles on seniors highlight the importance of social motivational instruments [REF] to overcome the barriers of acceptance in older adults.

The adoption of social inclusion drivers such as the establishment of common goals that have to be obtained through the collaboration with the elder community and/or with elder relatives represent an incentive for lifestyle adherence on seniors patients.

Goal of this task is to build the components of the on-line community of the epCARE stakeholders. An adequate client and server architecture will be designed using Web-services technology that will communicate through the ROBOHOME infrastructure. We will explore Open Source software like the one already used by UMIL inside the Open DCN project: on Apache, MySQL environments, using CakePHP development framework and Smarty template engine. Interfaces developed in WP8 will be incorporated.

Through the community, the patients will access structured knowledge provided by the clinicians and new knowledge can be created through the interaction among users, increasing the trust in the care. To this aim, free and informed discussions between community members will be supported. The ROBOHOME social platform will also provide a continuous osmosis with the most popular social networks [109]. Through conversation in the community, socialization and externalization of knowledge [110] will take place. This, along with the increase of knowledge on the therapy and co-morbidity and the degree of compliance of the patient with his treatment measured by the epCARE game engine, will be used to compute the patients‘ reputation inside the community this exploring a novel hybrid method to build reputation. In ROBOHOME, the reputation system will therefore also empower cooperation as well as competition to increase patients‘ motivation [111].

The community will allow also self-organising a network of social ties among stakeholders, defined by symmetric or asymmetric relationships and will allow deriving self-organising clusters [112, 113] that can be used to refine patients profiling.

Educational games can also be easily embedded in the social dimension. In fact, experiences with applications oriented towards promoting active lifestyles on seniors highlight the importance of social motivational instruments [114] to overcome the barriers of acceptance in older adults. The adoption of social inclusion drivers such as the establishment of common goals that have to be obtained through the collaboration with the patient community and/or with patient relatives represent an incentive for game adherence on seniors patients.

**Task x.x** Build a repository of stories that can be narrated by the elders, related to a particular period of their life. This can be part of the memory activities but it has the very important impact on the elders that they can still feel important in the society [MORE COMMENTS FROM POLICLINICO]. On the other side, this can generate collective knowledge of our close past that would get otherwise lost. To this aim, an adequate infrastructure based on automatic voice recording and *speech to text translation has to be set-up [CAN BDIGITAL PROVIDE THIS? WHAT SHALL WE DO WITH THE MATERIAL? PROVIDE IT TO A PUBLISHER?].*

## Task 6.2 Services specification [BDIGITAL, UMIL, GIRAFF]

According to the community structure defined in the Task 6.1, a set of services will be provided to be integrated within the each component used by each different kind of user. Three community component will be developed: web application, smartphone app and Giraff-based application. Each component will provide its own list of services. Moreover, depending on the type of user, the services available in each component may also vary. Through these services the users involved within the community will have access to tool to help them stay in touch at all times, display the status of the sensors and to send notifications.

The set of services which will be intended to integrate within the ROBOHOME platform would be the followings (TO BE DEFINED…):

* Alerts
* News
* Forum
* Videoconference
* Achievements
* Calendar
* Help
* Medical reminders
* Social reminders
* Notifications
* VoIP calls
* Recommendations (types of recommendations)
* Score rankings
* One way communication
* Monitoring results

## Task 6.3 SOA layer and Communications [BDIGITAL, UMIL, GIRAFF]

The Care Station will be the central node of communication among the different platform components. This station will be a web application installed on a dedicated server, which will have access to the internet in order to accept and send communication requests to other components. Other components involved within the community architecture will be a smartphone and the Giraff robot. Communications among them will be implemented using a service oriented architecture (SOA) developed with Open Software components. The issue of confidentiality will be analyzed to be guaranteed in all communications.

*[Communication diagram]*

## Task 6.4 Care Station [BDIGITAL]

The Care Station claims to be the base station installed on a dedicated server as a web application. All the community services and communication layer will be based on a single web platform. Other components will interact with this station through communication layer defined in task 6.3. ROBOHOME community will resort to two devices more that will communicate with the Care Station providing the overall set of community services:

* **Smartphone** – will be used by Informal Caregivers to be in touch with the people they care for and which have the ROBOHOME installed in their home.
* **Giraff robot** – will be used by Elderly to be in touch with their Formal/Informal Caregivers and also with other elderly who are users of ROBOHOME.

This station will provide different features depending on the user’s role that uses it. There will be three types of user roles defined within this application:

* **Formal caregivers** – a specific GUI will be provided for this user role, a set of specific services will be provided for users who have this role.
* **Informal caregivers** – a specific GUI will be provided for this user role; furthermore a specific smartphone application will be provided (see Task 6.5) which will be connected with Care Station.
* **Elders** – for this type of users a different GUI will be provided (see Task 6.6)

## Task 6.5 Smartphone application [BDIGITAL]

To provide better community accessibility and usability for Informal Caregivers a smartphone application will be developed within this task. In this way the Informal Caregivers will have two alternatives to use the community, through the web application or through a mobile application. In this way the mobility benefit of this device will be used, which will offer a better use of services such as “contactme button” or “shopping list”. The mobile application will integrate some of the services provided by the Care Station and moreover will offer other complementary services that are specific only to this application. Within the Task 6.3 the set of communications will be defined between Care Station and smartphone application.

## Task 6.6 Application for Giraff robot [BDIGITAL, GIRAFF]

In order to use the community from the device as the Giraff robot it was decided to create an exclusive access to the Care Station for the elderly. In case if this station detects a user with the Elderly user role it will display a specific and adapted GUI on the one hand for this type of user and on the other hand for such device. To design the GUI and to address issues of accessibility and usability, it will be taken into account the size and type of the screen provided by Giraff robot. Being a touch screen, it is aimed to design a GUI with large buttons, to show clear information with high contrast colors and large font.

**Full support to deliver graphical/video content defined by clinicans, relatives or other stakeholders to Giraff monitor or thorugh Giraff to the home TV will be provided.**

Giraff API and plug-in support option will be explored.

## WP7 – Integration (GIRAFF, SXT, KORIAN, ….)

Integration will start early in ROBOHOME2.0. To realize an effective prototype all the technical choices that are related to more than one component have to be discussed at length and fully approved by the consortium to avoid divergence and achieve a unified technical view of the system. For this reason all tasks will start early with an initial phase devoted to discuss the specifications of communication between the different modules, as the highest standardization of communication interfaces would be desirable.

Giraff robot.



Figure 11 - The Giraff robot (old version)

Gaming will be provided by a gaming centre that will be fully integrated inside the RoboHome infrastructure, thus providing valuable data to the stakeholders and to the Virtual Caregiver for tuning the mix of activities and advising the elder.

## Task XXX (M7-M24) Communication design and implementation (BDIGITAL, UMIL, GIRAFF, POLIMI, …)

This is a critical task for integration. In this task the communication between the game center, Giraff, the community and the monitoring system will be designed and implemented. This task will start early so as to shape the development of the sub-components of each Robohome components that deals with communication, maintaining a shared view of the system. The type of data, the possible links, the technological requirements (bandwidth, protocol, transmission media) as well as the functional requirement (data anonimization, organization) will be taken into account. In particular, data confidentiality and safety will be a main concern in the design phase and will be properly addressed using OASIS web service security specifications. Connection with specific community of interests or specific sites (e.g. ruzzle game site) will be provided.

## Task 7.x: Integration and testing of the community services (BDIGITAL, UMIL, GIRAFF..)

All the services developed in the WP6 will be integrated in the whole ROBOHOME platform. Suitable tests will be performed to evaluate the provided functionalities according to the specifications defined in the WP2. Several communication tests will be performed with the purpose of ensuring the full integration of all components that are part of the community.

## Task 7.xx (6-24) Integration of the selected and developed sensors in the sensorized home (SXT, GIRAFF, POLIMI, BDIGITAL,

After the design and optimization of all components of the system, the integration phase is very delicate and critical. The system integration represents the connection between technology and medical application. The assembly of every biomedical instrumentation requires not only the specific technical knowledge but also the knowledge of ergonomy and usability aspects especially when the device as to be deployed at home to a non-expert user.

The development of preliminary prototypes will help to define the sensor-network integration process step by step. Indeed, the extensive set of bench testing performed with each submodule developed in Tasks 5.1-5.4 and the results of these tests will be used as reference for the bench testing after the integration of the sensor network.

The network of sensors will be a modular sensorized home that allows its personalization with respect to the user scenario.

The network of sensors will be integrated in a middleware that will provide to the intelligence the updated information on the required parameters. The most suitable standards will be identified and used to facilitate interoperability. All of the selected and developed devices will have most different transmission capabilities and cabling the entire house cannot be feasible. A structure based on WiFi transmission will be the most reasonable. It could be based on a Hub or concentrator that integrates for instance a Raspberry card with a set of USB ports and a WiFi transmitted to the Intelligence.

Technical and functional testing of the sensorized home will be performed and particular attention will be devoted to the characterization of the performance of the integrated system in terms of robustness, usability, and dependability.

**Definition of Usability**

According to the ISO 9241 part 11, the following definition applies to **USABILITY:** “Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (it is extremely important to design and devise the user-centric process based on an in-depth, clear-cut understanding of the context of use and the expected nature of user).

Usability is the study of the ease with which people can employ a particular tool or other human-made object in order to achieve a particular goal.”

According to ISO/IEC 9126 Usability is “a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users”. Among these attributes are:

 Understandability

 Learnability

 Operability

 Attractiveness

The compliance of the robot with the patient has been shown as a promising factor to stabilizing the emotional unbalance in people affected by Alzheimer and in autistic people, who see the robot companion as a friend, while still reacting nastly to other human people [QUOTE]

## Task XXX (M2-M6). Data format and communication (UMIL, GIRAFF, )

Data format and data communication protocols among the different components and the different stations should be defined. Issues related to anonymization, privacy and safety will be considered here.

## WP8 – Pilot

Frailty syndrome is the most important in the elderly population and is defined as a state of excessive vulnerability to environmental factors accompanied by a progressive decrease in the functionality of many organs and body systems. This functional loss occurs gradually, resulting in disability situations that diminish the quality of life and can even lead to death (Fried LP, Walston J. Frailty and failure to thrive. In: Hazzard WR, Blass JP, Ettinger WH Jr, et al, eds. Principles of Geriatric Medicine and Gerontology. 5th edition. New York, NY: The McGraw-Hill Companies;2003;1487-1502).

We are targeting elderly subjects who are at risk of frailty, cognitive impairment, dependence and social exclusion. **Frailty** syndrome is defined as a state of excessive vulnerability to environmental factors accompanied by a progressive decrease in the functionality of many organs and body systems [Ref: Fried LP, Walston J. Frailty and failure to thrive. In: Hazzard WR, Blass JP, Ettinger WH Jr, et al, eds. Principles of Geriatric Medicine and Gerontology. 5th edition. New York, NY: The McGraw-Hill Companies;2003;1487-1502]. Beyond this classical phenotype definition, the term frailty is operatively used in geriatric medicine to identify older adults who are at increased risk for future poor clinical outcomes, such as development of disability, dementia, falls, hospitalisation, institutionalisation or increased mortality [Ref: Of. Frailty. In Principles of Geriatric Medicine and Gerontology, 4th; Hazzard W.R., Bierman R.L., Blass J.P., Ettinger W.H. & Halter J.B., eds; McGraw Hill, New York, NY USA, pp. 1119-1156]. According to the Cardiovascular Health Study (CHS) index definition, an individual is classified as frail if he/she meets three or more of the following five criteria:

• Weight loss (>5% in last year)

• Exhaustion

• Weakness (decreased grip strength)

• Slow walking speed (>6 to 7 seconds for 15 feet)

• Decreased physical activity (males <383 kilocalories); females <270 kilocalories)

When one or two of these characteristics are met a condition of **pre-frailty** exists. Otherwise, the person is classified as robust. [Ref: [http://now.aapmr.org/med-rehab/geriatrics/Pages/Geriatric- Frailty.aspx](http://now.aapmr.org/med-rehab/geriatrics/Pages/Geriatric-%20Frailty.aspx)]

Subjects will be eligible for the ROBOHOME2.0 project if:

* pre-frail subjects
* with more than 65 years (75 years????)
* without a cognitive impairment at baseline (Mini Mental State Examination score ≥ 24)
* living at home.

Possible case scenarios:

* subject meeting the eligible criteria living at home with a non-married son who works for 8 hours a day
* subject meeting the eligible criteria, still mostly autonomous, living alone (no close relatives), affected by multiple morbidities, at high cardiovascular risk (e.g. diabetes mellitus, hypertension, hypercholesterolemia, atrial fibrillation) but without a previous major event
* subject meeting the eligible criteria, living at home with a sitter, with relatives living in a different house in the same city, with a previous stroke with mild residuals (mild strength reduction of left limbs, walking with a cane to feel safer)

Geriatric department of Milan who follows 1000 new out patients/year of elderly subjects (age > 75 years) and 2644 in follow-up out patients (2011). Patients are routinely visited at least once a year, and are collected at each visit informations regarding the health status, drug use, clinical history, arising of adverse events, e.g., hospitalizations, development of comorbidities, and life-style. Moreover, tests to assess cognitive ability (MMSE), self-sufficiency and autonomy (ADL, IADL), physical ability (Chair Stand test) Muscular strength (Hand-Grip test), Geriatric Depression Scale (GDS) will be administered; arterial blood pressure measurement, weight and height measurement for the Body Mass Index (BMI) calculation are also performed.

At the same level of importance is monitoring the elder to detect early decline. This would help avoiding depression and falling with risk of fractures that are two of the main causes of fast early decline decline

State of the art in social care [PCL].

How can we go beyond? Which tests should be devised? What can we measure?

N-of-one trial approach can be used to use a limited number of patients [PCL can further elaborate].

Stakeholders will be consulted since project start to evaluate the evolution of the system. How many GPs? How to choose them? Which environment?

3) PILOT TESTING (POLIMI PCL)

With the diffusion of wearable device, some of the standard tests for cognitive or physical decline have been proposed to be instrumented. EPFL has proposed an instrumented way to carry out the Berg Balance test, typically used to assess the equilibrium of neurological / post-stroke patients. Description of the test. We will define here possible standardized tests that could be implemented inside RoboHome2.0 using the devices and or the robot. For instance the QMCI test, recently developed [PCL may further elaborate on this].

Additional tests can be explored by using instrumented everyday life objects. For instance the relationship between standard tests (e.g. Berg Balance scale) and the data that can be acquired by the smart cane or by the games targeted to sit-to-stand exercises will be explored and possible correlation will be evaluated [POLIMI may further elaborate on this].

Typical tests considered are:

* Allacciare I bottoni.
* Alzarsi dal letto.
* Alzarsi e sedersi sul divano con le braccia conserte.
* ADL / IADL
* Minimental test

Integration of clinical measuring devices can be required. If we can integrate apps would be much better. We may buy applications if needed, we do not need companies.

We have to consider gender issues.

**From PCL:**

In monitoring it would be good to insert:

* SLEEP. Number of hours of sleep and its regularity (elders have often a disordered sleep for bad habitudes, included ipnotic medicaments, that are sconsigliato).
* FOOD. Quantity and regularity of meals (often elders eat small amounts of food and are disordered. They eat at wrong hours, assume too much sugar, ….
* DRINK. Both as quantity of liquids (problem of lack of thearsty stimulus) and as quantity of alcohol (this is underestimated but it is a large problem).
* BATHROOM. Number of times that the elder goes to the bathroom to evacuate.

Besides these standard devices, we would like to have:

* A general way to instrument everyday life objects like: cane (e.g. consider http://www.medgadget.com/2013/12/isowalk-a-smart-cane-that-adapts-to-its-user.html) or a trolley, that would provide force and motion information. In case, we could also try to instrument handles but it would be more difficult.
* Processing to detect stability in walking, especially with the instrumented cane (I GUESS THAT THIS COULD BE PATENTED).

Therefore RoboHome allows a telemonitoring capability of the elder at home, that can provide to caregivers the information to adopt preventive strategies for the patient, and send to the virtual therapist information that guide its behavior, closing the loop with the elder and with its behavior.

With the diffusion of wearable device, some of the standard tests for cognitive or physical decline have been proposed to be instrumented. EPFL has proposed an instrumented way to carry out the Berg Balance test, typically used to assess the equilibrium of neurological / post-stroke patients. Description of the test. We will define here possible standardized tests that could be implemented inside RoboHome2.0 using the devices and or the robot. For instance the QMCI test, recently developed [PCL may further elaborate on this].

The relationship between parameters that can be monitored with ROBOHOME2.0 and the following typical tests of a geriatric comprehensive assessment will be evaluated:

* Mini Mental State Examination (MMSE)
* Katz index (basic activities of daily living - ADL) and Lawton Scale (instrumental activities of daily living - IADL)
* Chair Stand test

Integration of clinical measuring devices can be required. If we can integrate apps would be much better. We may buy applications if needed, we do not need companies. Among the clinical parameters to monitor (+ alert system) we would suggest:

* blood pressure with alert system when the parameter passes certain upper and lower thresholds
* heart rate with an alert when the parameter passes certain upper and lower thresholds
* integration of glucose monitoring in case of patients with diabetes mellitus or pre-diabetes condition, with an alert when the parameter passes certain upper and lower thresholds
* reminder for assumption of pharmacotherapy with a system to track the response to the reminder/ the accomplishment of the task (possible???)
* falls??? (Is it possible to detect a fall?)

The idea would be always that the elder does not have to wear anything. He can use devices for measurements.

We have to consider gender issues.

All these data will go to the monitoring center that will analyze these data and transfer to Virtual caregiver required semantic information on the elder status. [POLI: how?].

We will go one step further and use these same devices as possible devices to execute, at home, standard evaluation tests like for instance, Berg-Balance test [Ref: Berg KO, Wood-Dauphinee SL, Williams JT, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. Physiotherapy Canada 1989;41:304-311.] or Mini Mental State Examination [Ref: Folstein MF, Folstein SE, McHugh PR. Journal of Psuchiatric Research 1975;12:189-98]. Validation of these tests will be carried out as integral part of the project.

Additional devices will be collected through standard sensors like, gas alarm or fridge open. Pressure sensor combined to TV remote controller can be used to monitor how long an elder is sitting down watching TV. A set of these devices will be deployed and information collected.

Other devices will be considered like foot plantars, like the ones developed by Nike or the more sophisticated ones by Moticon that allow recording the pressure and the motion of a foot over 24 hours.

Cellular phone information from intertial sensors will be used to detect the movement quantity of the elder throughout the day [REF LITERATURE].

The minimal set of sensors that will be considered as fundamental in WP2 will be fully developed and integrated in WP8 inside RoboHome 2.0.

Another element in monitoring is related to location of objects of common use, typically glasses, keys and phone. Phone can be located through GPS signal [APP or other instruments]. Possible solutions to locate the keys and the glasses could be based on RF-ID sensors. However, these requires a reader to be placed inside all the rooms with a high impact on the house. The alternative is to use active reading devices based on active tagging. To this aim a miniaturized localization device will be developed for keys and glasses. This will be based on low power Bluetooth and is hosted in a small lodge inside the frame. This system collaborates strictly with Giraff.

**Scenario**

**Jessica does not find her keys, call Giraffs and asks for the keys. Giraff activates and ask to the virtual caregiver help. This logs the actual power of the signal from the keys and guides Giraff towards an increase of the signal. Giraff starts moving to the right towards the sitting room, that is prioritized in the list of the rooms in the house. It then moves towards the dining room and registers and increase in the signal and moves in that room until it gets close to a drawer on the top of which sits the glasses. Giraff calls then the elder to get the glasses.**

Standardization of input devices.

The solution envisaged here is based on populating a data base stored inside the Virtual caregiver, that is able to store the detailed data for a fixed amount of time. History lumped data will be identified and send back to the community along with data that summarise the monitoring, exercising activity of the elder day by day. Such approach allows to use the most hetereogenous input and make them available through standardized data base queries (SQL).

Lastly a cooperative system in drug distribution will be developed in the form of a drug dispenser. This will be constituted of a set of drawer, each with an electro-magnetic lock + a led and will be controlled remotely by the virtual caregiver. Only the right drawer is open at the time in which the elder should take prescribed pills. This approach requires that a caregiver fills the drawers at the beginning of a week, but it then guarantees that pills are not taken more than onece or forgiven. At due time the virtual caregiver warns the elder through all the devices available, Giraff, cellular phone, TV and so forth and it renew the memo every given period, until the drawer is not opened and pills are extracted [<http://www.google.com.tr/patents/US8588964>].

Maximum use of Wifi connection, typically Bluetooth connection, will be considered for the development and to have the minimum impact of the elder’s home. Local modules for transmission will be considered and Giraff’s itself will work as collector.

We have to consider gender issues.

Task xx. Identification of available sensors.

The worldwide challenges of the long-term care of the elderly

The proportion of older people in the population is also growing, increasing the number of those with chronic health problems because of accumulated exposure to chronic disease risk factors over

their lifetime. Older people often suffer from a combination of multiple chronic diseases and social problems requiring a long-term care which is part healthcare and part social service. Long-term care to frail and pre-frail individuals encompasses a broad array of services delivered in home, community or institutional settings by paid professionals and paraprofessionals, as well as unpaid family carers and other ‘informal’ helpers. The assistance needed by these individuals includes personal care, household chores and life management activities, often entailing interaction with various parts of the medical, mental health, housing and income maintenance systems. Irrespective of the cross-national differences

encountered in policy, funding, infrastructure and provision, countries confront similar long-term care

challenges, namely fragmented services, disjointed care, less-than-optimal quality, system inefficiency and difficult-to-control costs [Ref: Kodner D. (2004) Beyond care management: the logic and

promise of vertically integrated systems of care for the frail elderly. In: M. Knapp, D. Challis, J. Fernandez & A. Netten (Eds) Long-Term Care: Matching Resources to Needs, pp. 101–118. Ashgate, Aldershot]. A response to these challenges has been sought in the development of integrated models

of care delivery, which take a more holistic view of clients and their needs. “Integrated care” has been defined by Kodner & Spreeuwenberg (2002) as a “discrete set of techniques and organisational models

designed to create connectivity, alignment, and collaboration within and between the cure and care sectors at the funding, administrative and/or provider levels”. The role of ICT in integrated care interventions for the care of the elderly is widely recognized by the EC.

The current situation of the elderly home care in Italy

It is known that due to cultural reasons, most of the Italian elderly people and their families prefer an “aging in place” option [Gori C. & Da Roit B. (2006) The Italian way to commodification of care. In: C. Ungerson & S. Yeandle (Eds) The Changing Boundaries Between Paid and Unpaid Care, pp.223–258. Palgrave, London]. Yet this preference encounters in practice the challenges of an underdeveloped community care system. In fact, even if in the last 30 years the expenditure devoted to long-term care and the provision of services in kind have grown, the Italian welfare state is still characterized by a ‘familistic’ approach where the public sector devotes a scarce amount of money to care (prioritizing cash benefits over services in kind) and the arrangement of care is largely left to families [Gori C. Home care in Italy: a system on the move, in the opposite direction to what we expect. Health Soc Care Community. 2012 May;20(3):255-64]. The cash benefit in form of companion payment represents the main public long-term care input, which, in most of the cases is used to employ migrant care workers who are the main carers for the elderly at home. The working conditions of these sitters might be very hard, and they often need to spend most of their time in helping the elder in the activities of daily living, so that some other needs of the elder are necessarily neglected. The main task of family members often consists in organizing and monitoring the work of the sitters, and the life pace of the contemporary society often prevents them from spending time with the elder. In addition, with the companion payment family carers receive a monetary support but do not receive the information and counseling that in fact all the surveys show they want, especially with regards to the diseases that affect elderly people and the provision of healthcare [Lamura G. et al. (2010) Migrant workers in the long-term care sector: lessons from Italy. Health and Ageing Newsletter 22 (1), 1–6.]. The system seems to have found an “equilibrium” as most of the stakeholders gain some practical advantages from current arrangements [Gori C. Home care in Italy: a system on the move, in the opposite direction to what we expect. Health Soc Care Community. 2012 May;20(3):255-64]. Nevertheless, this equilibrium exposes the care for the elder to the risk of an unsatisfying quality, and if it is difficult to adequately meet the existing needs, short of time and human resources, it is very hard to implement good monitoring and preventing strategies against the development of a condition of frailty and disability.

With such a background, the RoboHome2.0 intervention would represent an additional aid and resource to favor a comprehensive care to the elder at home, integrated in and integrating the community of stakeholders surrounding the elder. Establishing a network of providers of social and health care, not RoboHome2.0 would represent an additional virtual care provider but it would also promote the creation of an integrated care system.

**Methods.**

Population. Elders meeting the eligibility criteria (see above for target subjects) willing to participate (who signed an informed consent)

Intervention. RoboHome2.0 integrated in a network of social and health care providers, represented by the relatives and/or non-family home caregivers, friends, the general practitioner, the specialist in Geriatrics

Comparator. Usual care

Outcome. The primary outcome will be the development of a frailty condition (see above for the definition). According to the principles of a Comprehensive Geriatric Assessment, the following outcomes will be also measured at baseline and throughout the study:

Measures of

* physical performance
  + Tinetti scale [Ref; Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. JAGS 1986; 34: 119-126]
  + Short Physical Performance Battery (SPPB): 4-m walking speed, balance and chair-stand tests [Ref: Guralnik JM, Ferrucci L, Simonsick EM et al. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995; 332: 556–61]
* muscle strength (hand-grip strength)
* functional (ADL and IADL)
* cognitive status (MMSE)
* mood (Geriatric Depression Scale)
* nutritional status
* quality of life
* satisfaction
* frequency of access to Emergency Department/hospitalization/istitutionalization
* adherence to medications
* quality of life and satisfaction of the caregiver

Additional specific outcomes might be added according to the phenotype of the elder, the specific tasks required by the elder to the RoboHome2.0 (for example, HbA1c for a diabetic elder; number of daily naps

Follow up Time. 1 year (???)

Study design. Non-randomized controlled study on N (10???) eligible patients receiving the intervention and N controls, matched for age, gender, general practitioner, geographic area/neighborhood, home care situation (i.e. living alone or with a family caregiver, or with a migrant care worker), morbidity. The two groups of subjects should not know each others

Setting. Which country??? For example in Lombardia, one suggestion for setting and recruitment might be: The subject will be selected through the contact with general practitioners willing to collaborate and the GP will help in the selection of the elder receiving the intervention and the matched control, among his/her assisted people. The same GP will be included in the network. Alternatively (both strategies might be implemented) it is the geriatrician to individuate the subject, the subject’s GP is contacted and then, assured the GP’s willingness to participate, the matched control is selected. Personnel of the Geriatrics of the Fondazione IRCSS Ca’ Granda of Milan would act as the specialists of the network.

## WP10 Project Management

**Objectives:**

The main objective of the project management work package is to ensure a successful completion of the REWIRE project providing administrative and scientific co-ordination. Objectives of the scientific coordination are:

• Overall scientific and ethical management of the project;

• Communication with the Commission, with the Consortium and with other project bodies;

• Monitoring of scientific progress and reporting;

• Ensuring the completion of tasks timely and in a correct way by the participants;

• Overseeing science & society issues, related to research conducted within the project;

• Promotion of gender equality in the project;

• Risk Management Plan implementation;

• Managing IPR issue.

Objectives of the administrative-financial management are:

• Overall financial, administrative and contractual management of the consortium, ensuring continuous and timely communication;

• Obtaining financial statements of partners;

• Managing the Consortium Agreement among the partners;

Organisational and logistic support for training activities, conferences, workshops and meetings.

**Description of work:**

This work package is aimed at scientific and strategic project management including project meetings, project internal reviews, strategic discussions and the technical coordination among partners. The basic aim of this work package is to keep the project correct dynamics by setting the appropriate mechanisms to achieve the objectives. It will work to ensure the successful completion of the project by interacting with all the other WPs, not only in terms of tasks and deadlines fulfillment but also in terms of quality of the results. Particular attention will be paid to the management of risks and issues and to their early detection.

Two subcommittees will be formed: one clinical aimed to discuss and develop the clinical and diffusion aspects of the project and one technical, more oriented to the technical development. The two committees will strictly cooperate in following the project development, meeting the deadlines and analyzing the risks or criticality in due course.

## Task 10.1(M1-M36) Research guidelines and co-ordination of activities (UMIL).

ROBOHOME brings together researchers from different institutes and different countries. In order to establish common operational procedures and taking into account the enlarged ROBOHOME partnership, the PSC (Program Steering Committee, involving all partners) prepares written guidelines and operational instructions to be followed by the partners for carrying out their research activities.

UMIL establishes the guidelines for the research program to be carried out. The P1 develops, during the first two project months, all the operational tools and procedures to be followed by the partners in the carrying out of their activity. Particularly critical will be the correct addressing of ethical issues that is demanded to the Ethical Advisory Board of the project. This will have the responsibility for monitoring the conformity of the project to the ethical standards.

## Task 10.2(M1-M36): Logistics & IT (UMIL, SAS, ….)

This task is carried out by the P1 and deals with: 1) the organization of the meetings (kick-off, guidelines, progress, review meetings and conclusive conference); 2) the development and maintenance of the project IT infrastructure: all the partners will have access to a dedicated area of the web-site (see WP9). Large use of IT-based communication platforms, like Skype and WebEx will be used to cut the costs and increase the responsiveness.

## WP9 – Dessemination and exploitation

Identify a proper metric to evaluate each component and the whole platform.

Identify questionnaires adequate to evaluate the compliance with the technology (e.g. TAM questionnaires).

If Koren enters the consortium. Business model for which the RSA becomes open structures that provide services also at home, operating as a central node, thus as a service provider.

The Continua Health Alliance[[92]](#footnote-92) is promoting the development of end-to-end, plug-and-play connectivity of personal health devices and services. It is expected that for the beginning of the pilot several devices with these specifications will be available at reduced prices and this will made easy to integrate standard clinical measurements that will be defined in WP2. This make us confident about possible approval by ethical committess of hospitals like PCL and SAS that will support our pilot.

The worldwide challenges of the long-term care of the elderly

The proportion of older people in the population is also growing, increasing the number of those with chronic health problems because of accumulated exposure to chronic disease risk factors over

their lifetime. Older people often suffer from a combination of multiple chronic diseases and social problems requiring a long-term care which is part healthcare and part social service. Long-term care to frail and pre-frail individuals encompasses a broad array of services delivered in home, community or institutional settings by paid professionals and paraprofessionals, as well as unpaid family carers and other ‘informal’ helpers. The assistance needed by these individuals includes personal care, household chores and life management activities, often entailing interaction with various parts of the medical, mental health, housing and income maintenance systems. Irrespective of the cross-national differences

encountered in policy, funding, infrastructure and provision, countries confront similar long-term care

challenges, namely fragmented services, disjointed care, less-than-optimal quality, system inefficiency and difficult-to-control costs [Ref: Kodner D. (2004) Beyond care management: the logic and

promise of vertically integrated systems of care for the frail elderly. In: M. Knapp, D. Challis, J. Fernandez & A. Netten (Eds) Long-Term Care: Matching Resources to Needs, pp. 101–118. Ashgate, Aldershot]. A response to these challenges has been sought in the development of integrated models

of care delivery, which take a more holistic view of clients and their needs. “Integrated care” has been defined by Kodner & Spreeuwenberg (2002) as a “discrete set of techniques and organisational models

designed to create connectivity, alignment, and collaboration within and between the cure and care sectors at the funding, administrative and/or provider levels”. The role of ICT in integrated care interventions for the care of the elderly is widely recognized by the EC.

The current situation of the elderly home care in Italy

It is known that due to cultural reasons, most of the Italian elderly people and their families prefer an “aging in place” option [Gori C. & Da Roit B. (2006) The Italian way to commodification of care. In: C. Ungerson & S. Yeandle (Eds) The Changing Boundaries Between Paid and Unpaid Care, pp.223–258. Palgrave, London]. Yet this preference encounters in practice the challenges of an underdeveloped community care system. In fact, even if in the last 30 years the expenditure devoted to long-term care and the provision of services in kind have grown, the Italian welfare state is still characterized by a ‘familistic’ approach where the public sector devotes a scarce amount of money to care (prioritizing cash benefits over services in kind) and the arrangement of care is largely left to families [Gori C. Home care in Italy: a system on the move, in the opposite direction to what we expect. Health Soc Care Community. 2012 May;20(3):255-64]. The cash benefit in form of companion payment represents the main public long-term care input, which, in most of the cases is used to employ migrant care workers who are the main carers for the elderly at home. The working conditions of these sitters might be very hard, and they often need to spend most of their time in helping the elder in the activities of daily living, so that some other needs of the elder are necessarily neglected. The main task of family members often consists in organizing and monitoring the work of the sitters, and the life pace of the contemporary society often prevents them from spending time with the elder. In addition, with the companion payment family carers receive a monetary support but do not receive the information and counseling that in fact all the surveys show they want, especially with regards to the diseases that affect elderly people and the provision of healthcare [Lamura G. et al. (2010) Migrant workers in the long-term care sector: lessons from Italy. Health and Ageing Newsletter 22 (1), 1–6.]. The system seems to have found an “equilibrium” as most of the stakeholders gain some practical advantages from current arrangements [Gori C. Home care in Italy: a system on the move, in the opposite direction to what we expect. Health Soc Care Community. 2012 May;20(3):255-64]. Nevertheless, this equilibrium exposes the care for the elder to the risk of an unsatisfying quality, and if it is difficult to adequately meet the existing needs, short of time and human resources, it is very hard to implement good monitoring and preventing strategies against the development of a condition of frailty and disability.

With such a background, the RoboHome2.0 intervention would represent an additional aid and resource to favor a comprehensive care to the elder at home, integrated in and integrating the community of stakeholders surrounding the elder. Establishing a network of providers of social and health care, not RoboHome2.0 would represent an additional virtual care provider but it would also promote the creation of an integrated care system.

**Methods.**

Population. Elders meeting the eligibility criteria (see above for target subjects) willing to participate (who signed an informed consent)

Intervention. RoboHome2.0 integrated in a network of social and health care providers, represented by the relatives and/or non-family home caregivers, friends, the general practitioner, the specialist in Geriatrics

Comparator. Usual care

Outcome. The primary outcome will be the development of a frailty condition (see above for the definition). According to the principles of a Comprehensive Geriatric Assessment, the following outcomes will be also measured at baseline and throughout the study:

Measures of

* physical performance
  + Tinetti scale [Ref; Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. JAGS 1986; 34: 119-126]
  + Short Physical Performance Battery (SPPB): 4-m walking speed, balance and chair-stand tests [Ref: Guralnik JM, Ferrucci L, Simonsick EM et al. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995; 332: 556–61]
* muscle strength (hand-grip strength)
* functional (ADL and IADL)
* cognitive status (MMSE)
* mood (Geriatric Depression Scale)
* nutritional status
* quality of life
* satisfaction
* frequency of access to Emergency Department/hospitalization/istitutionalization
* adherence to medications
* quality of life and satisfaction of the caregiver

Additional specific outcomes might be added according to the phenotype of the elder, the specific tasks required by the elder to the RoboHome2.0 (for example, HbA1c for a diabetic elder; number of daily naps

Follow up Time. 1 year (???)

Study design. Non-randomized controlled study on N (10???) eligible patients receiving the intervention and N controls, matched for age, gender, general practitioner, geographic area/neighborhood, home care situation (i.e. living alone or with a family caregiver, or with a migrant care worker), morbidity. The two groups of subjects should not know each others

Setting. Which country??? For example in Lombardia, one suggestion for setting and recruitment might be: The subject will be selected through the contact with general practitioners willing to collaborate and the GP will help in the selection of the elder receiving the intervention and the matched control, among his/her assisted people. The same GP will be included in the network. Alternatively (both strategies might be implemented) it is the geriatrician to individuate the subject, the subject’s GP is contacted and then, assured the GP’s willingness to participate, the matched control is selected. Personnel of the Geriatrics of the Fondazione IRCSS Ca’ Granda of Milan would act as the specialists of the network.

## Task 10.3(M1-M36): Legal & Administrative issues. (UMIL, All partners)

This task mainly deals with the following actions:

1) Definition of access rights to the project knowledge base. The PSC establishes the rules for the access and the exploitation of the pre-existing knowledge of the individual partners and of the results;

2) Maintenance of the Consortium Agreement, defined during the negotiation phase, dealing with technical (contribution of each partners, technical resources, scheduling), commercial (confidentiality, ownership of results, etc.), organizational (composition and rules of the PSC), financial (responsibilities, etc.), legal (form of cooperation, penalties, settlement of disputes, etc.) provisions.

In particular, UMIL will have in staff also the director of the Tecnology Transfer Office, with the role of scouting the technology developed and secure the results as early as possible to avoid that disclosure would make patenting not possible.

## Task 10.4 (M1-M36): Reporting (UMIL, All partners)

This task focuses on project’s reporting starting from the individual reports provided by the partners. Periodic reports for the EU are issued every 12 months and at project completion. The reports contain an overview of the activities undertaken during the period, a summary of the S&T results, a list of the deliverables published and of the milestones reached during the period, a description of the monitoring actions (measurement / evaluation / corrective actions) undertaken to assure adherence to the project workplan, the financial statements by each participant and their summary.

## Task 10.5 (M1-M36): Risk Management Plan Implementation (UMIL, All partners)

Risk management addresses the monitoring of scientific/technical results, their dissemination/ exploitation and of the overall project coordination. It comprises the supervision of the project management performance and its assessment, change of procedures, if necessary, and monitoring of the impact of such changes on the overall project progress.

1. Giannakouris k., Aging characterizes the demographic perspective in the European Societies, Eurostat, Statistics in focus, 2008, 72. <http://eppeurostat.ec.europa.eu> [↑](#footnote-ref-1)
2. American Association of Colleges of Nursing, Nursing Shortage Fact Sheet, 2010. [Online]. Available: <http://www.aacn.nche.edu/media/FactSheets/NursingShortage.htm>.. P. Buerhaus, BCurrent and future state of the US nursing workforce,[ J. Amer. Med. Assoc., vol. 300, no. 20, pp. 2422–2424, 2008. [↑](#footnote-ref-2)
3. J. Fasola and M.J. Mataric, Using Socially Assistive Human–Robot Interaction to Motivate Physical Exercise for Older Adults, Proceedings of the IEEE Vol. 100,No. 8, August 2012. [↑](#footnote-ref-3)
4. E. Baum, D. Jarjoura, A. E. Polen, D. Faur, and G. Rutecki, BEffectiveness of a group exercise program in a long-term care facility: A randomized pilot trial. J. Amer. Med. Directors Assoc., vol. 4, pp. 74–80, 2003. [↑](#footnote-ref-4)
5. D. Dawe and R. Moore-Orr, BLow-intensity, range-of-motion exercise: Invaluable nursing care for elderly patients, J. Adv. Nursing, vol. 21, pp. 675–681, 1995. [↑](#footnote-ref-5)
6. M. D. McMurdo and L. M. Rennie, BA controlled trial of exercise by residents of old people’s homes, Age and Ageing, vol. 22, pp. 11–15, 1993. [↑](#footnote-ref-6)
7. V. Thomas and P. Hageman, B Can neuromuscular strength and function in people with dementia be rehabilitated using resistance-exercise training? Results from a preliminary intervention study, J. Gerontol. A, Biol. Sci. Med. Sci., vol. 58, pp. M746–M751, 2003. [↑](#footnote-ref-7)
8. S. Colcombe and A. Kramer, BFitness effects on the cognitive function of older adults, Psychol. Sci., vol. 14, pp. 125–130, 2003. [↑](#footnote-ref-8)
9. S. J. Colcombe, A. F. Kramer, K. I. Erickson, P. Scalf, E. McAuley, N. J. Cohen, A. Webb, G. J. Jerome, D. X. Marquez, and S. Elavsky, BCardiovascular fitness, cortical plasticity,and aging,[ in Proc. Nat. Acad. Sci. USA, 2004, vol. 101, pp. 3316–3321. [↑](#footnote-ref-9)
10. W. Spirduso and P. Clifford, BReplicationof age and physical activity effects on reaction and movement tim time, J. Gerontol., vol. 33, pp. 26–30, 1978. [↑](#footnote-ref-10)
11. Z. B. Moak and A. Agrawal, BThe association between perceived interpersonal social support and physical and mental health: Results from the national epidemiological survey on alcohol and related conditions, J. Public Health, vol. 32, pp. 191–201, 2010. [↑](#footnote-ref-11)
12. L. K. George, D. G. Blazer, D. C. Hughes, and N. Fowler, BSocial support and the outcome of major depression,[ British J. Psychiatry, vol. 154, pp. 478–485, 1989. [↑](#footnote-ref-12)
13. E. Paykel, BLife events, social support and depression,[ Acta Psychiatrica Scandinavica, vol. 89, pp. 50–58, 1994. [↑](#footnote-ref-13)
14. B. Prospective relations between social support and depression: Differential direction of effects for parent and peer support? J. Abnormal Psychol., vol. 113, pp. 155–159, 2004. [↑](#footnote-ref-14)
15. S. A. Stansfeld, G. S. Rael, J. Head,M. Shipley, and M. Marmot, BSocial support and psychiatric sickness absence: A prospective study of British civil servants, Psychol. Med., vol. 27, pp. 35–48, 1997. [↑](#footnote-ref-15)
16. http://www.giraffplus-project.eu [↑](#footnote-ref-16)
17. Fried LP, Walston J. Frailty and failure to thrive. In: Hazzard WR, Blass JP, Ettinger WH Jr, et al, eds. Principles of Geriatric Medicine and Gerontology. 5th edition. New York, NY: The McGraw-Hill Companies;2003;1487-1502 [↑](#footnote-ref-17)
18. http://www.callcentrehelper.com/how-to-use-vocal-pitch-and-pace-on-the-phone-2644.htm [↑](#footnote-ref-18)
19. A. Kristoffersson, S. Coradeschi, A. Loutfi, User-Centered Evaluation of Robotic Telepresence for an Elderly Population. 2nd International Workshop on Designing robotic artefacts with user- and experience-centred perspectives, Nordi-Chi, 2010. [↑](#footnote-ref-19)
20. Nathan DG. Careers in translational clinical research - Historical perspectives, future challenges. JAMA 2002;287(18):2424-7. [↑](#footnote-ref-20)
21. [Joseph D. Novak](http://en.wikipedia.org/wiki/Joseph_D._Novak) & Alberto J. Cañas (2006). ["The Theory Underlying Concept Maps and How To Construct and Use Them"](http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm), [Institute for Human and Machine Cognition](http://en.wikipedia.org/wiki/Institute_for_Human_and_Machine_Cognition). [↑](#footnote-ref-21)
22. Moon, B.M., Hoffman, R.R., Novak, J.D., & Cańas, A.J. (2011). [Applied Concept Mapping: Capturing, Analyzing and Organizing Knowledge.](http://www.appliedconceptmapping.info/) CRC Press: New York. [↑](#footnote-ref-22)
23. M. Daoutis, S. Coradeschi, A. Loutfi, Integrating Common Sense in Physically Embedded Intelligent Systems. In Proc. 5th Int. Conf. on Intelligent Environments, Volume 2, pages 212- 219, 2009. [↑](#footnote-ref-23)
24. Christensen H, Griffiths K, Jorm A. Delivering interventions for depression by using the internet: randomised controlled trial BMJ 2004;328:265. Griffiths K, Farrer L and Christensen H. The efficacy of internet interventions for depression and anxiety disorders: a review of randomised controlled trials. Medical Journal of Australia, 2010 [↑](#footnote-ref-24)
25. Di Rienzo et al. [↑](#footnote-ref-25)
26. Paré G, Moqadem K , Pineau G, and St-Hilaire C, Clinical Effects of Home Telemonitoring in the Context of Diabetes, Asthma, Heart Failure and Hypertension: A Systematic Review, J Med Internet Res. 2010 Apr-Jun; 12(2).

    [↑](#footnote-ref-26)
27. Liu, Baoding, and Yian-Kui Liu. "Expected value of fuzzy variable and fuzzy expected value models." Fuzzy Systems, IEEE Transactions on 10.4 (2002): 445-450; Didier Dubois, Henri M. Prade, ed. (2000). Fundamentals of fuzzy sets. The Handbooks of Fuzzy Sets Series 7. Springer. ISBN 978-0-7923-7732-0. [↑](#footnote-ref-27)
28. Wayne PW et al. Effect of Tai Chi on Cognitive Performance in Older Adults: Systematic Review and Meta-Analysis. JAGS, 2014; 62: 25.39 [↑](#footnote-ref-28)
29. Rebok GW et al., (ACTIVE study) JAGS, 2014; 62: 16-24. [↑](#footnote-ref-29)
30. Pirovano et al., submitted to Games4Health, 2014. [↑](#footnote-ref-30)
31. Pirovano et al., 2014 [↑](#footnote-ref-31)
32. Folstein MF, Folstein SE, McHugh PR (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. Journal of psychiatric research 12 (3): 189–98. DOI:10.1016/0022-3956(75)90026-6. [↑](#footnote-ref-32)
33. Berg, Katherine; Wood-Dauphinėe, Sharon; Williams, J.I.; Gayton, David (1989). "Measuring balance in the elderly: preliminary development of an instrument". Physiotherapy Canada 41 (6): 304–311. [↑](#footnote-ref-33)
34. F.D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology", *MIS Quarterly* vol. 13, no. 3, pp. 319–340, 1989. [↑](#footnote-ref-34)
35. V. Venkatesh, M.G. Morris, G.B. Davis, and F.D. Davis, "User acceptance of information technology: Toward a unified view", *MIS Quarterly*, Vol. 27, No. 3, pp. 425–478, 2003 [↑](#footnote-ref-35)
36. (Broz et al. 2013) [↑](#footnote-ref-36)
37. F.D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology", *MIS Quarterly* vol. 13, no. 3, pp. 319–340, 1989. [↑](#footnote-ref-37)
38. V. Venkatesh, M.G. Morris, G.B. Davis, and F.D. Davis, "User acceptance of information technology: Toward a unified view", *MIS Quarterly*, Vol. 27, No. 3, pp. 425–478, 2003 [↑](#footnote-ref-38)
39. http://www.theage.com.au/news/entertainment/when-fantasy-is-just-too-close-for-comfort, *The Age*, June 10, 2007. Mori, Masahiro (1970). Bukimi no tani The uncanny valley (K. F. MacDorman & T. Minato, Trans.). Energy, 7(4), 33–35. (Originally in Japanese). 48 J. Seyama, R.S. Nagayama, The Uncanny Valley: Effect of Realism on the Impression of Artificial Human Faces, Presence, Vol. 16, No. 4, August 2007, 337–351, 2007 [↑](#footnote-ref-39)
40. Pirovano et al., 2014. [↑](#footnote-ref-40)
41. NA Borghese, M Pirovano, PL Lanzi, S Wuest and ED de Bruin (2013), Computational Intelligence and Game Design for effective home-based stroke at Home Rehabilitation. Games for Health Journal. April 2013, Vol. 2, No. 2: 81-88. [↑](#footnote-ref-41)
42. Fasola and M.J. Mataric, Using Socially Assistive Human–Robot Interaction to Motivate Physical Exercise for Older Adults, Proceedings of the IEEE Vol. 100,No. 8, August 2012. [↑](#footnote-ref-42)
43. C.D. Fisher, The effects of personal control, competence, and extrinsic reward systems on intrinsic motivation, Org. Behav Human Performance, vol. 21, 273-288, 1978.

    . Fasola and M.J. Mataric, Using Socially Assistive Human–Robot Interaction to Motivate Physical Exercise for Older Adults, Proceedings of the IEEE Vol. 100,No. 8, August 2012. [↑](#footnote-ref-43)
44. . Fasola and M.J. Mataric, Using Socially Assistive Human–Robot Interaction to Motivate Physical Exercise for Older Adults, Proceedings of the IEEE Vol. 100,No. 8, August 2012. [↑](#footnote-ref-44)
45. “From Game Design Elements to Gamefulness: Defining ‘Gamification’”, Sebastian Deterding et al., Proceedings of the 15th International Academic MindTrek Conference. 2011 [↑](#footnote-ref-45)
46. http://en.wikipedia.org/wiki/Gamification [↑](#footnote-ref-46)
47. Csikszentmihalyi M, ―Flow: The psychology of optimal experience,‖Harper Perennial, 1991. [↑](#footnote-ref-47)
48. Kirk J, ―Burning man,‖ http://www.gq.com/news-politics/newsmakers/201202/burning-man-sam-brown-jay-kirk-gq-february-2012?currentPage=1, 2012 [↑](#footnote-ref-48)
49. “Meaningful play - getting gamification right”, Sebastian Deterding, Google Tech Talk 2011 [↑](#footnote-ref-49)
50. “Design outside the Box”, Jesse Schell, DICE Summit 2010 [↑](#footnote-ref-50)
51. Clark et al., 2012; Clark et al., 2011. [↑](#footnote-ref-51)
52. http://wiifit.com/ [↑](#footnote-ref-52)
53. M. Pirovano, R. Mainetti, G. Baud-Bovy, P.L. Lanzi, N.A. Borghese, IGER – Intelligent Game Engine for Rehabilitation, IEEE Trans. CIAIG, submitted. [↑](#footnote-ref-53)
54. Cf. Also: Mainetti R, Sedda A, Ronchetti M, Bottini G, Borghese NA. (2013) Duckneglect: video-games based neglect rehabilitation. Technology and Health Care 21 97–111 97. DOI 10.3233/THC-120712 IOS Press. [↑](#footnote-ref-54)
55. M Pirovano, R Mainetti, G Baud-Bovy, PL Lanzi, NA Borghese, Self-Adaptive Games to Support Rehabilitation at Home, IEEE Trans. on CIAIG, under review; N.A. Borghese, P.L. Lanzi, R. Mainetti. M. Pirovano (2013), Apparatus and method for rehabilitation emplying a game engine, US Application number: 13/911577, 6th June 2013. [↑](#footnote-ref-55)
56. Pirovano et al., 2014 [↑](#footnote-ref-56)
57. Berends, Johan H. and Veldhuis, Gerrit J. and Lambeck, Paul V. and Popma, Theo J.A. (1995) Device equivalence in integrated optics. Journal of Lightwave Technology, 13 (10). pp. 2082-2086. ISSN 0733-8724. [↑](#footnote-ref-57)
58. Chakravarti SN, Weaver R, Iper SSK, Hook T, Sierakowski A, Winstel K, Spieck J, Prakash DP, Tian X, Robson N, Wang H, Stillman W, Rice J, Flietner B, Jung L, Iyer SS. Device equivalence of logic performance in 0.18 μm and extension to 0.13 μm embedded DRAM technology Proc. VLSI Technology, Systems, and Applications, 2001, pp. 101-104. [↑](#footnote-ref-58)
59. http://en.wikipedia.org/wiki/Whac-A-Mole [↑](#footnote-ref-59)
60. Mainetti R, Sedda A, Ronchetti M, Bottini G, Borghese NA. (2013) Duckneglect: video-games based neglect rehabilitation. Technology and Health Care 21 97–111 97. DOI 10.3233/THC-120712 IOS Press [↑](#footnote-ref-60)
61. Foley JD, Van Dam A, Hughes JF, Feiner SK. Computer Graphics: Principles and Practice, 2nd edition, Addison-Wesley,

    2011. [↑](#footnote-ref-61)
62. http://projects.ict.usc.edu/mxr/faast/ [↑](#footnote-ref-62)
63. M. Pirovano, R. Mainetti, E. Surer, P.L. Lanzi and N.A. Borghese Melding Exercises and Games to Design Effective and Sage Exergames for Rehabilitation, submitted Games4Health Journal, Special Issue on Rehabilitation games. [↑](#footnote-ref-63)
64. Schell J. The Art of Game Design: Book of Lenses. Elsevier, (2008). Raph Koster. A Theory of Fun for Game Design (2004). Katie Salen, Eric ZImmerman -Rules of Play: Game Design Fundamentals (2003). [↑](#footnote-ref-64)
65. C. Erikson, Hierarchical levels of detail to accelerate the rendering of large static and dynamic polygonal Environments, Ph Thesis, Univ. North Carolina, Chapel Hill 2000. [↑](#footnote-ref-65)
66. Ramscar, M., Hendrix, P., Shaoul, C., Milin, P. and Baayen, H. (2014), The Myth of Cognitive Decline: Non-Linear Dynamics of Lifelong Learning. Topics in Cognitive Science, 6: 5–42. doi: 10.1111/tops.12078 [↑](#footnote-ref-66)
67. S.Kim A.K. Dey Simulated Augmented Reality Windshield Display as a Cognitive Mapping Aid for Elder Driver Navigation, CHI2009 [↑](#footnote-ref-67)
68. Becchio, C., Cavallo, A., Begliomini, C., Sartori, L., Feltrin, G., Castiello, U. (2012) Social grasping: from mirroring to mentalizing. Neuroimage, 61(1), 240- 248. doi: 10.1016/j.neuroimage.2012.03.013; Sartori, L., Xompero, F., Bucchioni, G., Castiello, U. (2012) The transfer of motor functional strategies via action observation. Biology Letters, 8(2), 193- 196. doi: 10.1098/rsbl.2011.0759. [↑](#footnote-ref-68)
69. Togelius J, Whitehead J and Bidarra R (2011) Procedural content generation in games. IEEE Transactions on Computational Intelligence and AI in Games 3(3):169-171, doi: 10.1109/TCIAIG.2011.2166554. [↑](#footnote-ref-69)
70. E. Propp, Morphology of the Folktale: Second Edition, Revised and Edited with Preface by Louis A. Wagner, Introduction by Alan Dundes, 1968, original version in Russian, 1928. [↑](#footnote-ref-70)
71. Villacorta P, Quesada L and Pelta D. Automatic Design of Deterministic Sequences of Decisions for a Repeated Imitation Game with Action-State Dependency - Proc. CIG 2012. [↑](#footnote-ref-71)
72. Alamia M, Borghese NA, (2010) Creating long gait animation sequences through Reinforcement Learning Frontiers in Artificial Intelligence and Applications; Volume 226, 2011; Neural Nets WIRN10 - Proceedings of the 20th Italian Workshop on Neural Nets, pp. 144 – 151. [↑](#footnote-ref-72)
73. Riedl and Young, Narrative Planning: Balancing Plot and Character, Journal of Artificial Intelligence Research 39 (2010) 217-268. [↑](#footnote-ref-73)
74. Csikszentmihalyi M, ―Flow: The psychology of optimal experience,‖Harper Perennial, 1991. [↑](#footnote-ref-74)
75. Kirk J, ―Burning man,‖ http://www.gq.com/news-politics/newsmakers/201202/burning-man-sam-brown-jay-kirk-gq-february-2012?currentPage=1, 2012 [↑](#footnote-ref-75)
76. http://www.badbloodgame.net/games/badblood/ [↑](#footnote-ref-76)
77. T. W. Bickmore and R. W. Picard, Establishing and maintaining long-term human-computer relationships,[ ACM Trans.

    Comput.-Human Interaction, vol. 12, no. 2, pp. 293–327, Jun. 2005.. [↑](#footnote-ref-77)
78. J. Fasola and M.J. Mataric, Using socially assistive Human-Robot Interaction to Motivate Physical Exercise for Older Adults, Proc. IEEE, Vol. 100, 2012. [↑](#footnote-ref-78)
79. M. Zuckerman, J. Porac, D. Lathin, R. Smith, and E. L. Deci, BOn the importance of self-determination for intrinsically motivated behavior,[ Personality Social Psychol. Bull., vol. 4, pp. 443–446, 1978. [↑](#footnote-ref-79)
80. E. Deci and R. Ryan, Intrinsic Motivation and Self-Determination in Human Behavior. New York: Plenum, 1985, pp. 29, 318, 322. [↑](#footnote-ref-80)
81. http://company.zynga.com/games/farmville [↑](#footnote-ref-81)
82. Pirovano et al., 2014 [↑](#footnote-ref-82)
83. AI Gaming programming 4, Ed. Steve Rabin, Charles Riever Media, Course Technology, 2008 [↑](#footnote-ref-83)
84. Cattinelli I., Goldwurm M., Borghese N.A. Interacting with an artificial partner: modeling the role of emotional aspects, Biol. Cybern. 2008. [↑](#footnote-ref-84)
85. Mainetti et al., 2012. [↑](#footnote-ref-85)
86. . Mainetti et al., 2012. [↑](#footnote-ref-86)
87. Pirovano et al., 2013. [↑](#footnote-ref-87)
88. Prisacariou et al., 2013, 2014; FUSION. [↑](#footnote-ref-88)
89. Frosio et al., 2013; Frosio et al., 2011. [↑](#footnote-ref-89)
90. Resnick P., Zeckhauser R., Friedman R., Kuwabara K. (2000) Reputation Systems. Communications of the ACM 43 (12) 4548. Hoffman K., Zage D. & Nita-Rotaru C. (2009) A survey of attack and defense techniques for reputation systems. ACM Comput. Surv., 42, 1:11:31. [↑](#footnote-ref-90)
91. Leimeister, J.M.; Sidiras, P.; Krcmar, H., "Success factors of virtual communities from the perspective of members and operators: an empirical study," System Sciences, 2004. Proceedings of the 37th Annual Hawaii International Conference on , vol., no., pp.10 pp.,, 5-8 Jan. 2004

    doi: 10.1109/HICSS.2004.1265459 [↑](#footnote-ref-91)
92. http://www.continuaalliance.org/ [↑](#footnote-ref-92)