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Type of action: Research and innovation actions

# ROBOHOME2.0

## Service ROBOt to monitor, assist and evaluate the elder at HOME

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## 1.1 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%, going from 84.6 million in 2008 to 151.5 million in 2060. Similarly the number of people aged 80 years or over is expected to almost triple from 21.8 million in 2008 to 61.4 million in 2060[1] and the availability of nurses is already becoming an issue in the US[2]. Physical activity, cognitive stimulation, social inclusion, balanced diet, therapy adherence and regular clinical screening promote a lifestyle that **slows down the decline, thus enabling the elder to live at home healthier and for a longer time**. This is becoming a priority in Europe as recognized by the EC community: managing frailty and functional decline, 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). Several approaches have been proposed to address these aspects but a comprehensive solution is far to be provided. Moreover, a high emphasis is often put on wearable devices for monitoring that limit the compliance of the users, especially on the long run.

**Robohome2.0 is an intelligent system, integrating an existing robotic platform with environmental sensors, and smart objects, advanced user interfaces, a virtual community and an activity center, to provide assistance, transparent monitoring and continuous clinical evaluation of the elder at home through a full-fledged, modular, personalized, and compliant approach.**

Such high interactivity is remarked by "2.0" in the title of the proposal borrowed from Web2.0 concept[3]. Indeed, ongoing robotics, smart objects and smart homes and Human Robotic Interfaces (HRI) research plays a key role in this panorama for matching increased life expectancy with the enhancement of the quality of life as people grow old. Robohome2.0 builds upon most recent results in these areas to realize a prototype, test it into real-life environment so to get the ambition to find its way to the market. To this aim,

Robohome2.0 will assemble **off-the-shelf components** in a robust and reliable way to get a **low-cost hierarchical system that can be deployed massively at elders' home**.

Such system provides several key aspects of **clinical monitoring**: a) Early cognitive and physical decline is monitored by the robot observing and analyzing common everyday tasks (e.g. preparing coffee), in cooperation with adequate sensorized objects, thus making the **elder not aware of being monitored (transparent monitoring)**. b) Profiling of phone conversation identifies **meaningful changes in the emotional content** associated to some degenerative diseases. c) **Physiological sampling** (e.g. glucose level, pressure) is provided by an adequate devices network. d) A **smart drug dispenser provides to the elder the right pills at the right time** thus increasing therapy adherence. e) **Activities of Daily life (ADL)** are also monitored (e.g. number of hours of sleep; home temperature). The robot **assists the elder in a confident** independent living in finding lost objects inside the house (e.g. the mobile phone, keys) and gives him recommendations and suggestions through a Virtual Caregiver avatar.

**Robohome2.0 supports an active lifestyle recommending and guiding the elder through a personalized mix of physical, cognitive and social activities, with an adequate challenging level.** We fully explore **gamification** to maximize motivation, sustain attention, and train memory and automatic narration to provide long life engagement. These concepts are explored also in educational games on elder diseases and lifestyle. Gamification is exploited also through the **virtual community** that provides support for social activities so that the elder is incentivized **to avoid isolation**. The community connects caregivers, GPs, geriatrists and elders that are able to exchange information and increase **collective knowledge**. Activities, assistance, recommendations and monitoring is **managed by the robot through an embodied Virtual Caregiver, context aware,** that uses the huge amount of heterogeneous data coming from sensors, community and activity center to evaluate elder's state, tune activities and refine elder profile. A distributed voice command system **enables voice commands**.

**Giraff robot** has been identified as the most suitable robot for Robohome2.0. Giraff is the result of progressive work in the domain of assisted living partly financed by the AAL "ExCITE" and FP7 "GiraffPlus" projects. It is basically a robotics base carrying a control PC and an adjustable touch-screen monitor, whose target price for massive

[1] Giannakouris k., Aging characterizes the demographic perspective in the European Societies, Eurostat, Statistics in focus, 2008, 72. http://eppeurostat.ec.europa.eu

[2] P. Buerhaus, BCurrent and future state of the US nursing workforce, J. Amer. Med. Assoc., vol. 300, no. 20, pp. 2422–2424, 2008. Nursing Shortage Fact Sheet, American Association of Colleges of Nursing, 2010. Online at http://www.aacn.nche.edu/media/FactSheets/NursingShortage.htm .

[3] http://oreilly.com/web2/archive/what-is-web-20.html

production is below 1k Euros. It was awarded "**Most Promising Innovation" of 2011 by the AAL organization.** It has an open software architecture that allows to easily add functionalities.

## Specific Objectives

**1. To improve Giraff robot capabilities of interaction with the elder.** Giraff will be transformed from a tele-operated robotics platform into a robotic platform endowed with autonomy fully exploiting vision capabilities offered by adding a 3D camera, like Kinect. This makes Giraff an active companion for the elder that can assist in finding objects, give him/her feed-backs and recommendations, monitor him/her and carry around the activity center to allow the elder exercising in the best time and place (WP3, D3.2).

**2. To design and implement interfacing modalities that promote good emotional relationship between the elder and the robot.** This is a very powerful mean to guarantee motivation in the interaction, easiness and even pleasure. We aim at **maximum compliance with the elder** to foster the development of stable and positive bonds. **Gamification, interaction modalities, unified GUIs and assistance in everyday life tasks** is part of this. We exploit several social intricacies in the interface with Giraff, like humour, references to mutual knowledge, continuity behaviors, politeness and trust[4]. The information gathered by the sensors and the caregivers inputs **is used by the Virtual Caregiver to create meaningful recommendations** to the elder (WP2, WP3, D2.3, D3.3).

**3 To prevent frailty, cognitive and physical decline and social exclusion, a hands-off network of sensors is designed to offer an evaluation of daily activities and behaviors transparently to the user.** Instead of instrumenting the elder**, we instrument everyday life objects**, like a tea cup, a comb, a fridge handle, depending on elder's habits. Instrumentation will provide wireless, real-time synchronous data on motion and handling pressure. We sensorize also objects like walking sticks or trolleys to evaluate gait stability **indoor and outdoor**. We combine vision provided by Giraff with information provided by all the sensorized objects to derive a "**signature**" of the movement. From these data we **define and validate indexes that will be made available to clinicians for elder evaluation.** Transparent tests of clinical assessment of cognitive decline are administered as spot questions or spot activities intermingled in the everyday tasks and games. We also explore **pitch analysis of phone conversations** to early detect onset of cognitive neurodegenerative diseases. (WP5, WP6, D5.1, D5.2, D5.3, D6.1).

**4. To develop a context-aware intelligent virtual caregiver** which realizes a **closed-loop assistance system** that cooperates with caregivers and clinicians. The virtual caregiver will analyze the huge amount of heterogeneous data provided by the monitoring systems and the activity center and it will a) **suggest physical, cognitive and social activities**, adapting **the level of difficulty to the current elder's status;** b) **tune the estimated state of the elder**; c) **provide the caregivers and the GPs with** relevant information on the elder status (WP3, D3.1, D3.3).

**5. To develop assistance in everyday tasks by the Giraff robot.** A key element to promote a solid bond between the robot and the elder is trust. One element that can help creating this bond is solving problems, even small, in everyday life. Loosing objects is common and enabling **Giraff to locate them for the elder** can promote trustiness in the relationship. A novel system based on distributed microphones pairs with DSP processing capabilities will allow the elder to call Giraff, also when in a different room, realizing a **distributed command system**. Giraff will **guide the elder in taking prescribed physiological measurements, like blood pressure or glucose, at the correct time intervals through video/animation instructions with voice explanation**. A **smart drug dispenser** will made available only right pills at the right time with alert signals remembering the therapy timing (WP3, D3.1, D3.4).

**Scenario:** Mike is wandering around at home, while Giraff, comes to him and says: "Today is the birthday of Max, your nephew, why don't you call him?" Mike illuminates, and with a smile, he looks for his mobile phone to call Max. Unfortunately, he could not remember where he put it. He calls again Giraff and asks "where is my phone?". Giraff activates the automatic location system, and after a while it moves towards the kitchen and takes a picture with its Kinect camera to the phone, partially showing under a box. Giraff sends a voice message to Mike, who can get the phone and calls Max. Mike is so grateful that he wants to kiss Giraff for this help… and Max too.

**6 To design and implement a personalized activity center**, based on the gamification paradigm and fully integrated with the robot and with the community of users. The service provides cognitive and physical exer-games that can be played preferable with other peers through the virtual community. **These games will be designed upon a set of exercises defined by the clinicians to specifically train declining functions.** Social activities, like playing cards through the virtual community, is also supported to promote socialization[5] (WP4, D4.3).

**7. To promote elders education to a healthy lifestyle, self-empowerment, and increase their perceived usefulness in the society aiming at improving quality of life of users and their formal and informal caregivers.** The activity center provides exer-games to support education to a healthy lifestyle, promoting elders self-

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[4] T.Bickmore, R.Picard, Establishing and maintaining long-term human-computer relationships, ACM Trans. CHI, Volume 12:2, 2005, pp 293 – 327.

[5] Alexopoulos G. Depression in the elderly. Lancet, 2005; 365: 1961-70.

empowerment. The approach will be based on **ontology automatic narration**[6] to define mini-games that can be casted into episodes, matched to pieces of knowledge on the diseases or lifestyle. We explore how to combine this with stochastic models, like **stochastic finite state machines** to chain episodes into narration. **Reinforcement learning** is explored to steer narration towards themes tuned on elder preferences. Popular containers like fairy tales[7] or sports competitions will be used. We implement also a **repository of real life stories** provided at regular intervals by the community manager (WP4, WP6, D4.2, D6.2).

**8. To field test a complete ecosystem, involving all players, to gather evidence of Robohome2.0 benefits.** The satisfaction of the end users is the "north star" in guiding Robohome2.0 development. An end user advisory board will be set early in the project to help keeping the project on track. The system will be deployed and tested first in the living labs provided by ORU and SAS and later at elders home (WP8, D8.4).

**9. To demonstrate the cost-effectiveness of the technology and develop a proper business model to massively deploy Robohome2.0 within a sustainable care system.** We envisage a business model based on **providing service** through a specialized company like KORIAN. This will be supported by an ICT service provider that provides the cloud hosting the users community and the data. Such system will integrate the developed components into a flexible, scalable and modular system that can be offered to the elders at home. **Such model will be tested agains the data collected in the pilot** and against the actual solutions on the market and available services **Costs and benefits will be made explicit** (WP9, D9.3, D9.4, D9.5).

## 1.2 Relation to the workprogramme

| Robohome2.0 Contribution | Mile stone | PHC19 target outcomes |
|---|---|---|
| Cognitive impairments, frailty and social exclusion will be addressed with a holistic approach based on: monitoring, assistance and evaluation that are interleaved and provided at the point of need. Data are gathered mainly in a transparent why, while the elder carries out the daily activities | **5** | Citizens in an ageing population are at greater risk of **cognitive impairment**, **frailty** and **social exclusion.** |
| Cognitive impairment will be addressed in a pro-active way, by proposing activities and exer-games that are adapted to the actual elder competences, status and psycho-physical condition. Cognitive tests of clinical validity will be administered to the elder in a transparent way through the activity centre. Early detection of cognitive degenerative diseases through audio analysis of phone conversation will be explored. | **3** | How Robohome2.0 will reduce the risk of **cognitive impairment** |
| Data from the activity center and monitoring systems are used to evaluate the current psycho-physical status. This allows Robohome2.0 identifying possible physical and cognitive decline. Validation of these decline indexes will be included; they will be functional to a) adapt the activities mix to the changing user conditions; b) follow up the user status keeping the carers informed and favoring appropriate and timely interventions. Robohome2.0 will help the elder in therapy adherence: it provides measurement of physiological parameters, it increases elder's awareness on lifestyle importance and it provides a smart drug dispenser. | **3** | How Robohome2.0 will reduce the risk of **frailty**. |
| Robohome2.0 will set-up a community of users that will propose connection with other elders. The community will support multiplayer gaming and social activities. It will also be the place to exchange experiences and knowledge. Robohome2.0 will suggest to the users to stay in touch with relatives, friends, etc. A profiling of social activities through log book and phone conversation analysis will be carried out. | **3** | How Robohome2.0 will reduce the risk of **social exclusion**. |
| Robohome2.0 will push the elder keeping active with an everyday cognitive and physical training, properly calibrated on the single user's needs, assuring rewarding experience. Robohome2.0 will help the elder in some simple but basic tasks related to independent living such as finding objects, remembering meetings, drugs to assure prescription adherence and assists him/her with the diet. Specific supervision of physiological parameters will | **3** | with considerable negative consequences for their **independence**, |

6 M. Fayzullin, V. S. Subrahmanian, M. Albanese, C. Cesarano, A. Picariello, Story creation from heterogeneous data sources, Multimedia Tools and Applications, 33(3), 351-377, 2007.

7 V. Propp, Morphology of the Folktale: Revised and Edited with Preface by L.A. Wagner, Introduction by A. Dundes (Vol. 9), University of Texas Press, 2010.

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| be included into the Robohome2.0 so to alert critical situations. Robohome2.0 will send the alarm directly to the adequate caregiver. | | |
| The carers will be helped in the care practice by daily monitoring information. An increased participation to elder life through the community will allow providing recommendations and information. Audio-video connection will help in keeping a strong bond also when being physically present is not possible. | **4** | **quality of life**, that of those who care for them… |
| The lack of recognition of physical and cognitive decline could provoke delayed interventions which amplify the decline itself, inducing a negative loop which impacts on the requests to the health and care system. Transparent monitoring inside Robohome2.0 allows to objectively assess cognitive and physical decline continuously over time. Robohome2.0 will communicate periodic reports to the GP, so to allow prompt and tuned intervention in case of worsening conditions. A business plan will be elaborated on this, substantiated by project results. | **4** | and for the **sustainability of health and care systems**. |
| Hereafter, an analysis of the crucial ingredients of the aim of the call with respect to the Robohome2.0 proposal is detailed. **Service robotics:** Robohome2.0 is based on a commercial off-the shelf service robot (Giraff), which will be enriched with adequate features. **Transparent Monitoring system:** we will monitor the elder through the use of everyday objects without requiring that he/she wears any device. **Activity centre:** it is based on gamification and provides a customized mix of activities involving also the community of users. **Assisted living environment:** sensors to monitor the home and elder's behavior and smart assistance systems will be integrated into Robohome2.0 . | **5** | The challenge is to develop new **breakthroughs** for **active and assisted living** based on **advanced ICT solutions**. |
| Core of the system is the Giraff robot that embodies an intelligent virtual caregiver. It monitors him/her through a monitoring network embedded in the house and in cooperation with sensorized objects of everyday use, thus achieving a monitoring completely transparent to him/her. It advices him/her and suggests tailored activities and looks for lost objects. | **3** | Proposals should focus **on service robotics** in **assisted living environments** which can help an ageing population to remain active and independent for longer. |
| - *behavioural disciplines:* to develop emotional bonds with the service robot is fundamental for a good interaction. Therefore interfacing modalities and interface design will be inspired by this. UOP and PCL, having complementary expertise in Human Robot Interaction and elder psychology respectively, will contribute to functional design and testing of the components and the whole system to maximize user acceptance.<br>- *social disciplines:* social scientists (KOMMUN, PCL) will assure both in the virtual community design and in the evaluation phases that the project has a positive impact both on the user social inclusion and on the caregivers.<br>- *health disciplines:* regular physiological sampling, clinical assessment and smart drug dispenser provide clinical monitoring and compliance. This will be complemented with providing structured knowledge and education through gamification. Teams of clinicians (PCL, SAS and KOMMUN) with complementary specializations and a group of bioengineers (POLIMI) will collaborate to develop and validate tests based on the analysis of ordinary life actions to assess the physical and cognitive status of the elder. | **4** | The project should combine **multi-disciplinary research** involving **behavioural**, **sociological, health** and **other relevant disciplines**. |
| Robohome2.0 will be built with modularity and flexibility in mind both at the hardware and software level. Environment monitoring will be built upon scalable protocols, like z-wave, already diffused in the domotic field. Sensorized objects will be built integrating a transmission module based on most diffused wireless transmission protocols. The activity centre will provide a mix of personalised and adaptive exer-games. The system will be managed by the virtual caregiver that will implement deductive reasoning on the whole data received and organized inside the frame of an ontology. | **4** | Characteristics of the solutions developed should be their **modularity**, **cost-effectiveness**, **reliability, flexibility** in being able to meet a range of needs and societal expectations, |

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|---|---|---|
| The use of off-the-shelf components and standardization, and the integration of already developed sensors will allow to realize a cost-effective system and meet the widest range of functional requirements. | | |
| Robohome2.0 will be tested in specific living labs in Sweden and Spain and in elders apartments. This will be fundamental to develop a system that can be really acceptable and compliant with the end users. The pilot test in WP8 allows evaluating the compliance and suitability of Robohome2.0, as well as the safety of the technology. An end users advisory board will be set to have an external highly qualified feed-back on project development. | **4** | **applicability to realistic settings**, **safety** and **acceptability to end-users**. |
| The activities proposed will be designed having gender in mind, realizing games episodes inspired to at least two themes, one most suitable for females and one for males. Similarly, the avatar of the virtual therapist and all the elements that are gender sensitive, will be designed such that a configuration in the male and female version would be possible. | **2** | **Gender and ethical issues** should be paid due attention. |

## 1.3 Concept and approach

### 1.3.1 Overall concept

Robohome2.0 builds upon the successful EC funded projects Excites and Giraff plus, coordinated by ORU and Fitrehab and Rewire, coordinated by UMIL. Robohome2.0 is a **hierarchical platform** aimed at supporting the elder at home, for a prolonged time, monitoring and guiding him/her to a healthy lifestyle. It consists of three hierarchical levels (Figure 1): 1) **a Core layer** constituted of an intelligent **Virtual Caregiver** that provides feed-back and recommendations to the elder suitable to his/her state and lifestyle, **embodied into a service robot** that provides assistance. 2) **a service layer** that includes a **distributed pervasive monitoring system, transparent to the elder** that provides quantitative information on early physical / cognitive decline and social attitude, and an **activity center** that guides the elder in activities, tailored to elder idiosyncrasies and needs, and implemented through gamification to stimulate maximum adherence and motivation. 3) **a Community of users** connecting elders and other actors, aimed at improving socialization and knowledge.

1) The **Virtual Caregiver** in the core layer receives heterogeneous information from monitoring systems, community and activity center. It will use an ontology based system to categorize them and propose a mix of activities with the proper level of challenge, tailored to the elder status. Moreover, it helps the elder **to adhere to therapy prescription** by means of a **cooperative smart drug dispenser.** It also assists the elder with audio-video instructions and digital animation in **taking physiological samples** through a set of adequate devices or applications. Welcome messages, recommendations, feed-backs, are all provided to the elder throughout the day to the elder by the Virtual Caregiver avatar, using real-time synthesized speech[8]. The Virtual Caregiver also analyzes the historical data on physiological monitoring and psycho-physical assessment, to identify trends and oscillations. W**arnings related to anomalous values are automatically generated and transmitted to GPs and caregivers**. An initial profile of the elder characteristics, idiosyncrasies and needs is carried out before installing the system at home. A given lifestyle, clinical and diet regimen is defined by the elder and his/her caregivers. **This information will be organized into structured knowledge through an adequate ontology** that is

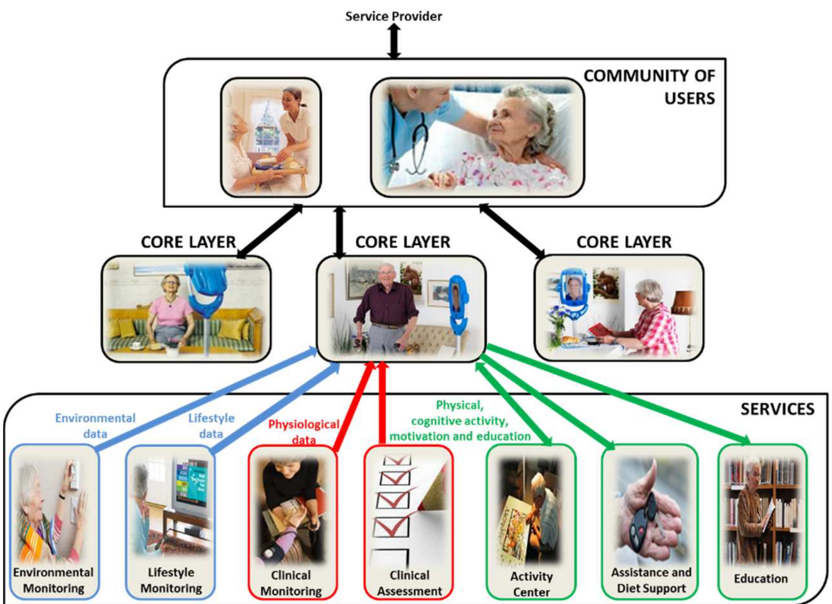


*Figure 1 - The hierarchical structure of Rohohome2.0. The core layer is constituted of the Virtual Caregiver embodied in the Giraff robot; the service layer is a modular layer that provides monitoring data to the virtual caregiver and offers functionalities to the elder: e.g.the activity center. The elder, his/her caregivers and the clinicians are all part of a community of user.*

[8] https://developers.google.com/translate/

used to provide recommendations, set-up monitoring parameters (e.g. critical thresholds) and tune the mix of activities, through Description Language approach. The Giraff robot is enhanced providing **autonomous navigation capabilities:** it will be able to reach the elder upon being called, to search for a lost object, to answer requests, to fetch the elder to monitor him/her. Interfacing modalities with Giraff are carefully designed and implemented to favor the **establishment of stable and positive bonds.** To this aim, an innovative **voice command system** is designed and implemented to enable the elder to call Giraff from any room in the house. This is particularly useful when help is needed.

2) The **service layer** contains the monitoring systems and the activity center. **Environmental monitoring** is obtained integrating off-the-shelf devices into a sensorized home network. Low-power devices and standard protocols, like Z-wave, will be implemented. **Elder psycho-physical monitoring** is carried out through an innovative **solution transparent** to the elder. Typical everyday life tasks, like preparing a coffee or walking with the help of the walking stick, will be surveyed. We sensorize objects with miniaturized micro-architectures that sense pressure and movement and transmit them through Bluetooth connection to Giraff. Sensors data and motion data acquired by Giraff's camera are synchronized and acquired in real-time to derive a description of the task in terms of **pressure and movement temporal profile.** This **constitutes a "signature"** of the interaction with the object. The motion pattern is compared over time to derive a **quantitative motion degradation indexes.** We investigate which indexes can provide clinical assessment. The **activity center** provides exercises and supports social activities. **Physical and cognitive exercises are guided by video-games:** the elder sees him/herself in the form of an avatar interacting with a virtual scenario with his/her movements tracked in real-time. We fully explore a novel concept of **technology equivalence** allowing the elder choosing the best time, place and modality to exercise. A full layer of gamification is built on top of the different exer-games to promote socialization and to make games long lasting. This is based on automatically building stories, from episodes, exploring the combination of **automatic narration techniques with stochastical models**. Some episodes will be aimed to **educate** the elder on lifestyle and therapy.

3) The **community of users,** acts as **a bridge towards other elders**, relatives, caregivers and clinicians. Audio-video communication is fully supported to enrich the interaction: exploiting technological equivalence, the elder is able to communicate through Giraff display, home TV or smart phone. This largely increases the potential use of the system, **improves patient to doctor communication** and promotes socialization with other pairs. The **community of users** publishes the performance of the elders in the games to promote cooperation and competition that reinforces motivation. We implement algorithms based on the analysis of social relationships inside the community to **identify groups of elders** that may share the same interests and have a similar states. These clusters are also used to refine patients profiling. The community is also a **source of collective knowledge**. This will have a multi-media format and involves all the aspects of the elder life: therapies, illness, psychological issues, social issues.

**Scenario.** Robohome2.0 proposes as month theme, "the political changes in Spain, after King Juan Carlos in 1978 restored democracy in Spain". A lot of stories were recorded and sent to the community and the story of Francisco, who entered in politics that days to serve its city, Seville, was prized the best by the community members and made public on the Robohome2.0 community site. A journalist of "El Pais" discovered it, interviewed Francisco and wrote together a small book on the organization of elections and the first steps of political parties in that period, in Seville. The book was a large seller one.

These three layers **cooperate, under the supervision of the Virtual Caregiver, to provide key functionalities:** a) regular clinical monitoring to control physiological parameters, b) cognitive and physical assessment to early detect decline, c) lifestyle and social behavior evaluation to early detect risk of exclusion, d) personalized training through cognitive and physical games, e) promotion of social activities, f) increase elder's self-empowerment, g) assistance in everyday tasks, and h) meaningful interaction with Giraff. These functionalities, are not isolated but they are tightly interconnected. For instance, regular physical exercise has been shown to be effective at maintaining and improving the overall health of elderly[9,10,11]. Physical fitness is associated with higher functioning in the executive control processes[12], correlated with less atrophy of frontal cortex regions[13], and with improved reaction times[14] compared with the sedentary. Social interaction has been shown to have a positive impact on

[9] E. Baum, D. Jarjoura, A. E. Polen, D. Faur, and G. Rutecki, Effectiveness 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.

[10] 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.

[11] 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.

[12] S. Colcombe and A. Kramer, BFitness effects on the cognitive function of older adults, Psychol. Sci., vol. 14, pp. 125–130, 2003.

[13] 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, Cardiovascular fitness, cortical plasticity,and aging,[ in Proc. Nat. Acad. Sci. USA, 2004, vol. 101, pp. 3316–3321.

[14] W. Spirduso and P. Clifford, BReplicationof age and physical activity effects on reaction and movement time, J. Gerontol., vol. 33, pp. 26–30, 1978.

general mental and physical wellbeing[15], in addition to reducing the likelihood of depression[16,17,18]. **We will fully exploit the unique possibility of Robohome2.0 of addressing all these aspects to provide functionalities through the best mix of components for each elder.** Such approach does call for various competences that are well represented in the multi-disciplinary teams of SAS, PCL and KOMMUN and in the rest of the consortium as well, that includes bioengineers (POLIMI), experts in HRI (UOP) and ICT researchers by ORU, UMIL, BDIGITAL and UMA. The consortium will allow developing strong inter-disciplinary research, promoting a **bidirectional translation research approach**[19] to come up with a shared view on how the Robohome2.0 platform should be (WP1, WP2). Plenary meetings at the different partners sites will allow to better elucidate problems and current solutions and to make clear the current technological offer.

### 1.3.2 Technology Readiness Level (TRL) analysis

The project is positioned in different TRL considering the various components and the whole platform.

**Clinical monitoring** of physiological parameters will be accomplished integrating in Robohome validated off-the-shelf components. These components will be used by the virtual caregiver providing instructions in audio-visual form. Data will be transmitted to the community. This activity is expected to be at TRL7 at the end of the project.

**Cognitive and physical assessment.** Sensorized everyday objects (TRL3) will be combined with motion acquisition through Giraff robot to provide synchronous motion and pressure data. Motion acquisition requires Giraff robot to approach the elder and orient the camera adequately with respect to the elder (TRL2). The fused data will be used to segment movement into components (TRL4) and derive a degradation indexes of clinical validity (TRL1). The high effort in this work in Task5.1 and 5.2 will provide a TRL6 technology at the end of the project. Voice pitch analysis explored for early detection of onset of cognitive degenerative diseases is at TRL1 presently. We expect to obtain a TRL4 by the end of the project. We will also explore cognitive and physical exer-games provided by the activity center from which specific assessment parameters can be evaluated. The starting point is TRL1 and we expect to have the parameters validated by the end of the project (TRL5).

**Lifestyle and social behavior evaluation.** We will use standard components that will be assembled into a modular and flexible network (TRL8/TRL9) and integrate it with the robot. Its information will be integrated with data from monitoring and from the activity center to update the elder profile and tune the recommendations and monitoring (TRL4). We expect to arrive at TRL7/8.

**Activity centre.** The activity centre is largely based on the IGER game engine that is being currently validated on the field within the REWIRE project (TRL5). We extend it to support cognitive exer-games and multiple output devices. We build a new layer to address knowledge acquisition and long term motivation through gamification and automatic narration. Both these extensions starts from TRL2. We expect to arrive at TRL7 with the pilot.

**Promotion of social activities.** This will be supported by a virtual community of users that will be built starting from BDIGITAL experience inside the projects Rewire, Backhome, and Saapho, in which it has coordinated the work related to the implementation of the community services and environment monitoring (TRL5). The community features will be tailored to requirements of Robohome2.0. It is expected to arrive at TRL7. The community will also support multi-player games. Multi-player view will be integrated through multiple video streaming through for instance WebRTC technology (TRL8). Multiple videos will be combined with a dynamical graphical scene showing scores and other relevant information (TRL2). We expect the component to be at TRL7.

**Increase of knowledge**. This is mediated by the community of users (TRL5) and by continuous education through gaming created through automatic narration (TRL3). We expect to arrive at TRL6.

**Assistance in everyday tasks.** Proposed systems on the market for locating objects have limitations in range and power consumption. The technology is now at TRL3 but it is likely to increase its level at the time the project will start. We will explore this technology in combination with robots navigation. We expect to bring this methodology at TRL5. Cooperative drug dispenser will be built upon micro-architectures already explored by SXT (TRL5) integrated with micro electro-mechanical devices. We expect to bring this component at TRL8 by the end.

**Meaningful interaction**. A tight collaboration between psychologists, HRI experts and ICT researchers will allow building meaningful and attractive interfacing modalities. We will start from UOP and PCL competences (WP4) and shape Robohome2.0 throughout the development to promote compliance with the elder and provide HRI and GUIs at TRL7. In particular, we will explore an ecological approach for both the autonomous navigation of the Giraff and

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[16] L. K. George, D. G. Blazer, D. C. Hughes, and N. Fowler, Social support and the outcome of major depression, British J. Psychiatry, vol. 154: 478–485, 1989.

[17] E. Paykel, Life events, social support and depression, Acta Psychiatrica Scandinavica, vol. 89, pp. 50–58, 1994.

[18] Stice E, Ragan J, Randall P. 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.

[19] Nathan DG. Careers in translational clinical research - Historical perspectives, future challenges. JAMA 2002;287(18):2424-7.

its approach to the elder, starting from the work of UMA (TRL4). We expect to arrive at TRL7 at the end. Lastly, an innovative distribute voice command system will be realized to provide a natural interface between the elder and the robot, starting from the experience of SG (TRL4). We expect to arrive at TRL7.

### 1.3.3 Relationship with National and International Research and Innovation activities

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 interacting with an assistive environment has been explored in the **Companionable** project (www.companionable.net/), where a mobile robotic companion interacts with a smart home sensorized environment with the aim of cognitively stimulating and monitoring the elder against decline. The **Robo M.D.** project[20] was aimed specifically to detect critical situations like falling and launch an alarm. These concepts have been further developed in the **Excite[21]** and **Giraff plus** projects (www.giraffplus.eu/), coordinated by ORU. In Giraff plus a wide range of environment and activities signals are used to monitor the elder and to provide a pictorial representation of his/her activities and lifestyle. Monitoring is complemented with a robot that provides video-communication with caregivers. The **Robot Era** project (www.robot-era.eu/robotera/) provides a set of robots that assist the elder in specific functionalities of everyday life. On the other end, a few projects have explored the use of low-cost technology to support the elder at home. The project **Mobiserv** (www.mobiserv.info/results/) will deliver a robotic prototype capable of sensing the user's personal environment and adapting to the user's behaviour. The **Oldes** project (www.oldes.eu/home.html) offers 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. The **Wecare** AAL project (www.wecare-project.eu/) explores social aspects in building a community to support elders living alone. Several projects have been based on developing wearable devices to monitor elders at home. The **Rosetta** project (www.aal-europe.eu/projects/rosetta/) was aimed to monitor activities of elderly persons with sensors to generate alarms 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 in the **Cupid** project (www.cupid-project.eu/) that completes monitoring with specific rehabilitation exercises. **Happy Aging** (www.aal-europe.eu/projects/happy-ageing/) is a system for lifestyle monitoring, for issuing reminders and detection lack of activity or unusual behaviors. **Hope** (www.hope-project.eu) is targeted to Alzheimer patients and can provide alarms and communication with health professionals. It connects several house sensors and gives reminders and warnings via voice. **eCaalyx** (http//www.ecaalyx.org) uses worn physiological sensors to monitor the elder at home. The aim of the **Interaction** project (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 (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 patients affected by psychiatric illnesses. However, the need to wear sensors limits strongly the usability of these systems that are still bounded mainly inside the research domain. All these projects improve the elder life in some of its aspects; however they come short in providing a complete support to the elder in terms of monitoring and assistance, as well as providing connection with his/her caregivers. A different approach was followed in the **Fitrehab[22]** and **Rewire** projects (www.rewire-project.eu), coordinated by UMIL, in which a **hierarchical architecture** has been developed to support rehabilitation at home. Rewire, in particular, has shown that assembling off-the-self components, patients discharged by the hospital, are enabled to continue exercising intensively at home, still under clinicians supervision. Monitoring the performance, adapting the games at point of needs and motivational feed-back to the user and informative feed-back to his/her supervisors are deemed to be a winning strategy. Robohome2.0 builds on this concept and extends it to **support the elder at home**. Besides research projects, a few companies have approached assisted living market through robotics. **Kompai[23]**, developed by Robosoft inside the Domeo project (www.aal-domeo.eu/) is a companion robot, meant as an open robotics architecture with, presently, limited capabilities. The **Giraff** robot, developed by GIRAFF (P3) (www.giraff.org/) is a robotics platform with a contained costs and a good interfacing with the elder. Thus, it has **been selected as the most suitable service robot** for Robohome2.0. The other pillar of Robohome2.0 is the introduction of **gamification. Exer-games** have been widely explored in EU projects mainly targeted to rehabilitation as a good way to stimulate, motivate and guide patients. In the **Script** project (www.scriptproject.eu/), games are combined with small robots

[20] http://www.innovation4welfare.eu/307/subprojects/robo-m-d.html
[21] http://www.aal-europe.eu/projects/excite/
[22] http://www.innovation4welfare.eu/287/fitrehab.html
[23] http://www.robosoft.com/robotic-solutions/healthcare/kompai/index.html

and are aimed at guiding patients in the rehabilitation of wrist and hand functions. The project **H_Cad**[24], aimed to rehabilitate cognitive dysfunctions was carried out through tasks used in occupational therapy inside a controlled environment. The EU project **Backhome**[25], investigated how to provide cognitive rehabilitation tasks to people with severe disabilities. 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 (www.cupid-project.eu/) designed exer-games specifically targeted to people with Parkinson providing audio, visual and tactile feedback. The **RGS** system (rgs-project.upf.edu) 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 mechanics make them not fit for prolonged exercising. The **IGER** (Intelligent Game Engine for Rehabilitation) game engine[26,27] developed inside the **Rewire** project (htttp://www.rewire-project.eu) is an exception. This is a **game engine**: a set of tools that are aimed, on one side at making the games run on the machine they are designed for, 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. In particular, it contains the functionalities required to configure and adapt the exer-games to the user and to supervise him while exercising at home. Thus, IGER offers therefore a good starting point to Robohome2.0. The **Mundus** project (www.mundus-project.eu) coordinated by POLIMI, has proposed a modular assistive device for people with severe disabilities. A pilot study including 20 end-users have demonstrated a high level of compliance and acceptance by the users. Modularity, personalization and full testing with end-users are driving elements brought into the Robohome2.0 experience.

### 1.3.4 Overall approach and methodology

Activities required to develop Robohome2.0 can be grouped into four main areas: monitoring, assistance, training, and virtual communities. We will here analyze the research and development required inside each area.

#### Monitoring

Monitoring has different facets that all contribute to make the elder and his caregivers feel safe and supervised at home. In Robohome2.0 it will include: ***clinical, physical and cognitive, social, and environmental monitoring.***

***Clinical monitoring*** is aimed at regular sampling of physiological parameters and at maintaining under control the acquired diseases through regular drug assumption. Huge progress has been achieved by ICT in the last years for **clinical monitoring** at **home**. For instance, Zephir technology has proposed a suit for clinical tele-monitoring and Alive a specific suite for heart monitoring. More recently, IMEC has proposed wireless ECG, EMG and EEG devices that can be connected to Android phones to enable reliable long-term ambulatory monitoring of various health parameters. Portable devices for glucose measurement are also available with 42 different models only in UK[28] and sampling through Android phone has been made available[29]. All these systems are nowadays a reality for **many elder people, who are given the capability to monitor their own health, taking at-home the physiological samples required.** More recently **devices targeted to fitness and wellbeing are being developed**: Samsung and Apple have integrated in their smart phone on sale later this year, apps for monitoring a comprehensive array of vital signs: heart-rate, blood pressure, temperature and lung function. Although no approval as medical devices has been announced yet, they do provide an interesting consumer alternative. In Robohome2.0, the most convenient sensor/system to measure a specific required physiological parameter is identified in Task 2.1 and interconnected in Task 5.6. Data will be provided to the Virtual Caregiver, that is able to **guide and advice the elder through video and voice feed-back,** while taking samples. Sometimes, it is still difficult to understand the reliability of the final measure, without remote or direct assistance of caregivers. Thus, we take advantage of Giraff's capabilities to provide direct video-connection to the GP or remote caregivers when physiological samples have to be taken. **Therapy compliance** is facilitated by a **cooperative smart drug dispenser**. Several solutions have been proposed for hospital use[30, 31], through a centralized control integrated inside the hospital ICT. We develop inside

[24] http://www.signomotus.it/h_cad_site/h_cad_accessible/system_description.htm
[25] http://www.backhome-fp7.eu/content/project
[26] M. Pirovano, R. Mainetti, G. Baud-Bovy, P.L. Lanzi, N.A. Borghese, IGER – Intelligent Game Engine for Rehabilitation, IEEE Trans. CIAIG, submitted. Short version in Proc. CIG 2012.
[27] N.A. Borghese, P.L. Lanzi, R. Mainetti, M. Pirovano, Apparatus and method for rehabilitation employing a game engine, US Application 13/911577, 2013
[28] http://www.diabetes.co.uk/diabetes_care/blood_glucose_monitor_guide.html
[29] https://www.glooko.com/android
[30] Laurie K. Garda, Wendy Armstrong, Amy Blew, Jyotsna Rao ,US Patent US20120253509, 2013.
[31] Steven N. W. Hunter, David M. Browning, Dennis J. Fuhrman, William C. Park, IV. Automatic apparatus for storing and dispensing packaged medication and other small elements, US7100792 B2, 2006.

Robohome2.0 **a novel, low-cost, simplified solution dedicated to one person (Task 3.7).** This is constituted of a set of drawers, each with a **remotely-controlled electromechanical lock** managed by the Virtual Caregiver. Only the right drawer is open when needed. This approach still requires that the real caregiver or the elder fill the drawers at the beginning of a week, but it then **guarantees that the right pills are taken at the right time.** *The clinical monitoring activities will be mainly technological and they requires clinical validation. Nevertheless an important piece of research is required to find the best solution in terms of usability and motivation.*

***Physical monitoring*** is performed with three main modalities. In the **first modality**, identified common assessment tests, **are carried out at-home under remote supervision** of the caregiver through audio-video communication (tele-operated monitoring). Smart Giraff navigation system allows to carry out the tests **in the most comfortable situation and location for the elder**. In a **second modality**, **we substitute the clinician with the Virtual Caregiver.** This reminds to the user not only when he/she has to perform a test but it also guides him/her step by step during test execution through explicative audio-video animations, providing also the ICT support to complete them. In this second modality, the elder moves in front of Giraff that picks up the elder movement through its 3D camera. From motion data, a score is automatically computed by the Virtual Caregiver. Most suitable tests aimed to balance and they can be Berg-balance[32], TUG[33] or Morse Fall Scale to prevent falls[34]. These tests have been clinically validated and can be used to obtain an objective picture of the elder status. Validation of the tests administered in this autonomous modality are integral part of the proposed project (Task 3.6). In the **third modality**, **monitoring is carried out while observing motion associated to everyday activities**. The progress in micro and nanotechnology and the availability of miniaturized sensors, has made available a huge range of small wearable devices, from simple pedometers to computerized trainers that allow measuring heart rate, calories consumption, local speed and additional parameters of physical exercises (e.g. www.polar.com/us-en/products). Fitness is still the leading application for this (e.g. sites.garmin.com/edge/). Similar principles have been applied to develop products aimed at tracking and profiling human motion. For instance Xsens was the first to develop a motion capture system based on the integration of accelerometers, gyroscopes and magnetometers (www.xsens.com /); Gait-up has developed sensors aimed at profiling the user with accurate evaluation of the activities through worn sensors (www.gaitup.com/). Miniaturization of sensors and integration inside clothes has been also pursued in the **Interaction** EU project through smart textile[35]. **Such sensors communicate with a Smart phone** that will act as a Hub and integrates all the data into lifestyle evaluation provided by apps like Digifit[36] or Zausan[37] apps. **However, the above mentioned sensors allow collecting limited amount of information and they require that the user wears them** that makes their compliance limited for long time use. A different approach has been proposed in very recent EU projects. **Caretoy** (www.caretoy.eu/) proposes wireless sensorized toys mainly composed of two soft air-filled chambers connected to a pressure sensor made of elastomers with a cylindric shape. A rigid case inside the toy contains the control unit. The system provides a gross discrimination of actions on the object[38]. **CogWatch** (www.cogwatch.eu/) introduces a device that contains a 3-axis accelerometer and 3 axes force sensitive resistor in a small package that fits to the base of objects such as mugs, jugs and kettles[39]. We further develop these approaches by **combining motion acquisition through Giraff with sensorized everyday objects to provide combined s motion and pressure data.** These, combined with synchronous motion data acquired from Giraff's camera, allow to derive a detailed characterization of movement profile as reported in Section 1.4.1. This would allow an **automatic continuous transparent monitoring of the elder** with daily assessment that allows an early detection of deterioration in the motor performance (Task 5.1 and 5.2). *This activity has a large research and development component in the transparent monitoring.*

***Cognitive monitoring*** is based at evaluating the basic cognitive function: memory, reasoning, orientation, and at detecting cognitive deterioration associated to onset of degenerative diseases like Parkinson, Alzheimer or Fronto-Temporal Dementia. As for physical monitoring, assessment is carried out through validated tests that have typically the form of questionnairs and that may be tele-operated. We explore the possibility to operate these tests

[32] 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.

[33] Podsiadlo, D; Richardson, S (1991). "The timed 'Up & Go': A test of basic functional mobility for frail elderly persons". Journal of the American Geriatrics Society 39 (2): 142–8. PMID 1991946.

[34] Morse JM, Morse RM, Tylko SJ. Development of a scale to identify the fall-prone patient. *Can J Aging* 1989;8;366-9.

[35] http://cms.interaction4stroke.eu/drupal

[36] http://www.digifit.com/shop/health.asp.

[37] http://z-devicetest.zausan.com/index.php?lang=en

[38] Serio SM, Assaf T, Cecchi F, Laschi C, Dario P. A novel Wireless Toy for Measuring Infants' Bimanual Actions. The Fourth IEEE RAS/EMBS Int. Conference on Biomedical Robotics and Biomechatronics Roma, Italy. June 24-27, 2012

[39] J Hermsdörfer J, Bienkiewicz M, Cogollor JM, Russel M, Jean-Baptiste E, Parekh M, Wing AM, Ferre M, Hughes C. CogWatch Automated Assistance and Rehabilitation of Stroke-Induced Action Disorders in the Home Environment. D. Harris (Ed.): EPCE/HCII 2013, Part II, LNAI 8020, 343–350, Springer 2013,

also by means of the Virtual Caregiver. QMCI[40] or mini-mental test[41] seem particularly suitable to be transposed into a computerized form. The best graphical form for the questionnaires is identified. We show the questionnaires to the elder on Giraff's display accompanied with Virtual Caregiver instructions, collecting the answers through the touch screen display or through gesture recognition developed in Task 4.1. The avatar will provide **voice feed-back, adequate to the actual performance**, to encourage the elder and increase effectiveness of the administration. Alternatively, smart phone based apps are considered like Doctot[42]. We explore the **use of TV to administer these tests,** in which case a TV remote controller is used to select the answer. We provide a **transparent assessment** also for cognitive decline. In this case, data are gathered through specific spot questions proposed for instance at the beginning or at the end of any activity.

**Scenario:** Ann is on her sofa and switches the TV on. Robohome2.0 has pending questions to complete cognitive evaluation. It realizes that the TV has been switched on, and sends to the TV the Virtual Caregiver avatar to welcome Ann and ask her politely the "daily question": "which day is today?". Ann answers correctly, the avatar smiles and says bye to her. The TV program of the last channel selected appears to the screen.

**Both teleoperated and transparent monitoring will be analyzed and validated by clinicians** in Tasks 3.6 and 5.2; suitable scales will be defined. Additional information provided by the results of **cognitive activities, like puzzles, riddles, or other memory games** made available by the activity center is also considered (Task 4.3). *This activity has a large research and development component in the development of transparent monitoring.*

**We will also develop a second form of cognitive transparent monitoring.** Degenerative diseases in their early stages are often associated with anxiety and mood disturbances, psychosis, and compulsions[43]. We aim to early detect these symptoms through **analysis and profiling of phone conversations** as described in Section 1.4.1. We combine this information with the analysis of lifestyle data and in particular with **time of day and frequency of the calls** as some people with dementia phone their loved ones over and over again. The person with dementia may forget that they have already called, or may be insecure or anxious, therefore changing the voice spectrum of the conversation. (Task 5.4, Task 6.6). *This activity is mainly research in the development and experimentation of transparent monitoring of degenerative diseases through profiling phone conversations.*

***Social monitoring.*** This is a new aspect that is becoming very important in a society in which the familiar bonds are less tight than in the past. One of the main risks for elders is exclusion and isolation that can easily lead to depression and poor quality of life. Although an automatic identification of all the possible activities is beyond reach, we identify some representative activities. The duration and frequency with whom the elder exercise in group, provided by the activity center (Task 4.8), the logbook of activities (e.g. teaching at third age University, going to theatre), the degree of interaction with the community (Task 6.3) can all provide an estimate of the elder **social behaviour**. *This activity will be mainly technological, based on SW development.*

***Environmental monitoring.*** The possibility to supervise the house and control the appliances has long been recognized as an interesting business opportunity in the domotic field: gas and light alarms have been developed as standalone (e.g. www.beghelli.it/), or as devices that can be also integrated in a house control panel (allarmiwireless.net/shop/). The latter approach is particular suitable to add new devices at need. More recently this approach has been extended to assisted living environment (e.g. www.tunstall.co.uk/) in which some of the sensors contribute to determine the elder habits, like pressure sensors under the sofa or bed, presence sensors or TV monitoring. BDIGITAL has already realized a prototype that integrates sensor of temperature, humidity, luminosity, presence and gas alert into a **low-cost micro-architecture able to transmit the data remotely through wireless connection**[44] Such architecture based on a Raspberry low-cost micro-controller will be fully exploited in Robohome2.0: most promising off-the-shelf sensors that fulfill specifications set in WP1 and WP2 are integrated into a modular network that uses the recent novel standards, like **low-power Bluetooth** for minimal intervention and longest battery duration. **Protocols widely diffused in the domotics field**, are adopted to maximize system extensibility. Such network feeds the data to the ontology defined in Task 3.4 and used to refine the suggestions to the elder (Task 3.5). *This activity will the result mainly in a technological effort (Task 5.3).*

[40] O'Caoimh R, Gao Y, McGlade C et al. Comparison of the Quick Mild Cognitive Impairment (Qmci) screen and the SMMSE in Screening for mild cognitive impairment. Age Ageing 2012; 41(5): 624–9.
[41] Folstein MF, Folstein SE, McHugh PR. Journal of Psuchiatric Research 1975;12:189. Molloy DW, Standish TIM. A guide to the Standardized Mini-Mental State Examination. Int Psychogeriatrics 1997;9: 87–94.
[42] http://www.doctot.com/doctot-apps/dementia-app/.
[43] Grossman M. Fronto temporal dementia: a review. J Int Neuropsychol Soc. 2002;8:566–583
[44] E. Vargiu, L. Ceccaroni, L. Subirats, S. Martin, and F. Miralles. User Profiling of People with Disabilities - A Proposal to Pervasively Assess Quality of Life. In ICAART 2013 - Proc 5th Int Conf Agents Artif Intell, Volume 2, J. Filipe, A. L. N. Fred (Eds.) Barcelona, Spain, 15-18 February, 2013. SciTePress 2013.

## Assistance

Assistance **supports the elder during daily life** and provides recommendations. Assistance in everyday life is a growing market, mainly developed as Apps for smart phones (e.g. www.hexstudio.com/, www.easilydo.com/). It builds mainly on two concepts: improving the functionalities of a **digital agenda** and **linking the data coming from the connected devices**. We aim here to complement these with a specific function (Task 3.8) that implements a **locating service** that search for objects that are typically lost by the elder: reading glasses, phone and keys. New solutions are emerging for tagging objects, based on sticks or key rings used with specific Apps[45], but elderly people would have still to find the objects by themselves and, moreover, the mobile phone has not to be lost! The phone could be located through GPS signal, but usually GPS signal cannot be received at home. Also RFID technologies is being explored for tagging objects, but is not suitable for our case as RFID tags require a reader to be placed inside all the rooms. We explore in Robohome2.0 an alternative based on **miniaturized active tags** described in Section 1.4.1. We envisage the elder **asking Giraff to go and search for the lost object** through a **distributed voice command system** (Task 5.5). The same location service is also made available through a phone App (Task 6.6) or through Giraff itself by means of voice or gesture control, or through the home TV, exploiting device equivalence. *Research and development applies to the location of everyday objects*.

**Scenario.** Mary is at Elif's home when she realized that she has not her keys with her. She is upset as she thinks that she has lost her keys. She call Giraff with her app and asks it to find if the keys are in the house. After a while Giraff's replies sending to Mary's mobile phone a picture taken with its 3D camera in which the keys are shown over the Kitchen table. Mary is relieved, she calls her daughter who has a copy of the keys, to get into her house.

**Diet** is an important aspect of a good lifestyle. Recommendations on diet will be gathered through the community and the caregivers and proposed as recommendations by the Virtual Caregiver (Task 6.6). *This activity will the result mainly in a technological effort with leading technology*.

**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 recipes, compatible with her diet regimen, are displayed, organized along a few dimensions like time of cooking. She chooses a "Carbonara pasta" 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 recipes order, ranking higher the successful recipe.

## Training

The Activity Center supports social activities and guides the elder through tailored physical/cognitive **exer-games**. The activities and their goals will be **planned and negotiated between the elder and his/her caregivers**. Exer-gaming has received a strong push in the last years by novel tracking devices, like Nintendo Wiimote Controller and Balance Board, Sony Move, the Microsoft Kinect, that have revolutionized the way people play video games, making interaction much more intuitive. It was soon recognized[46] that **these devices allow the acquisition of motion and interaction data of good quality that are useful in many domains**. Alongside, powerful games engines have been made available under open source license, or with limited costs (Unity3D or Panda3D). This widely opened the game field. 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.** This has allowed UMIL developing the IGER game engine that serves as nucleus of the Robohome2.0 game center. IGER integrates **methods of computational intelligence** for **users' monitoring** and **adaptation**, IGER games are fully configurable so that they can be **tailored by the clinicians to the user 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**

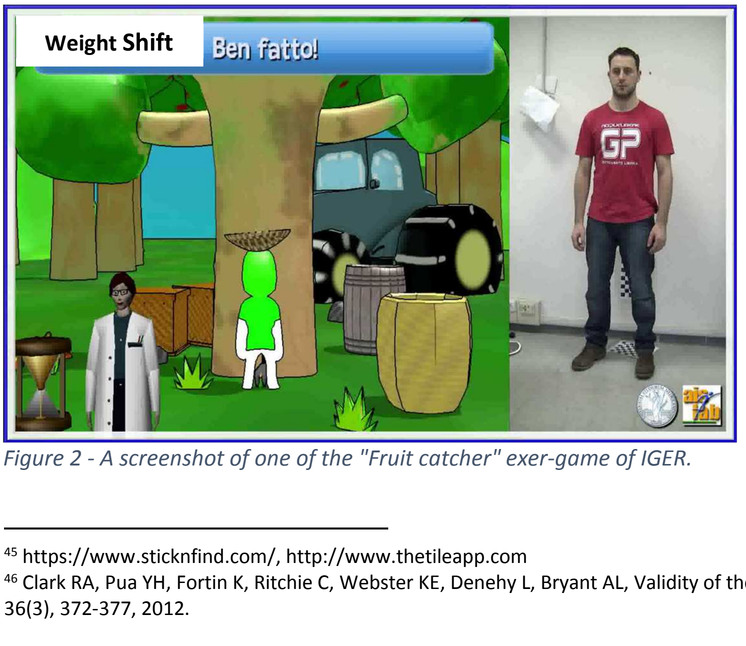

*Figure 2 - A screenshot of one of the "Fruit catcher" exer-game of IGER.*

[45] https://www.sticknfind.com/, http://www.thetileapp.com

[46] Clark RA, Pua YH, Fortin K, Ritchie C, Webster KE, Denehy L, Bryant AL, Validity of the Microsoft Kinect for assessment of postural control, Gait & Posture, 36(3), 372-377, 2012.

**gameplay is continuously monitored using a fuzzy system,** to avoid wrong postures or wrong movements. 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 guides the user 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[47,48]. Finally, **several input devices can be interfaced to IGER thanks to its specific input abstraction middleware**. The cognitive and physical exercises defined by the virtual caregivers in Task 1.2 is analyzed **and transformed into mini-games** (Task 4.3)**,** in which the **desired trained movement or function has to be used to achieve the game goal**. For instance a balance exercise can be guided by an exer-game requiring the user to catch with a basket on the head fruits falling from a tree (Figure 2). A meaningful gameplay is developed in which **clear interaction and feed-back with reasonable lasting effects, enjoyable environment, music, sound, rich graphics** are adopted according to the rules of good game design[49]. Moreover, the gameplay is designed to be fully configured to the elder ability and idiosyncrasis so that it can be adapted by the Virtual Caregiver to the actual state of the elder. *This activity will the result mainly in a technological effort with leading technology.*

**Scenario.** Giraff approaches Mary and asks her if she is ready for her daily exercising session. The Virtual Caregiver shows her the daily program and at the same time it analyzes the environment data downloaded from the environmental sensor network. The Virtual Caregiver analyzes the data and realizes that it is too hot and humid today to maintain the same level of exercising as the days before and downgrades the games difficulty. It sends a message to both the elder and the caregivers and allows Mary to start her daily exercise**.**

**Motivation** is indeed at the heart of keeping exercising. However, exer-games alone are not sufficient to maximize elders motivation. Thus, in Robohome2.0 we fully explore **Gamification**[50]**.** This involves the use of game design and game mechanics for a purpose other than entertainment. Gamification techniques leverage people's natural desire for competition, achievements, status, self-expression and closure[51]. In single-player settings, gamification concerns **designing gameplay such that the user feels rewarded when accomplishing a task.** One mean is adding a game on top of the exercise, providing a goal and meaningful gameplay, as well as feedback. In addition, a **various and targeted reward systems can be devised**. This can provide: points or virtual coins gained, achievements and levels reached. Such rewards can be shown for instance by a progress bar or spent inside a **community of players**, showing relative achievements through ranking or leader boards[52]. In multi-player settings, gamification can be implemented through direct or indirect competition, or through collaboration. Indirect competition follows the use of scores **integrated into a social engine**. Direct competition can be implemented by providing multi-player play, so that two people can directly compete. This is already available in many online games, especially sports and shooter games (wiisports.nintendo.com/). At last, collaborative games can be played by several people, all pursuing the same goal. Collaboration 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. If too challenging player would give up soon, while if the task is too easy the game becomes boring and uninteresting soon. **A good game design, nice graphics, effective gameplay, clear feed-back and proper challenge level[53] all contribute to enter the player in a state of flow**[54]. Flow theory is widely accepted as guiding principle by the game design community: 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. 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[55]. In the latest years, **gamification has been gaining a lot of interest in very diverse fields** and it can be found everywhere[56]: 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[57]. **In Robohome2.0 we will design a layered gamification approach that addresses: a) game design, b) game play, and c) supports automatic narration.**

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[56] "Meaningful play - getting gamification right", Sebastian Deterding, Google Tech Talk 2011
[57] "Design outside the Box", Jesse Schell, DICE Summit 2010

a) We will explore **personalization of game design**. A parametric game design is adopted, in which some game assets and scenes can be uploaded either through randomized control[58], or according to the preferences captured by the elder profile (Task 3.4). Personalization is traditionally a key factor to increase intrinsic motivation[59], [60]. Elders cognitive capability decreases with aging. Thus, the game design should have an **adequate cognitive load** and an appropriate **level of details** (LOD) of the scenes (Section 1.4.1).

b) The game play takes full advantage of IGER functionalities to tune the game difficulty to the elder state, to provide meaningful feed-back and to monitor correctness of movements.

c) Single exer-games have limited motivation capabilities. A stronger motivation can be obtained when **exer-games are embedded inside a narration in which each single episode introduces the next one**. **Automatic narration** is a research topic of great interest for artificial intelligence scholars[61]. A whole research field has been recently born from this interest, **Computational Narratology**, that aims at interpreting, generating and analyzing narrative using information processing techniques. Achieving automated storytelling can be beneficial for different purposes: producing novel and interesting stories to be consumed without the need of an author, tutoring students of narrative by analyzing and providing story corrections, or providing interactive and **dynamically created stories for video games**[62]. Various methods for the automated generation of stories have been proposed in the literature: (i) problem solving, (ii) data-mining methods and (iii) knowledge-based. Problem solving methods define a set of agents, actions and goals, then reason in order to drive the story to a conclusion by letting each agent pursue its goal. Well-known examples are the Talespin system[63], Author[64], Universe[65], Ministrel[66], Mexica[67]. Similar effects are achieved using systems based on autonomous agents, such as the Virtual Storyteller project[68]. The use of autonomous agents is also useful for interactive purposes, allowing users to interact with the storytelling process[69]. Some systems have also been paired with a virtual presentation layer, as with Fabulist[70]. Data-mining methods do not use any underlying structure and can thus work with diverse story types. These methods are still novel, with the first notable example coming from[71]. Knowledge-based methods work on a database of rules, actions and relationships and try to create a story that is coherent and interesting. The created story thus depends on the chosen knowledge base. The first recorded system that implements this method is the Novel Writer system, developed by Sheldon Klein[72]. Other known systems are Brutus[73], Gester[74]. Some systems use common sense knowledge bases[75], while others use story schemas[76]. Some approaches, pioneered by Peinado et al.[77] are based on the ontological definition of the story context, actors and possible actions. Although automatic narration can be developed, the control over the gameplay is still stereo-typed, with limited variability in the sequence of episodes. We will explore in Robohome2.0 the combination of **knowledge-based methods for automatic narration** with **stochastic control** to introduce a controlled variability in the evolution of the narration. We go also one step further creating a **flexible narration engine that can produce a narration from different themes, chosen according to elders idiosyncrasies and preferences,** and that guarantees that the narration will guide the elder through the mix of activities prescribed, thus **taking into account the constraints posed by the cognitive and physical**. *This activity combines technological development (multi-player support) with research intensive tasks: LOD in level generation (Task 4.6 and Task 6.1) and automatic narration (Task 4.4).*

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**Serious games** have been introduced not only to guide physical or cognitive activities but **also for education.** This is the role of serious games implemented in vocational training, of which one of the most popular is Flight Simulator. They have been applied also to other fields like business, construction, mining, sports, and so forth. The benefits of serious games have been acknowledged by medical community, in which comprehensive reviews have found that the effects of such games are generally positive[78,79]. Many examples of serious games specifically created to teach very diverse medical notions, such as epidemiology[80], anatomy[81], the respiratory and circulatory system[82] can be found. A first attempt to teach about therapy is badblood (www.badbloodgame.net/), which is aimed generally to educate healthy people on the most dangerous illnesses. We will explore here the use of serious games, not only to guide the elders into activities, but also **to educate them on their diseases, therapy and lifestyle and motivate them**. This is part of an **empowerment strategy**[83], in which the elder and his/her caregivers collaborate in setting adequate clinical goals and lifestyle. However, such serious games have limited content and are not suitable for prolonged use. Thus, we use the same approach adopted for automatic narration (Task 4.5). *<u>This activity is mainly technological development on the technology developed inside Robohome2.0 in Task 4.4.</u>*

The sense of immersion inside a game does also contribute to flow. We are aiming to further increase this by exploring to use the elder silhouette instead of the avatar of Figure 2, as explored in Duckneglect[84] in which the user sees himself mirrored on the display (Figure 3). However, a clean **silhouette is obtained from 2D cameras only with controlled background**, that is beyond reach inside a house. Kinect has raised the expectation of a robust foreground segregation, but this was not the case as neither Kinect SDK1.8 nor the new Kinect2.0 produces a clean silhouette (Fig. 3, right). A few attempts to improve background subtraction, based on spatial and temporal smoothing turned out to be not completely satisfactory[85]. Recently a parametric approach based on level sets, combined RGB and range images for foreground segregation of objects of predefined classes was proposed[86]. Such method has shown to be effective only for simple objects like shoes. Moreover, it is not compatible with real-time (a delay of 70ms is introduced on high end computers) not compatible with autonomous robots computing capabilities. We develop here a method on silhouette extraction, described in Section 1.4.1, that **refines the segmentation produced by the Kinect depth map through information from the RGB image**. *<u>This is mainly a research activity (Task 4.2).</u>*

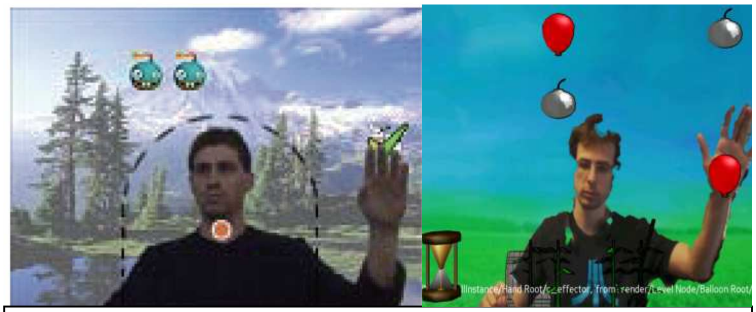

*Figure 3 - Silhouette integrated inside a Virtual Environment in Duckneglet (left). Silhouette extraction through Kinect SDK1.8 (right).*

## Service Robot and Virtual Caregiver

Services in Robohome2.0 are provided by Giraff robot (www.giraff.org/). This is a robotic base that carries a touch screen monitor, speakers and a high-resolution camera with selectable zoom capabilities. The screen is a pan-tilt unit which enables a greater and controllable field of view, while its height over the base is adjustable to create an eye-level view with the elderly. The base hosts a Windows 7 embedded OS (Intel Core i7, 4GB RAM, powerful enough to run a game engine) that: a) controls the motors and can propel the robot in any direction, b) runs a videoconferencing application, c) receives the input from the touch screen and displays the output. Giraff supports WiFi communication through 802.11x protocols and USB2. It comes with two main software applications. The first is *Pilot* that allows users/visitors to access and control Giraff over Internet connection. The second application is *Sentry*, an administration software that manages Giraff and Pilot visitors, and allows administrators to configure Giraffs, alarms and communications options. These applications will be integrated in Robohome2.0. There are no other commercial mobile telepresence solutions like Giraff in Europe today, and none specifically focused to homecare anywhere in the world. There are five commercial products similar in concept to Giraff but focused on other applications. **Anybots – QB** is a finished product in the market but not suitable for home care service at this

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time for various reasons including price (~13000€ plus additional support costs), stability (it uses dynamic balancing technology for movement similar to the Segway) and a very small display size. The company is committed to its current product direction and gives no indication of serious interest in homecare. **VGo Communications – VGo** is perhaps the product with the most "finished look" but also not suitable for home care service for various reasons including also a very small display size. Its main emphasis is on enterprise communications, but VGo does describe several use cases around patient monitoring and remote hospital and home visits. VGo's short height (1.2 meters) make it an attractive avatar for small children. **In Touch Health – RP-7i and RP-VITA** The RP-7 series is the oldest mobile telepresence product in the marketplace with a strong focus on clinical health care. It is used in clinical settings to allow specialists to conduct a virtual patient visit from a remote location. It has advanced features including autonomous navigation and obstacle avoidance, a second display for data and integration of biometric devices. However, its price point is well in excess of 100 000 €, far beyond what is feasible for home care. InTouch has also partnered with iRobot to create the RP-VITA, a lower-cost version of the RP-7i, and is based on a subscription model (monthly service fee). However, at 3 600 €/month the economic model is still based upon leveraging very high-cost resources (specialists) and is far beyond what can be justified for home care. **Suitable Technologies – Beam** Suitable Technologies is a spinoff of Willow Garage and produces the Beam. Beam is perhaps most like Giraff in design philosophy because it is near-human height, uses a large display to present a near-life size portrait of the visitor, has HD video quality with zoom and high-quality audio. Based on technology developed at the highly-regarded organization Willow Garage, Beam is a well-designed product but has a high price point (more than 14 000 € plus a monthly service fee) and still lacking some essential features needed for home care. For example, it weighs nearly 50 kg so is difficult to transport, and cannot traverse even small door thresholds. It also has a sophisticated local interface to the device itself, well beyond the UI capabilities of most elderly who are receiving home services. **Double Robotics – Double** is essentially a "kit" consisting of a motor-powered frame and an iPad docking port (the user supplies their own iPad) with basic application software to drive the device. The price point is attractive at 1 800 € but it has none of the features required for home care and has no specific market focus, but rather is a truly generic platform. For example, Double uses the iPad for its audio and video, designed for someone sitting directly in front of the device as opposed to the wide, high-quality field of view required in a home care application. It has limited call management features (compared to the Giraff *Sentry* system) and no ability to make social gestures such as nodding, or turning. Additionally, none of these products provide a **general development platform such as Giraff for third-party application development, plug-ins and direct camera and motor control**. For all these reasons Giraff appears the best option for Robome2.0.

Giraff is further extended in Robohome2.0 with **autonomous navigation** (Task 3.7) and with **a more natural interfacing with the elder** (Task 8.1). A 3D camera, possibly a Microsoft Kinect, is added. This acquires a 2D RGB image and a depth map (range image) from which a single colored 2.5D image is obtained. From the range images, a 3D map of the house is built, for instance using the recently developed APIs based on **Kinect fusion**[87, 88] and used as basis for navigation. This is based on reactive planning. Two are the major challenges: to manoeuvre in tight spaces, without being trapped in local minima, and to deal with 3D-shaped objects. It is important to notice that, for the Giraff robot, the common assumption of worst-case, constant shape along its height is quite unreal, and prevents finding possible free space to traverse. We work towards a navigation solution that accounts for these features by extending to 3D the previous work of the UMA group on 2D reactive navigator[89], which models the robot shape as a polygon and embeds its kinematic constraints into different motion models through the so-called Parameter-Space Transformations. We will explore here **how to introduce additional proxemic constraints to path planning.** For instance, the elder may not like that Giraff approach him frontally, or to stand too close. **Navigation will be triggered in several ways**: by the elder asking Giraff to look for an object, by the elder or a caregiver asking Giraff to go in a room to take a picture, or by the Virtual Caregiver asking Giraff to do some monitoring.

From the architectural point of view (Task 3.1) we define a **middleware that provides a common interface to all components:** the monitoring systems, the input from the community, the services provided for assistance and the data required and provided by the activity center. This same middleware allows interfacing the robot sensors and actuators, providing a unifying view of the system. **Guidelines are provided by the ongoing universAAL project**[90] aimed at providing a separation between the services provided and their implementation. Such middleware will allow all components to write and read relevant data in a consistent and simple way, guaranteeing at the same time maximum standardization and scalability. **Dedicated high throughput channels are reserved to**

[87] http://research.microsoft.com/en-us/projects/surfacerecon/
[88] http://msdn.microsoft.com/en-us/library/dn188670.aspx
[89] .L. Blanco, J. Gonzalez-Jimenez, J.A. Fernandez-Madrigal, "Optimal Filtering for Non-Parametric Observation Models: Applications to Localization and SLAM", The International Journal of Robotics Research (IJRR), vol. 29, no. 14, 2010.
[90] http://www.universaal.org/index.php/en/

**graphics, video-communication and 3D camera**. To adequately storage the data, heterogeneous and arriving at different frequencies, new generation no-SQL data bases like Voldemort, MongoDB, Cassandra, Neo4j, are explored and compared with the traditional SQL ones. *Some activity is mainly technological (Task 4.1); navigation will be improved through research (Task 3.7).*

A **Virtual Caregiver** is embodied inside Giraff. This has access to all the data from monitoring systems, the information inserted through the community from his caregivers and the data provided by the activity center. To manage this rich information semantic models (ontology) are used in Task 3.4[91]. These will contain high level concepts that relate to the elder, various health conditions, the types of activities that they can perform, and also the high level concepts related to the information provided by the sensors. These semantic models are used to formulate rules leading to concrete recommendations that the system will make. Recommendations may involve calls to specific routines taken by Giraff, or recommendations of activities. **It is the starting point to promote a full collaboration between the service provider, the community of users (GP, relatives, social services) and the elder.** A reasoning layer is designed according to the functionalities defined in WP1, to provide the optimal mix of activities, to tune their level of difficulty to elder status and to add a flexibility in the design of the rules. This is achieved in Task 3.5 along the guidelines already explored by ORU[92]. **Such layer will evolve dynamically, according to the feed-back provided by the users through Robohome2.0.** This same layer provides the activation of the Virtual Caregiver Avatar to promote a meaningful interaction, as investigated in Task 8.1. The Virtual Caregiver guides also the elder through cognitive and physical clinical tests in cooperation with the activity center (Task 3.6). It alsos **transmit to specific members of the community the psycho-physical evaluation emerging from these tests as well as from the transparent tests** (Task 3.5).. *Research in this activity is mainly related to an efficient management of the huge amount of heterogeneous data to provide information that can be used in real-time.*

**Scenario:** Robohome2.0 realizes that Jane has provided the wrong answer to the question "which month of the year is today?" in the last times. The virtual caregiver increases the weight of the cognitive exercises proposing more riddles and puzzles during the day. It also warns Jane's GP and relatives, who push Jane to play more cards with her friends. After a while Jane did not answer wrong any more to Giraff spot questions.

### Human Robot Interfacing

A large effort will be spent to design a robot that develops a **meaningful relationship with the elder**. Humans use a wide range of paralinguistic cues to signal intention. Eye gaze, preparatory gestures, body language, and so forth are used to signal intentions, actions and goals. Robots that operate in public settings (e.g. nursing homes) can be safer and more effective if they were designed with similarly human-readable behaviours[93]. Unfortunately, care robots are severely limited in this respect. Their appearance does not evoke anthropomorphisation and their behaviour is not conductive for human-robot interaction. A remarkable exception is represented by Giraff robot that has been developed explicitly to maximize compliance with the elder[94]. To develop a meaningful relationship with the elder, an important aspect of the Robohome2.0 is studying how **Giraff interaction can be tailored** so naive users can use behavioral cues and voice explanation 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**. This will be fully investigated in designing the feedback provided the Virtual Caregiver in Task 8.1 that will leverage of Description Language (DL) developed in Task 3.2.

Another key feature for effective HRI is **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[95]. 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[96].** 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. This will be indeed the **modality that will be adopted** in Robohome2.0: interaction will be mediated by the Virtual Caregiver avatar through realistic animation and speech (Task 8.1). Similarly, the **most natural interfacing with Giraff will be**

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[91] MU Ahmed, A Loutfi, Physical Activity Identification using Supervised Machine Learning and based on Pulse Rate, Int Journal of Advanced Computer Sciences and Applications 4 (7), 2013.

[92] M Alirezaie, A Loutfi, Ontology alignment for classification of low level sensor data. Knowledge Eng. Ontology Dev KEOD Best Student Paper Award, 2012.

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[96] Li S, Wrede B Why and how to model multi-modal interaction for a mobile robot companion In: AAAI Technical Report SS-07-04: Interaction Challenges for Intelligent Assistants. Stanford: AAAI Press: 71–79 2007.

**used: gestures** (detected through Kinect, Task 3.3) or voice will be used to guide the interaction with the elder when they are both in the same room and will be fully used by the game center for interfacing[97]. When the elder is in a different room a distributed **voice commands** (Task 5.3) will be used.

**Scenario:** Mike has just received his new Giraff robot. He switched it on and the Virtual Caregiver waves him with a: "Hello Mike, my name is Giraff. I will stay with you as long as you like. I come from hot Savana, but I will be pleased to leave in your comfortable apartment". After a few days Giraff approaches him slowly and his Virtual Caregiver appears on the screen to say: "Hey Mike, why don't you give a call to Matteo, your nephew? It is his birthday". Mike adores having someone that does not pretend and takes care of him.

To provide a unified view of Robohome2.0, an effort to **unify the structure of the different GUIs** is carried out, identifying the most adequate basic modules. Moreover, the best appearance will be tailored to the current output device chosen: TV screen, touch screen or smart phone can all be used. *Some activity is mainly technological and carried out in (Tasks 3.2 and 8.1). Effort for maximized HRI effectiveness is research based (Task 8.1). We will explore in innovative distributed voice command system in Task 5.3*

## Community of users

The Robohome2.0 project aims to bring together all the major players through a unique community. Robohome2.0 is formed by three types of user groups: **Formal caregivers** – such as the clinical staff; **Informal caregivers** – such as families and carers of old people; **Elderly**– such as not only elders having a Giraff at home, but also other elders who subscribe to Robohome2.0 community. The community has different purposes for each type of user. Clinicians are able to access, in particular, to the time series of physiological measurements and assessment scales, while caregivers to lifestyle. The bi-directional audio-video channel provided by Giraff's *Pilot* software will be fully exploited to supervise the elder when taking physiological samples, to assist when doing assessment tests at home or just to discuss any particular issue. The most important user is the elder, for whom the community is intended as a tool of **motivation, adherence and cognitive and social stimulation**. The community provides 1) **Social support** in order to put the elder in contact with relatives and friends, to avoid isolation, to allow social activities like multiplayer gaming, to increase the opportunities of a reciprocal monitoring; to provide services; to allow the elder to be informed of personalized social and cultural initiatives that he/she can still attend and enjoy; to allow the elder to be informed of environmental information such as weather, news, etc.; to obtain information about diet. 2) **Healthcare support** 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. 3) **Data storage,** to memorize the historical data from the monitoring system and from the activity center. The same database architecture used inside Giraff will be adopted. The socio-sanitary interventions are mediated, at first, by the remote video communication capability of Giraff that will put in contact the elder with the person he/she needs. Interventions can be required by caregivers, by the elder themselves or by the Robohome2.0 intelligence that monitors elder activities and continually communicates with the formal and informal caregivers. **According to preset priorities, different types of alerts will trigger a different pathway.** The sanitary interventions eventually delivered can include telepresence visits, home visits, and direct calls to emergency services.

The success of virtual communities is due to a great diversity of factors. For instance, as studied by Leimeister et al.[98], 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. **Social networks** may play an important role in enforcing the relationship between elders and between an elder and his/her caregivers. Some remarkable examples have been studied, like SparkPeople (www.sparkpeople.com), which is a community of people wanting to lose weight, DLife (www.dlife.com) targeted to diabetes patients, stupidcancer.com which is a community of people aged below 40 with cancer. **BDIGITAL has already been explored the use of virtual community to educate and motivate patients in several research projects**. Inside 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. That social community provides also further useful features such as forum, news. **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. Community can constitute also a powerful drive for lifestyle adherence and exercising**: gamification will fully exploited in WP4 and the community will host motivational mechanisms based on reputation like leader boards[99]

[97] 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.

[98] 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.

[99] http://www.leaderboarded.com/home/

(Task 6.5). Thematic discussions and groups will allow to improve the collective knowledge on diseases, therapies and lifestyle that can also contribute to increase motivation. *Some activity is mainly technological and carried out in (Tasks 6.1-6.4), support to gamification will be carried out in correlation with Task 4.4 and 4.5 and self-organization of the community will be object of research in Task 6.5.*

### Deployment modalities

There is a progression in frailty: from robust to pre-frail to frail and **we are aiming preferentially to pre-frail elders**, 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 symptoms of cognitive degeneration, due to Alzheimer or dementia or other neurodegenerative diseases as well as evolutional depression. Cognitive behavioural therapy, cognitive stimulation and psycho-education delivered are effective in reducing symptoms of depression. Such interventions can be delivered also remotely[100]. 2) Elders who have developed stability problems and need assistance to move. 3) Elders who need to control a specific disease over time[101]. PCL, SAS and KOMMUN have a very large basis of elders to which to propose Robohome2.0, with PCL alone seeing more than 1,000 new elder outpatients/year (age > 75 years) and 2644 in follow-up (2011).

**SCENARIO:** After a stroke Mike developed a mild hemiparesis affecting particularly the leg. He needs rehabilitation to recover stability and strength, but he lives alone, far from any rehabilitation center. Thus, he is thinking to go into a Nursing Home. His geriatrist prospects him the possibility of having at home Giraff that can help him doing exercises with supervision of a physiotherapist. Mike adheres enthusiastically and his geriatrist illustrates the rehabilitation program to him and shows him the Robohome2.0 platform installed at the hospital. Mike decided to use Giraff at home. He trained regularly for two months recovering almost completely.

A personalized version of Robohome2.0 will be installed at home to the elders enrolled in the pilot tests (WP), where they can use it for five months. Robohome2.0 adheres well to the current goals of social services to exploit ICT technology to allow the elder living at home for a longer time. The pilot a**llows testing Robohome2.0 in real conditions**, with elders in different clinical, physical and cognitive state. With this target in mind, an exhaustive protocol for pilot testing is designed, including all the aspects: monitoring, evaluation and assistance. Results will allow not only to derive a preliminary evaluation of effectiveness, compliance, usability and reliability but also, through the comparison with standard care, the most appropriate business model to seamlessly connect Robohome2.0 to the network of services provided by hospitals, GPs and private and public service providers. Feedback obtained from the pilot test study outcome is crucial for the creation of best practices, guidelines and policy recommendations. Indeed Roohome2.0 can generate useful, feasible and realistic **policy recommendations**: knowledge and expertise acquired through the project execution will be carefully analyzed in order to identify and describe the keys for success and failure of such an assistance platform and methodology to overcome all the barriers. This information **is compiled to provide policy recommendations**, emphasizing generation of guidelines for the successful deployment of such platforms within the national health systems of the EU zone.

### 1.3.5 Sex and/or gender analysis

Sex and gender may play an important role. Activities and interfaces are designed taking into account also gender. For instance, a male and female virtual caregiver avatar will be provided to the elder, who can choose; the theme inside narration will take into account this issue, with sports themes possibly more liked by males. All these issues are taken into account early in the project when functional specifications are set in WP1.

## 1.4 Ambition

**Elders with physical and cognitive problems are recovered in permanent residency too early or too little is done to let them staying at home longer. Robohome2.0 is aimed to change this.**

### 1.4.1 Beyond the state of the art

Robohome2.0 aims to change this exploring **gamification with robots in AAL setting** to provide a complete system that tightly **integrates personalized** monitoring, evaluation, assistance and training inside a low-cost **distributed pervasive system that does not require the elder to wear any particular device or change habits**. The interaction among the components allows monitoring the psycho-physical status through the data collected during gaming or during daily activities, to continuously tune activities, in terms of exercise mix and challenge level and other gamification mechanisms update the elder profile according to exercise and monitoring outcome. **Such wealth of**

[100] 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

[101] 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).

**data will allow also deriving assessment of clinical quality**. State-of-the art Artificial Intelligence is used to organize and control effectively all these interrelated components (WP3).

## Service robot

Giraff is improved from being tele-operated to being autonomous, guided by the Virtual Caregiver, so that it becomes an **active companion**. New Giraff robot is proactive in assisting the elder: it monitors his/her psyho-physical state surveying everyday activities, helps him/her searching for objects and remembering drugs, provides suggestions and feed-backs and guides him/her through adequate activities that can be administered by itself or through other displays. We explore a framework, based on reactive planning such that Giraff can learn the best option to approach the elder, taking into account his/her state and idiosyncrasies, to provide an **ecological approaching control**. A novel solution based on **distributed microphones with embedded DSP processing** is explored for launching alarms and calling Giraff from anywhere in the house (Task 5.3).

## Monitoring

Psycho-physical monitoring of elder state is performed by a novel approach that combines a **robot to measure the elder movement** in combination with a set of **sensorized common use objects to measure objects interaction** in typical everyday activities (WP5). The proposed monitoring follows the evolution of both motion and pressure/force patterns adopted by the single user during the interactions with the objects to recognize meaningful performance changes. This new monitoring approach is called **transparent** because **the elder is not aware of being monitored**: he/she has not to wear anything and the monitoring system is completely pervasive and distributed in the environment. This approach allows to acquire the elder natural behavior without splitting the monitoring stage from the ordinary life. The transparent monitoring is based on the principle that gestures are the expression of the motor and cognitive abilities, and that they can change selectively with pathologies[102].

Regarding physical transparent monitoring, we will define a **Gesture Degradation Index** that analyzes the variability of the **motion and force** parameters on which variability is small in normal subjects[103]. An increase in their variability can be related with degradation in motor control. We fully explore such "**motion signature**" on different gestures like reaching and grasping with different hand shapes (e.g. a cup, a comb) in real settings of everyday life. **Statistical parametric models, like Gaussian Latent Variable Models (GLVM)**[104,105] and/or specific features, like for instance force pattern in the stance phase of gait, or grasping force in early lifting objects, or homogenous plots of the orientation angles of the arm segments[106], are also computed and evaluated. Data collected by Robohome2.0 may allow **setting the ground for novel early detection of neurological decline**. We analyze the **significance and sensitivity of several Degradation Indexes** defined on these parameters in cooperation with clinicians. A similar approach is developed to evaluate balance. A **Dynamic Gait Index** will estimate postural stability on the basis of motion and pressure data acquired through elder walking stick. This will equipped with accelerometers on its structure, eventually integrated with gyroscopes[107], and force-sensing resistors mounted on the handle and eventually on the base. The latter measure the weight borne by the walker, and the symmetry of the elder's posture. Whereas accelerometers assess the spatio-temporal parameters. Change in time of these parameters will indicate if the person's gait is becoming slower, unsteady or in increasing need of walking-aid assistance. Analogous sensors can be mounted on walkers.

**Scenario: T**he virtual caregiver asks Giraff to monitor Helen while brushing her hair. Giraff detects that Helen leaves the kitchen after breakfast and enter the bathroom, Giraff says Hello to her and when it detects that the brush has been raised, it starts acquiring Helen's movements with its 3D camera. The Virtual Caregiver combines the motion data with the pressure sensor profile and realizes that Helen brushing motion pattern was significantly changed being more jerky and irregular. The Virtual Caregiver asks Giraff to repeat this observation in the next days and this change persisted. After five days of monitoring a warning is sent to Helen caregivers.

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[102] I. Carpinella, P. Crenna, E. Calabrese, M. Rabuffetti, P. Mazzoleni, R. Nemni, and M. Ferrarin Locomotor Function in the Early Stage of Parkinson's Disease, IEEE Trans. Neural Syst. Rehab. Engin., Vol. 15, No. 4, 2007, 543-551. R. Baltadjieva, N. Giladi, L. Gruendlinger, C. Peretz, and J. M. Hausdorff, "Marked alterations in the gait timing and rhythmicity of patients with de novo parkinson's disease," Eur. J. Neurosci., vol. 24, no. 6, pp. 1815–1820, Sep. 2006. Ansuini Caterina; Begliomini Chiara; Ferrari Tania; Castiello Umberto Testing the effects of endgoal during reach-to-grasp movements in Parkinson's disease. Brain and cognition 2010;74(2):169-77.

[103] E.Todorov, M-Jordan, Optimal feedback Control as a Theory of Motor Coordination, Nature Neuroscience, 2002; E.Todorov, Optimality principles in sensorimotor Control, Nature Neuroscience, 2004.

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[105] N.D. Lawerence and A.J. Moore. Hierarchical Gaussian process latent variable models. In Z. Gharamani, Ed. Proc. Int. Conf. Machine Learning, vol. 24::481-488, 2007; Titsias and Lawrence, Proc. 13th Int. Conf. on Artificial Intelligence and Statistics (AISTATS) 2010.

[106] Grasso, R., Bianchi, L., Lacquaniti, F. (1998) Motor patterns for human gait : backward versus forward locomotion. J. Neurophysiol. 80 : 1868-1885.

[107] Giansanti D Maccioni G Macellari V Guidlines for Calibration and Drift Compensation of a Wearable Device with Rate-Gyroscopes and Accelerometers Proc. IEEE EMBS, 2007.

Regarding cognitive transparent monitoring, we will evaluate the **proper concatenation of the different actions that constitute everyday activities.** For instance, for preparing a coffee, we have to put coffee in the machine, put it on gas, pour coffee, take sugar, take milk, mix with spoon. Not the same order or set of actions is present. We can choose to put sugar first or after milk and/or coffee, according to the day preference. Proper mathematical models, based on Probabilistic Finite State Machines (PFSM)[108], that can provide the forecast of each next action according to the elder attitude are developed and deployed. The model will be able to extract high probability patterns of interaction with the environment and therefore compare the patient behaviour with the expected one. **Such a model will be developed and tested.** Gesture segmentation itself is a very active area of research in computer vision especially related to hand motion[109]. We go one step forward here, exploring the use of **motion and pressure data from the hold object to help segmentation**. **Auto-calibration of sensorized objects,** taking into account Giraff Kinect images captured will be developed. To support early detection of degenerative diseases like Alzheimer or Fronto-Temporal Dementia (FTD), we will develop a system for the **analysis of the profile of phone conversations.** Very recently attempts to profile the characteristics of phone conversations have been proposed[110]. We will analyse here the conversations in terms of **pitch, voice volume** and **pace**. Stress is detected using the innovative DYPSA[111] algorithm, developed by SG. The algorithm is now an established approach published in the Matlab Voicebox[112] toolbox. We will analyze the determinants that allow to define a reliable **emotional state of the elder** and **track it over time** to detect meaningful mood changes that can be linked to disease onset (Task 4.6)

### Assistance

Daily assistance is based on an automatic objects location service. Objects tags are realized by using new miniaturized **Bluetooth-4.0 (**also called Bluetooth Low Energy – BLE) **radio transmission**. This can provide very low-power, with the ability to run for years on standard coin-cell batteries. Moreover, it constitutes a diffused transmission standard and has very small dimensions, as a 50c Euros coin[113, 114], weighting a few grams, and it can be fitted or attached to the desired objects without changing the size the shape or the mass of the object. When requested to search, Giraff will move autonomously following the radio signal[115], until the object is at a very close range. The same functionalities are provided through a smart phone app. However, Giraff will locate an object also when the elder is outside the house or when he/she is looking for the phone itself.

**Scenario** Jessica does not find her keys, call Giraffs and asks for the keys. Giraff starts moving a bit around to identify the direction of maximum signal power associated to the keys ID and starts moving towards the sitting room; it then moves towards the dining room until it gets close to a drawer on the top of which are the keys. Giraff calls then the elder. Jessica was very happy to find again her keys.

### Training

The activity center is an integral part of the environment assisting the elder. Education and activities are provided by Robohome2.0 heavily relying on **gamification (WP4)**. At the **core of gamification implementation is the design of the gameplay**. Indeed, a good game design, nice graphics, effective gameplay, clear feed-back and proper challenge level[116] all contribute to enter the player in a **state of flow**. Most effective gamification is obtained when users play in a cooperative or competitive mode[117] embedding gaming inside a **social dimension and** when a **reward system is used**. All these elements are integrated inside Robohome2.0 activity center. However, they are not sufficient to keep the user engaged for a long time as situations repeat after some times and therefore are not enough for long life gaming. **Robohome2.0 aims at combining gamification with adequate statistical methods effectiveness. This approach will foster a continuous adaptation and tailoring of the proposed game activity in order improve motivation and assure a long lasting interaction**. To this aim, we largely improve the IGER games[118], to incorporate a **hierarchial motivational layer** that involves gameplay and reward system (extrinsic motivation) and long life (automatic narration). To make exer-games compliant with elders, the

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[109] Scott A Green, Mark Billinghurst, Xiaoqi Chen, J Geoffrey Chase Human-robot collaboration: A literature review and augmented reality approach in design International Journal of of Advanced Robotic Systems (2008) Volume: 5, Issue: 1, Pages: 1-18; (3)
[110] http://www.callcentrehelper.com/how-to-use-vocal-pitch-and-pace-on-the-phone-2644.htm
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[112] http://www.mathworks.com/matlabcentral/linkexchange/links/797-voicebox-speech-processing-toolbox-for-matlab
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[114] http://www.indiegogo.com/projects/sticknfind-bluetooth-powered-ultra-small-location-stickers
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[118] N.A. Borghese, P.L. Lanzi, R. Mainetti, M. Pirovano, Apparatus and method for rehabilitation employing a game engine, US Application 13/911577, 2013.

details in the scene and their number **should be adapted to the elder's residual cognitive capabilities**. Finding the proper level of detail allows increasing the understanding of the scene and therefore motivation. To achieve this, we will explore the innovative use of a **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 at the point of need. We explore it both in the details of the elements in the scene and in their number. Evaluation of the best resolution is carried out throughout the project and an adequate **measure of cognitive load is defined** to match the profiling of the elder. The level of detail is complemented by a **controlled randomization of the scenarios and assets.** As already explored by UMIL[119], this makes the patient feeling confronted with an always new game, while the gameplay remains unchanged. We also provide to the elder some customization capability of assets, like for instance the game avatar, that can be loaded at run-time according to idiosyncrasies. This allows to incorporate a key element to increase intrinsic motivation[120], [121]. Lastly the pace of the game and the **challenge degree will be adapted to the elder status automatically** by analyzing in real-time the success rate to avoid that the game becomes either too easy or too difficult and the patient loses interest in it. Music and voice feed-back are provided. We also provide short-term extrinsic motivation under the form of feed-back from the Virtual Clinician Avatar that is constantly monitoring the patient, **giving advice on the exercises and praising him/her** when performs correctly. Short-term extrinsic motivation is also empowered by additional gaming-like solutions: **points and high-scores, colorful and meaningful feedbacks** associated to high compliance and high knowledge degree about the therapy and the illness. This is largely **enhanced by the social dimension of Robohome2.0 mediated by the Community of users**.

**Long-term motivation** represents a major issue when activity prolonged in time is required: games may get old soon and lose their appeal after few days of repetitive play. To this aim, we **develop automatic narration**[122]. In narration **the different mini-games associated to the activities** are **chained dynamically and automatically** to assume the form of a sport competition or of a fairy tale. In the latter case, we fully explore the morphology analysis developed by the Russian school[123] that has identified elements common to all fairy tales, like for instance the agonist and the antagonist, the fight, and so forth. We analyse the most interesting elements and extract few of them to be casted into a set of characters with a methodology based on ontologies. Two different approaches are explored to combine the different episodes. The first one is based on **stochastic finite state machines**[124] that allows creating stories with different sequences of episodes and scenes on the same plot. We go one step further and consider graphical models[125], adding to the transition probability matrix that determines each next episode, an a-priori distribution of the possible choices that takes into account the idiosyncrasies of the elder. The second solution is based on **reinforcement learning** in which each next episode of the narration is chosen in real-time according to a given cost function computed on the fly[126], [127]. We explore how to introduce **coherence, consistency** inside the cost function[128]. Reinforcement is provided by the elder him/herself with a qualitative feed-back for instance in the form of a smiley. We will explore the use of instrumented objects as **game input devices** Task 4.9 transforming objects like a cup or a comb into a "magic potion" or a "magic sword" functional to the gameplay. We also explore pressure sensing to realize magic effects like making objects disappearing thus exploring new gaming paradigms in which virtual everyday objects are used for playing. These objects can allow acquiring motion and pressure **temporal profiles associated to specific movements of clinical value**, like for instance the timing of stiffness increase in grasping[129] or the phase between the orientation angles when raising the arm[130].

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### Human Robot Interaction

As Giraff in Robohome2.0 is going to be a close partner to the elder, the need for a natural and effective communication is a fundamental issue to support meaningful, fruitful and long lasting interaction[131]. This will be mediated by both the **robot itself and the virtual caregiver with voice and graphical feed-back providing very rich interfacing possibilities**. We fully exploit these potentialities as follows: (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, we will **include a memory system that keeps track of the interaction history and supports subsequent tasks in a predictive way**[132]. (ii) **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[133]. Robohome2.0 **studies how a robot behavior can be generated to provide feedback, signal intentions and goals, by adequately filtering the reasoning process implemented by the Virtual Caregiver**. Moreover, we identify the "**compliant paths**" for the cared elder: finding the approaching mode of Giraff that is most acceptable to the elder would increase robot acceptance[134,135]. (iii) **Responsiveness:** typical performance of a robot involves a considerable amount of processing which inevitably leads to perceivable delays. Conversational fillers and back-channel feedbacks can be used to create the illusion of responsiveness, which is highly influential on acceptability. **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** (Task 8.1).

### Community of users

Robohome2.0 takes full advantage of users community, **offering the elders the possibility of comparing their state with other elders,** to find people with similar problems, helping preventing isolation and depression. Pattern matching technique applied on elders profile allows automatically suggesting which groups an elder may find interesting to join, finding personalized news or other content, thus making the elders **proactively increase their social engagement**. Through the community, elders **access thematic information on diseases, best practices, and lifestyle** and **new collective knowledge is created** through the interaction among users, increasing the **trust in Robohome2.0.** Informed discussions between community members and a **continuous osmosis with the most popular social networks**[136] is supported. Through conversation in the community, socialization and externalization of knowledge[137] will take place. We make available to clinicians a complete **therapy management system**, implementing a closed-loop workflow, through which they will be able to assess the elder status, review the results of the therapies and receive advice from the system based on the results. Using the portal of knowledge they have access to statistics and data regarding therapy outcomes, scientific articles and specialized information in general. Elders have access also to all the data stored in the system about their diseases and therapy, in an understandable fashion, so that they are always aware of their condition, making **the distance between them and the clinicians shorter**. This facilitates changing the elders role in clinical decisions **from mere passive actors to active ones**.

## 1.4.2 Innovation potential

The Robohome2.0 architecture introduces different systems in a harmonious way, creating a new and innovative standard for domestic assistance. Each component has peculiar features able to improve the process of the Virtual Caregiver to help elderly people and their family to avoid risky situations. Although a full patent search will be carried out in Task 9.6, a preliminary patent search has allowed to highlight the **highly innovation potential of the research activity proposed.**

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[137] Nonaka I., Takeuchi H., The Knowledge Creating Company, University Press, Oxford 1995.

### Patent Search

**Smart Drug dispenser.** Robohome2.0 aims to create a low cost, compact and easy-to-use solution to help elderly people or the their family in a friendly way. Medication dispensing cabinet for hospitals and drugstores are mainly dedicated to help nurses and clinicians during the handling of blisters and boxes or to improve the management process. They also try to prevent errors during refill, but neither a system has been designed for domestic use nor specific components able to help people to take their own drugs have been proposed. Patents that describe some medication dispenser are US8588964, US2013006415, CA2821616, WO2013142351 and CA2772899. This last very recent patent describes a medication dispensing cabinets, developed to store and dispense in a controllable way a wide variety of medications. While some of the drawers may be unlatched and can be opened, other drawers may be locked in order to improve the control of the access to the medication stored. This system does not act as an "assistance" in medication dispensing, but mainly as a supervisor for operators, able to prevent possible errors and limit the access to medication. The claims are mainly focused at describing the locking system, which is not suitable for creating a low cost, domestic system.

**Finding lost objects.** To help people who lost keys, glasses or other personal belongings in house (and also outside it), some solutions already available on the market. They use radio signals to detect the remote transceiver, previously attached to the lost object. The main difference introduced by Robohome2.0 is that Giraff will find the tagged object and signals them in an automatic way without the involvement of the owner. **Giraff will be the finder**, this is the more novel aspect, while commercial solutions require that the people move and find them. Some systems are based on apps for smartphones, which usually is the object which has to be found. Patents describing commercial solutions are US6366202 (1999) and US8130116 (2012), the second one introduces only a configurable range of detection.

**Sensorized objects for monitoring.** Several researches and publications describe the use of sensorized objects (doors, chairs, wristwatch etc.) to analyze human behavior and specific actions in order to identify risky situations in the daily life. Some other projects in the past proposed the use of instrumented or special objects to create a personalized, home rehabilitation system for specific pathologies (e.g. rehabilitation of patients affected by apraxia, rehabilitation of rheumatic patients). The novelty of the approach followed by Robohome2.0 is that the offered physical monitoring during normal daily actions trys to follow the evolution of both motion and pressure/force patterns adopted by the single user during the daily interactions with common objects in order to recognize his/her performance changes in time. The system will be completely transparent to the elder and it does not require to wear objects, differently from other systems patented to to monitor "actions" or "behavior modification" (patents US6611206, US6968294, KR20090030868 and KR20090025924). Patent CA2275733 introduced the general concept of measurement, monitoring and/or the analysis of motor control ability, performance and training for rehabilitation. Besides not providing any prototype, the scenario is very different from Robohome2.0 in which we do not have exercises, but normal daily activities; we do not have specific instruments but objects of everyday life and monitoring is carried out transparently to the user.

## 2. Impact

### 2.1 Expected impacts

Robohome2.0 well addresses the expected impacts listed in the work program for the specific research topic. The consortium gathers experts from different disciplines to develop and test a service robot able to provide elder monitoring, recommendation, evaluation and assistance at home in a holistic and exhaustive manner. Robohome2.0 aims at guaranteeing reliability and easiness of use paying a large research effort in tailoring a system able to fit the user's and his/her relevant caregivers' needs. Moreover, the multi-site nature of the final pilot requires the implementation of a system that can be valid, usable and compliant to different health social systems thus addressing the European and Global Market. Here below, we will describe how the proposal will address the specific expected impacts of the call.

The **STRATEGIC ROBOTIC AGENDA**[138] defines the categories of stakeholders for the robotic market domain. *"The diverse nature of the robotics industry leads to a wide range of stakeholders both inside and outside of the robotics community. … Stakeholders can be categorised into the following groups; -industry and service organizations; -research organizations;-end users, both commercial and consumer; -government and policy makers; -key representatives and opinion leaders within civil society; -financial institutions."* Robohome2.0 has the ambition to involve directly in the Consortium most of the key stakeholder of the list and has a detailed plan to share the results also with those stakeholders which by definition aren't directly in the consortium. Indeed, policy makers and consumer end users will be involved by the End-Users Advisory Board, opinion leaders and key representatives

[138] Strategic Research Agenda Produced by euRobotics aisbl 2014-2020 Robotics 2020 Draft 0v42 11/10/2013

will be reached by targeted DISSEMINATION activities. The presentation of the achievements to financial institutions will be an asset of the EXPLOITATION strategy of the project.

**Evidence for the benefits of service robotics developed, based on proof of concept and involvement of relevant stakeholders.**

The service robot used in Robohome2.0 is embedded in what is configured as an advanced telemedicine service. Telemedicine has a long history. Reviews quote it as beginning in 1948 when radiological images were transmitted for the first time by telephone from West Chester to Philadelphia, a 24-mile distance. Since then, electronics and computer science have allowed tremendous improvements and spread of telemedicine applications, but, despite the technical maturity, telemedicine services are still limited and the **market remains highly fragmented**[139,140,141]. A recent study shows **business models that determine how the application of telemedicine, in particular for post-stroke rehabilitation, can generate positive cash balance**[142]. This study at outpatient clinics in Oklahoma concludes that 340 telemedicine visits are enough to provide positive net cash flow per year with a recover of the initial investment within the 4th year of operation. **Elders assistance is becoming one of the most appealing applications of telemedicine** because of ramping numbers of elder population and increase in assistance costs that are a very strong incentive to search new ways to assist them. Late recovery in nursing homes is becoming one of the main issues to cope with in the next years, favoring the best lifestyle of elders. However, comprehensive solutions are still lacking. Telemedicine is a tool that should be integrated as much as possible into the usual practice of medicine and social services[143,144]. **However the integration of telemedicine services in healthcare systems is still an open challenge and requires high policy makers involvement to further develop;** several experiences report that initial **funding sources and reimbursement policies are the most important barriers that avoid widespread of telemedicine programs**[145,146]. However, apart the technological research, other issues strongly affect their capillary diffusion in European national and local environments. ***Within Robohome2.0, the following ROADMAP toward the above described targer will be implemented: 1) assess and demonstrate the efficacy of the proposed assistance methodology; 2) evaluate costs of the new solution versus the present operational modalities and point out economic benefits for all the involved actors, namely national and local socio-health systems, health institutions and citizens; 3) design a new model of care delivery taking in account the new devices and related schemes for delivery and maintenance beyond the more evident clinical aspects.***

Robohome2.0, thanks to the participation of a wide spectrum of potential stakeholders approaches these aspects. The stakeholders' involvement is indeed an essential requirement highlighted by the Digital Agenda of the EC for 2020 and necessary to make feasible any proposed solution in telemedicine field. **Robohome2.0 involves early in the project an end-user advisory board that represents the instances of the stakeholders.** This assures that all project decisions are taken according to the shared awareness and consciousness on the elder needs and make the final solution respondent to the healthcare service needs. SAS and KOMMUN represent the Socio-Health public providers with different assistance schemes and approach, while KORIAN represents a private service provider with a Global European market. By the results coming from the pilot, they will be able to assess the results of the care in terms of patient's improvement and personnel time expenditure to provide similar assistance level. It is not possible to evaluate the time course of the decline of the elders and its progression towards frailty, within the Robohome2.0 time frame. Nevertheless, we expect to show that elders with **Robohome2.0 tend to keep healthier and more active**, as provided by **the functional indicators** set-up for pilot. The quantitative evaluation of Robohome2.0 will be performed collecting data on daily usage of monitoring, activity center, assistance and community by the elders and the other users. Given the number of elders that will be included in the pilot tests, the assessment of efficacy will remain preliminary but it will be very precious to give directions towards to design a future randomized controlled trial. Moreover, the multi-site nature of the final testing phase that will be hold in three different European countries (Sweden, Italy and Spain) will guarantee that the proposed solution will be firstly adherent to the single National healthcare systems requirements but also to the ones shared at the European

[139] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions on "Telemedicine for the benefit of patients, healthcare systems and society", COM(2008)689, November 2008

[140] Meystre, S., The current state of telemonitoring: A comment on the literature. Telemedicine and E-Health (2005), 11, 63-9

[141] Paré, G., Jaana, M., Sigotte, C., Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base, Journal of the American Medical Informatics Association (2007), 14, 3: 269-277.

[142] McCue MJ, Palsbo SE. Making the business case for telemedicine: an interactive spreadsheet. Telemed J E Health. 2006;12(2):99-106.

[143] LeRouge C, Tulu B, Forducey P, The Business of Telemedicine: Strategy Primer, Telemedicine and e-Health, vol.16, n.8, October 2010

[144] Bensink, M., Hailey, D., Wootton, R., Home telehealth: Connecting care within the community. In: Wootton, R., Dimmick, S.L., Kvedar, J.C. (eds). The evidence Base. Oxon: Royal Society of Medicine Press, 2006, p 53-62

[145] LaMonte MP, Bahouth MN, Xiao Y, Hu P, Baquet CR, Mackenzie CF. Outcomes from a comprehensive stroke telemedicine program. Telemed J E Health. 2008;14(4):339-344.

[146] Hess DC Wang S Gross H Nichols FT Hall CE Adams RJ. Telestroke: extending stroke expertise into underserved areas. Lancet Neurol 2006 5(3):275-278.

level. This implicitly means that the results of the pilot will be of interest not only at local level but also at European level. In addition, we expect that the use of Robohome2.0 will help the family and the clinicians to recognize possible risky situations, making warning about the decline of the user which, on the contrary, might be disregarded by the caregivers. The use of tele-operated and transparent clinical tests inside Robohome2.0 will help to keep a **continuous evaluation of the state of the elderly and will drive prompt interventions in case of risk situations**. PCL, SAS, KOMMUN and KORIAN will represent the perspective of the elder themselves, main focus of Robohome2.0. For them, outcome to measure, besides health improvement, satisfaction of the service, perceived usefulness and ease of use (TAM model) evaluation of the invasiveness of the solution will evaluated. Another crucial element to assess the assistive outcome will be the capability of the user to interact and use of the system, considering a low-trained old person. Indeed for all consumer robots the capability to interact with untrained or minimally trained people in everyday environment is a crucial issue, that is fully taken care in Task8.1. A complete report on the assessment of Robohome2.0 from the different users point of view: effectiveness, compliance, usability and reliability in assisting the elders at home will be provided at the end of the project. SAS and KOMMUN will represent also the perspective of the policy makers and health system management and they will cooperated with KORIAN in developing a **business plane on the service business model envisaged** (Section 2.2a). An external support by Lombardia Region to which PCL, UMIL and POLIMI belong, will also be provided (Annex A).

**These elements of assistance outcomes (clinical impact with respect to statistics, number of risk situations avoided or warned by the system, user feedback and usability of the system) will be the leveraging factors to prove the effectiveness of the use of the system and consequently its eventual economic benefit**.

**Design a new model of care delivery taking in account the new devices and related schemes for delivery and maintenance the elder at home for prolonged time.**

Frailty, cognitive and physical decline are syndromes that progress slowly but constantly over time and the actual 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. The increasing share of elderly population coupled with the related healthcare costs are a great incentive towards the design of new care models to assist the elderly needs. In particular, a **modification of the structure and organization of the network of services, increasing the assistance on the territory is required**, **as already being explored by KORIAN.** ICT research and innovation can contribute in this reorganization, by supporting the shift of the core of the assistance from the hospital to the territory through innovative assistance models centered on the elder. Modalities of distribution of these new services are fundamental, as they can assure: (i) equity of access to the primary and secondary care, (ii) a better management of chronicity and continuity of care through a multidisciplinary approach and (iii) a valid support for emergency services.

Currently, **the panorama is populated by small companies that provide some of the needed services, while only a holistic comprehensive approach can support the effort of changing the care model**. In many European countries telemedicine services are diffused, in some cases specific services are sustained by national projects[147]. Here below we report the current situation in Spain, Sweden and Italy.

<u>The current situation of the elderly home care in Spain</u> In Spain, Regional Health Systems, part of the National Health System, have focalized their attention on e-health in the last twenty years, sharing the view and the development of systems and services based on telemedicine. Recent studies made in Spain by IESE Business School and Telefonica[148] revealed that 70% of chronically patients would like to use telemedicine if this would be possible, this percentage raises to 80% in the case of healthcare professionals. In this study the healthcare professionals told that the expected potential benefits would be an improvement of the self-care and responsibility of the patient for his/own health and an increment in the comfort of the process, focused in the reduction in the number of visits and in the agglomerations. In addition they pointed at a better control of the problematic patients and the early detection in some medical problems.There are some important barriers to the generalization of this practice: knowledge, technology, costs, privacy and interoperability of the data. Possible solutions for these problems would be training for the healthcare professionals in the use of this technology, design of the technology focused in the usability, improvement in the codification systems and data collected and the standardization.

<u>The current situation of the elderly home care in Sweden</u> In Sweden, the National Strategy for e-health was published already in 2006. It was a bootstrap document that has been developed through regular reports. Indeed

[147] http://ec.europa.eu/research/innovation-union/index_en.cfm?section=active-healthy-ageing
[148] http://www.iese.edu/research/pdfs/ESTUDIO-305.pdf

in Sweden, telemedicine is largely diffused: in 2008 there were already more than 100 applications in more than 75% of the hospitals. Principal applicational areas are: televisit (patient-doctor) and telemonitoring.

The current situation of the elderly home care in Italy Due to cultural reasons, most of the Italian elderly people and their families prefer an "aging in place" option[149]. 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[150]. 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[151]. 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 and the provision of healthcare. The system seems to have found an "equilibrium" as most of the users gain some practical advantages from current arrangements[152]. 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. In Europe the communication 689 of 2008 from the EC Commission[153] was finalized to sustain the member states in the realization, on a large scale, of telemedicine services, through initiatives as: increase confidence in telemedicine services, get deeper knowledge in regulatory, ethical and legal issue, solve technical issues and support the market. The EC prompted each member state to identify priorities for that state and push towards development with dedicated guidelines. This was perceived by the Economics and Social Committee of the EC[154] as a "cultural revolution" that should be framed inside the evolution of the health system in the whole Europe. Indeed, KORIAN is already exploring a service model in which a nursery homes become a place in which the elder can be recovered following acute episodes (e.g. stroke, major illnesses, surgery) for a relatively brief period of time, after which he/she can be sent home, under the remote supervision of a caring institution. This is the **model that has inspired Robohome2.0**: Assisted Living Environments may play a key role in renewing the system of integrated social and health assistance.

**Reduction of admissions and days spent in care institutions, and increase of time spent living in own home when ageing with emerging functional impairments.**

**Robohome2.0 intervention represent an additional aid and resource to favor a comprehensive care to the elder at home, integrated in and integrating the community of users surrounding the elder. Establishing a network of providers of social and health care, not only Robohome2.0 would represent an additional virtual care provider but it would also promote the creation of an integrated care system.** To make a home assistance solution feasible and deployable to the elderly the complete comprehension of the elderly needs is required. Indeed, the elderly with emerging functional impairments has the primary need of a continuous and personalized training and assistance at home possibly under supervision of both formal and informal caregivers. The possibility to offer such an integrated service at home seems the most ecological solution to train and monitor the elderly effectively. **Robohome2.0 will offer an integrated solution including all the main ingredients: monitoring, assistance and evaluation at home. The approach proposed is an advanced tele-assistance, for which the presence of a remote caregiver, connected through internet to provide 24h assistance, is not required as much activity is delivered by the virtual caregiver embodied inside Giraff**. The Virtual Caregiver will provide also clinical tests that will be both the tele-monitored gold standard tests and novel tests completely transparent to the user. These tests together with the assistance of formal caregivers will assure the reliability of the assistance updates provided to the user. Moreover, by having access to a patient's information, the care team will be able to make better informed treatment decisions which could reduce the number of physician office visits and hospital stays. Finally, keeping the elderly fit and in a good psycho-physical condition will avoid as much as possible traumatic events or urgent admission at Emergency Department. The Robocare2.0 community fosters a high communication between stakeholders to optimize the use of resources, both institutional and voluntary, reducing the risks of hospital

[149] 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

[150] 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

[151] Lamura G. et al. (2010) Migrant workers in the long-term care sector: lessons from Italy. Health and Ageing Newsletter 22 (1), 1–6.

[152] 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

[153] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0689:FIN:EN:PDF

[154]http://eur-lex.europa.eu/JOHtml.do?uri=OJ:C:2009:318:SOM:en:HTML

admissions and readmissions. The readmissions reduction will also have a beneficial impact of the Health providers budget. **Thus, the comprehensive and multidisciplinary home care solution offered by Robohome2.0 will finally have a great impact in the healthcare economy. This solution represents a ground breaking personalized service and reverse the trend towards the institutionalization of senior and disabled citizens while ensuring that they enjoy improved living conditions in their home environment.**

**Accelerate the robotics innovation turning the results of the research and the technology development into competitive products and services at a much faster pace.**

Robohome2.0 will participate to this goal thanks to the representation of a complete supply robotics chain inside its consortium, from the research (UMIL, POLIMI, UOP, ORU, BDIGITAL, UMA) to the robotic industry (GIRAFF) and its providers (SXT, SG), up to the global healthcare equipment suppliers (KORIAN) and end-users (PCL, SAS, KOMMUN). This will help in guiding the research to real opportunities offered by the market and end-user needs, ensuring a strategy that maximizes market impact and intake. The crucial element will be not only the development of a technical value chain, based on the robotics modules and components, but also in the tight involvement of stakeholders and service providers. These will facilitate the technology transfer process into the market. Robohome2.0 will support this process of technology transfer by properly addressing the guidelines of Intellectual property management into the CA.

**Improvement in quality of life of older persons and of their carers.**

To design such a cutting-edge solution that can be deployed to elders independently on their primary disease, it is important to sensitize the community of the elders towards their empowerment in order to make them more active in maintaining a healthy and active lifestyle. This process should start in a prevention phase to maximize the results. The elderly has to be persuaded towards the concept that an active participation in monitoring their health status can promote their adherence and compliance with treatment plans, help them assume more responsibility for their health and lifestyle and may prevent unnecessary emergencies. Moreover elders awareness that the service robot is serving them exactly at their point of need and in the full respect of their privacy makes the elders more confident on it. The assistance provided by Robohome2.0 is highly multidisciplinary and covers physical, cognitive, behavioral and social domains. The tight interaction between elder and community of users allows the elder to participate to social events and activities promoting his/her social inclusion Thus, Robohome2.0 has the potential to support a greater change in individual attitude and behavior and it will slow down the progression of elder decline. 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 burden as their age increase. The collection of memories, the bank of time, suggestions to youngers are all elements mediated by the community that would contribute to a less eager and more giving society. Moreover, having in mind that the effectiveness of a telemedicine solution is maximized only if the system can assure personalization, Robohome2.0 is designed and deployed as a modular system providing to each user only needed modules to offer the specific level and type of assistance. In Robohome2.0 personalization is achieved also in the activity center and continuously tuned by the Virtual Caregiver. Special attention is also devoted to implement interfacing modalities that promote a meaningful interaction with a good emotional relationship between the elder and the service robot in order to guarantee easiness and even pleasure in the interaction and to increase the compliance in system use. Robohome2.0 can help not only the elderly but also his/her formal and informal caregivers. Indeed, Robohome2.0 allows family members and care teams to respond to changes in elder's condition, to help prevent accidents and emergencies, and to coordinate necessary support. This care coordination makes the formal caregiver more aware of the daily elder conditions thus facilitating the decision making process that becomes better timed and successful. In the meanwhile the offered service will relief a bit the responsibility of the informal caregivers that can become more peaceful in the interaction and "management" of their beloved. In fact using Robohome2.0 they can trust a secure system that connects the elderly to all the interested care providers. **The Robohome2.0 solution empowers both elders and informal caregivers to take care of their health and to promote independence. This is crucial to decrease the current divide that partially prevents the spread of innovative ICT telemedicine solutions in healthcare. Thus Robohome2.0 will optimize the sustainability, will increase the social inclusion of the users and will strengthen the relationship between rehabilitation team, users and caregivers thus producing a better coordination of the care process that is completely centered on the end-user wellbeing.**

**Global leadership in advanced solutions supporting active and healthy ageing.**

Robohome2.0 collects and analyses of large volumes of health and lifestyle data (lifestyle, physiologic variables, movement patterns, cognitive performances, health variables such as hearth rate or pressure... ). This information constitutes the foundations on which the efficacy of the provided system can be assessed during the final multi-site pilot testing phase. However, this feature will not contribute to that end if the information collected is not shared. We pursue the idea of Robohome2.0 being an **experimental testing platform in which novel components can be tested and integrated.** To this aim Robohome2.0 integrability and interoperability will be guaranteed by its adherence to standards: Semantic, Terminology and coding (ICD (ICD-9-CM), LOINC, SNOMED, UHID, AIFA), and Synthactic (HL7, (CDA, Clinical Document Architecture), DICOM) standardization. Moreover, for modularity and extensibility, the software architecture is designed and developed as a multi-level one. Interoperability issues are also very important when considering future developments and exploitation of Robohome2.0. A system in which interoperability at all levels (syntactic and semantic) has been taken into account since the beginning of the design will be easier to integrate within the current infrastructure of hospitals and it is more likely to be widely adopted. Therefore, Robohome2 implements a secure model, performing authentication, providing authorization for integrity and confidentiality of information. The specific focus in Robohome2.0 on the economical and ethical aspects related to deployment of service robots able to train and monitor elder people at their point of need in their preferred environment will lead to a much richer understanding of the issues and the potential, which can then be applied when regulators need to consider the economic, social and ethical issues which Robohome2.0 will undoubtedly expose. The industrial partners of the consortium: GIRAFF, SXT and SG are already working on advanced telemedicine technologies for elderly and will first pursue the exploitation of the project results. The experience of Robohome2.0 will be crucial for these industrial partners because the tight link with the most relevant stakeholders together with the multi-site nature of the final test will strengthen their competitiveness and will enable them to develop innovative solutions meeting the needs of European and global markets.

### 2.1.1 Framework conditions

The analysis of the care models in the partners country allow to develop a realistic business plan based on continuity of care. During the lifetime of the project, contributions to technical roadmaps and standardisation of modular, multi-modal pro-active assisted living are examined and participation to CHA and/or AAL program is fostered. In particular, the **universAAL project**[155] aimed at providing a separation between the services provided and their implementation will be fully analyzed. To make Robohome2.0 a winning platform, rapid uptake of novel technology and devices should be guaranteed. This will be taken care at the component and interfacing levels. Giraff robot mounts a Windows 7 OS that allows acquiring Kinect data and running most common Game engines: Panda 3D and Unity 3D. IGER system has also been implemented under Windows OS. We aim at low cost devices already available in the market that comply with all the medical equipment safety and quality standards are required (EN 1060-1, EN 1060-3, EN 1060-4 and ISO 8106). Networks of large diffusion are considered to connect the components: z-wave protocol is considered for environmental sensors and low power blue-tooth for sensorized objects. The community of users is based on state of the art technology: Apache Tomcat, Java programming language, Spring framework, jQuery, Apache Tiles among others. The most suitable database type are chosen, selecting between SQL or noSQL databases to store the large amount of heterogenous data coming from the monitoring systems and the activity center. Motion data acquired by the activity center is represented and stored using most common solution, namely quaternions or rotation matrixes. XML or Json will be used to transmit the configuration data to the activity center. WebRT technology will be used to support multi-cast audio-video transmission require in multi-play gaming.

## 2.2 Measures to maximise impact

### a) Dissemination and exploitation of results

**A) Dissemination of project results** into knowledge, products, and exploitation are key indicators of the success of the project. The various types of partners in the project strengthen the means by which dissemination can occur and optimize the possibilities to disseminate amongst different potentially interested target groups. Academic partners are expected to disseminate on a research level by means of publications to international journals, possibly to open access journals, participation to international conferences and workshops. Clinical Partners will shape the information related to the project for the different stakeholders to produce user type specific material adequate to diffuse, and sensibilize the public and private service providers of the EC countries. The **dissemination strategy** in this project will be based on the following three aspects: 1) The knowledge developed by the project will be efficiently communicated to the academic, industrial business and general-public communities. Major activities will be publications, presentations at key conferences and workshops, talking to other Horizon2020 projects in the same call and projects in AAL, telemedicine, teleassistance and rehabilitation frameworks. Finally, maintaining contacts and reporting to standardization bodies. 2) Activities aiming to promote the awareness and

[155] http://www.universaal.org/index.php/en/

hence the exploitation of the project's results will be identified and pursued. Activities include organization of special events within major conferences or venues relevant for the project. 3) Potential stakeholders will be identified and promotion activities targeting communication of knowledge and potential industrial/business applications will be undertaken.

**Key Aspects and Target Groups.** The key aspects of the dissemination strategy are to define a concise, clear and convincing message associated to the project and its results. The project must successfully transmit the novelty and benefit of the results. Once established, the subsequent step is to identify the stakeholders and personalize the message according to the forum in which it is presented and according to the target audience. The following types of stakeholders/target groups have been identified: 1) The EC-ICT community: aim to raise awareness of Robohome2.0 objectives and to foster collaborations and exploit synergies between projects; 2) The industrial community: aim to communicate and promote the results on a technological and business level; 3) The wider/general public: aim to raise overall awareness on the project and partners to local media. The aim to announce the general objectives of the project at startup and promote results as they become available in the project; 4) The healthcare professionals: aim to raise awareness of the project with specific focus on how it impacts the field of health and care; 5) The media: aim to promote the project results to specific groups which include journalists and online forums; 6) The scientific community: aim to disseminate and inform of project results and increase the knowledge in the field; 7) The health policy makers and local governments: aim to disseminate and inform of project results and business plan trying to foster a new model of sustainable healthcare. **These target groups are aimed for general dissemination activities** where the common thread is to explain the project and its results on various technical levels in order to increase awareness and promote cooperation and synergies. In addition to these target groups, a s**econd level of dissemination will be employed specifically for markets and future exploitation.** The target audiences for this second level are: 1) SMEs offering vertical business solutions extending to other domains; 2) Educational Institutions; 3) News Service Providers; 4) Experts from the advertising sector. In this context, more business oriented promotion material is to be prepared. Specific opportunities that may be culturally related will fit under this second level of dissemination.

**Dissemination Tools** In order to reach the identified stakeholders and ensure an effective dissemination, the project foresees the following dissemination tools: **1) PROJECT LOGO.** This has already been designed and expresses the visual identity of the project. It reflects the projects vision and creates a trademark for the project that is easily identifiable. **2) PROJECT WEBSITE**. A **project web site** will be established (Task 9.2), including a presentation of the project objectives and methodologies and comprehending web facilities for communication and dissemination of information and progresses done by the project. Each partner will contribute to provide the contents that will be collected, organised and formatted by UMIL and published on the web. The content of the site will be updated regularly on a monthly basis. Links will be created with relevant web sites and documents. **3) PROJECT COORDINATED IMAGE** A project coordinated image will be prepared and will include the project logo, a coordinated set of project tools for reports and presentation of the project results, and the project brochure to be used in different dissemination occasions. **4) PRINT MATERIALS** Robohome2.0 will make use of print materials in a classical manner. Brochures are produced in the project in a technical and popular version. The choice of languages for the popular brochure will be directly related to the test site location. Other translations may be included as dissemination opportunities are presented. The brochure describes the project in a concise manner as well as outline the main steps and goals. All partners should be well visible on the brochure. Other printed material can be generated on a need to need basis, e.g., for special events. Electronic versions of the material will be available for download from the project website. **5) EDUCATION** The network of partners, the connections and the knowledge acquired within the project, will positively influence the didactic proposals that can be offered at a local or international level to students (undergraduate / postgraduate), to researchers or professionals (e.g. Master, Doctorate courses, Summer schools). **6) PARTICIPATION TO EVENTS** Participation to relevant international event for standardization and dissemination such as the Continua European Symposium 2014, AAL Forum 2014 and e-Healthweek 2014 and their following editions. A specific task of WP9 will be devoted to the participation in Trade Fairs and Exhibitions (Task 9.4). **7) PUBLICATIONS AND WORKSHOPS** Publication of technical and research papers in well-known scientific and industrial journals, magazines, newspapers (IEEE Transactions, BMC Journals, Elsevier Journals, ACM series) preferring always the open access journal to increase the target audience. Presentation of results at conferences, seminars, workshops (Tasks 9.3 and 9.4) both through speeches or posters. Within the initial dissemination plan, partners will contribute to create a list of possible conferences and events connected with the topics dealt with by the project in order to exploit all possible dissemination means. All intended publications must be put on the common website and submitted to provisions of the CA. To maximize the effectiveness of the result a good balance between fast publishing the results (requested by the research institutions) and thorough evaluation of their innovative potential and their suitability to be secured through a patent, has to be balanced. For this reason, partners will be required to submit to the PSC an early draft of any publication or document to be diffused so that its novelty impact can be evaluated in due time. **8) DATA and TOOLS SHARING** Selected algorithms and methods implemented in the project are made preferentially available to the scientific community under a GPL(or equivalent) licence through forums such as SourceForge. This will make it easier for other scientists to build their research upon Robohome2.0 results. Robohome2.0 will use open sources software instruments that will be made available for the design and setup of new rehabilitation programs. This will be a significant contribution to the research community.

**B) A clear Exploitation plan** is defined-The project is expected to have a strong outcome also in the ICT domain. Industrial exploitation modalities of the whole system and of single components will be discussed throughout the project and an exploitation plan set in Task 9.4 to detail the following: identification of exploitable results, market analysis, industry and competitive analysis, commercial relations and business plan. The exploitation plan will be devised of exploitation tasks which allow the consortium to identify Robohome2.0 related products that could have commercial applications, assess the opportunities and risks related to each product, evaluate the effort needed for commercialisation of the products and initiate contact with potential business partners of future clients. Exploitation rights within the consortium will be defined in the CA.

**Management of intellectual property** (Task 10.5) will perform the monitoring of Robohome2.0 IPR activities and IPR work, and based on this create an IPR Management List. The assessment of Robohome2.0 IPR involves mapping the IPRs in view of the Rrobohome2.0 activities to detect early possibility of securing research development. The IPR policies of the targeted standardisation bodies will also be considered in this context. IPR analysis will provide a basis for steering the technological activities (towards non-infringement of Third Party IPR) and building up of Robohome2.0 IPR itself. All issues regarding confidentiality, IPRs, Background Foreground, agreement on exploitation rights, and clarification of each individual’s rights and obligations are going to be included in the **Consortium Agreement (CA)**, document to be signed by all partners before starting the project. The PC is responsible for the use of IPR within the Consortium, according to the terms laid out in the CA. Primarily, the project aims to enrich and expand the state-of-art and state-of-practice of the home assistance and training methods deployed to the elderly in Europe. In order to carry out the work, the partners will develop and share know-how and technologies in many forms, including, but not limited to algorithms, tools, experiences and methodologies. The know-how exchanged between the partners may include, in certain cases, background. The partners are in agreement on the principles for the management of intellectual property, as summarized herein. The CA will be written in such a way that it is possible for all partners to carry out their project work whenever it is dependent on transfer of knowledge from other partners, whether this is foreground or background knowledge. The CA will protect the legitimate IP interests of all partners by explicitly limiting the rights to background knowledge and, where required, even limiting the rights to foreground knowledge developed during the course of the project when there is no need-to-know or need-to-use. In general, tools, methodology documents, benchmarks and case studies will be available to all; while some proprietary tools and algorithms developed by the partners may be available at the discretion and terms of their respective owners. In spite of the latter restriction, all the partners intend to pursue publications of the underlying principles of the technologies embodied in their tools in the appropriate academic conferences. Finally, all knowledge will be managed in accordance with the consortium agreement that will be timely prepared and signed by all consortium members

**Management of Knowledge, Technology Transfer, Plans for the use, IPR & Patents** All knowledge will be managed in accordance with the CA. Relevant discovery will be patented by partners that own associated background and foreground. Relevant licensees and spin-offs will ideally be transferred, so that established companies and emerging companies can benefit from the Robohome2.0 research.

**The Foreground Management and Plans** for the use will be updated by the IPR Policy committee which will consist of both technical and legal experts form the relevant partners. This group will report regularly to the Management Team and the Plans for use on new IPR generated during the project. The group will also prepare and regularly update the Foreground Management and IPR strategy of the consortium and present a Final Exploitation Plan to the penultimate and final meeting.

**Foreground Management** will be based on modern methods, such as BSCW on the private area of the webpage, which allow cooperative work on “living” documents. The Management Team is responsible for the day-to-day Foreground Management.

**External dissemination and Technology Transfer**: The wish and responsibility to publish research results and carry out Technology Transfer will be carefully weighed against the necessity to keep specific foreground within the consortium and not to endanger future exploitation. All partners provide information about planned publications to the consortium and the Management Team, so a publication can be delayed until patents applications etc. has been filled. This rule is valid up to 1 year after the end of the project. A **right of first refusal** is granted to the consortium industrial partners that will be privileged in exploiting technology developed. To avoid that other interesting opportunities are lost, a time limit will be defined for this option.

**Plans for using the foreground (IPR and Exploitation)**: The IPR regulations will be defined in the CA. The terms in the CA deal with the protection of foreground related to joint invention, application for patents and further use of foreground. In addition to this, terms are defined for the access-rights to foreground, mainly based on the document on the provisions for implementing integrated projects. The CA, a legally binding document, deals with: 1) **Protection of individual partners background**. 2) **Protection of IPR** gained in the project (foreground). 3) **Definition of the exploitation strategy** (patents, licensing etc.). 4) **A contingency plan** that ensures the access to foreground if a partner (with project-critical IPR) leaves the consortium.

## Business plan.

In the final phase, Robohome2.0 defines a **business plan**[156] to demonstrate the cost-effectiveness of the technology and develop a proper business models for technology transfer. The business model will be based on a **service model mainly elaborated by KORIAN**. In particular, a business plan will be elaborated on the basis of the four basic questions: What? Where? How? Why? To this aim the following sequential steps have been identified:

| STEP | PHASE | CONTENT | AIMS |
|---|---|---|---|
| 1 | Business description and context | Status analysis. Analysis of projects solutions on the market to support elders at home. Novelty introduced by Robohome2.0 in assisting elder at home. | Make explicit and structure the offer for selected business areas (clinical / social / comprehensive solution and so forth) in the context of assisting the elders at home. |
| 2 | Strategies and position in the market | Identify possible strategies to enter into the market (provider for the public / private services or directly to the elder). | Clear evaluation of the company strategies and evaluation of the business risk. |
| 3 | Development plan | Guide of all the decisions related to localization, production and marketing | Translate the first two steps into a concrete action plan, with timing and modalities. |
| 4 | Structure and Management | Evaluation of a congruent business structure with clear identification of roles and competences to achieve defined results. | Understanding of available resources and resources needed. |
| 5 | Financing resources | Definition of the financial resources that can be found to finance the business. | Identify financial provider |
| 6 | Economical-financial projections. | Projections of economic and financial return in a defined reference period. | Expected return and capital needs. |

In particular, in business description (phase 1), a clear market focus should be identified, for instance through successful use cases that can emerge from Robohome2.0 pilot. The economic evaluation is defined as **comparative analysis of alternatives based on the benefits and costs**[157]. These will be composed of direct and indirect costs. Incremental Cost-Effectiveness Ratio (ICER) will be considered as:

$$ICER = \frac{Cost_{Robohome2.0} - Cost_{TraditionalCare}}{Effectiveness_{Robohome2.0} - Effectiveness_{TraditionalCare}}$$

**Direct costs** of the National Health System are mainly costs of primary care, ambulatory visits, and drugs. In particular, the “sliding doors” mechanisms of evaluation, that is based on the number of admissions to primary cares, can be used (these data are available at SAS and PCL sites) to derive a **standard cost for each group of elder with similar clinical profiles**. Direct costs for Robohome2.0 also incorporate the costs of Robohome2.0 technology and its technical maintenance over time. **Indirect costs** are also identified. These can be, for instance, care-givers time, nurses intervention, devices needed both for assistance and for clinical monitoring. **Quantification of indirect costs** iscarried out in collaboration with Public Health Providers (SAS, MUNICIP and Lombardy Region) in the three states in which the pilot will be carried out: Spain, Sweden and Italy. In the phase of structure and management

[156] Pinson, Linda. Anatomy of a Business Plan: A Step-by-Step Guide to Building a Business and Securing Your Company’s Future (6th Edition). Dearborn Trade: Chicago, USA, 2004.

[157] Ortún V, Pinto JL, Puig-Junoy J. La economía de la salud y su aplicación a la evaluación. *Aten Primaria,* 2001; 27:62

(phase 4) of the business plan **RTL of the different components (Section 1.3.2) will be fully taken into account** in estimating the resources required to bring all components to the product level and to evaluate the time to market of several components. Such business plan can be the basis of any company that would enter into the field.

### Data management

Robohome2.0 will collect a large amount of heterogeneous data through monitoring systems, community and activity center. These data will be stored in the cloud hosting the community and are environment, lifestyle, physiological measurement, and data from the activity center. Given the nature of the data, no data sensitive issue is forecast. To adequately storage these data new generation no-SQL data bases like Voldemort, MongoDB, Cassandra, Neo4j, will be explored and compared with the traditional SQL ones. They will be then transmitted using XML or json standards. These data will be used for tuning the profile of the elder, the activities and to assess his/her status over time. The data will be resident on the service provider for the duration of the project and they will be deleted after project end, unless one or more partner make a request for the data, that has to be approved by PSC.

### b) Communication activities

Different communication activities to promote the projects results and findings among public audience will be established. The aim is to raise globally the perception of new possibilities for assisted living offered to the elder through grounded results. Conventional channels like exhibitions, meetings, scientific open access publications as well as non-conventional ones like LinkedIn, YouTube, Facebook, will be exploited to diffuse the project results. Given the variety of target audience and stakeholders the communication activities will be always tailored to the audience needs and knowledge in order to maximize the understanding. The communication activities will be leaded by the PC with the major support of POLIMI and PCL. Communication activities will include: **1) Robohome2.0 Website** As already explained, the Robohome2.0 website will be one of the main promotional tools of the project. It will be here that news and latest information about the project will be available. Public deliverables will be placed on the website as well as practical information about the project. **2) Newsletters** Robohome2.0 will produce a regular newsletter in electronic and printable formats. The newsletter will be generated every 6 months of the project and contain a list of latest achievements and initiatives in the Robohome2.0 project formatted to general audience. **3) Press Releases** will be made at regular intervals throughout the project. They will be provided initially by the PC exploiting the internal office of UMIL. A first press release is produced at project start, and translated into the language of the country of the other partners. **4) Articles.** Publication of scientific articles is an important aspect in order to disseminate the results, and as Robohome2.0 represents technical, social and medical aspects of at home monitoring and rehabilitation through gamification, a wide range of venues are suitable for publication. Suitable fields and communities for Robohome2.0 publication include: Technical journals in Computer Science related to sensor networks, robotics, artificial intelligence and human robot interaction; Journals and conferences in Health Sciences; Popular Magazines related to social welfare and care; Journals and magazines on standardization for ambient assisted living.**5) Project videos** During the project different videos will be created in order to disseminate the project results. These videos will be made available to the general public not only by means of the project website but also through the You-Tube channel. It will be possible to include in these videos also the direct experience of the elders involved in the final pilot testing phase to demonstrate the usability of the Robohome2.0 platform. Translation in the partners language is produced. **6) Social Networking** Social networking (Twitter, Facebook) is rapidly becoming a common means to disseminate EU projects. Robohome2.0 will endeavor to use social networking where relevant. Keeping in mind that the end user targets are typically an elderly generation with less exposure to online social media channels, the use of social networking will be kept to a reasonable amount in relation to the impact for dissemination. **7) Participation in External Conferences and Events** is encouraged to present project outcomes. In addition to presentation of scientific results as talks, Robohome2.0 may also have a stand or booth at suitable venues. **8) Organization of workshops** A dedicated workshop will be organized before the end of the project to sustain awareness about the project and its results. The workshop will be possibly included in an international conference to increase the visibility in the ICT and healthcare scientific community (Task 9.3). **9) Brochures and leaflets** will be prepared at the beginning of the project and at least every year will be updated to the ongoing results. They will be distributed during the main events, conferences workshops and meetings with audience in which each of the partners will be involved **10) Test sites.** As the long term handling of a test site presupposes a good relation with the community and elderly organizations, municipalities and general organizations surrounding the elderly, the projects needs to be viewed positively in such organizations and the general public. Living labs and pilot sites can give rise to contact with press / media and good results in test sites should be well spread in order to promote further test sites, increasing results impact. Results from test sites will naturally be included in the scientific dissemination strategy such as publications but non-technical results should be promoted via newsletters and press releases. The following table outlines the possible communication channels and how they reach to the various target groups. The selection of tools varies depending on the target audience.

| | | Target Group | | | | | |
|---|---|---|---|---|---|---|---|
| | | EC | Academia | Industry | HealthCare Professionals | General Public | Media |
| Comunication channels | Website | X | X | X | X | X | X |
| | Newsletter | | X | X | X | X | |
| | Press Release | | | | | X | X |
| | Publications | X | X | | X | | |
| | Videos | | | | | X | X |
| | Social Networking | | X | X | | X | X |
| | Participation to conferences | | X | X | X | | |
| | Organization of dedicated workshops | | X | | X | X | |
| | Brochures and leaflets | | X | X | X | X | |
| | Testsites | | | | X | X | |

# 3. Implementation

## 3.1 Work plan — Work packages, deliverables and milestones

### 3.1.1 Overall strategy and general description

The Robohome2.0 project will build on 10 work packages. *WP9* and *WP10* will cover transverse activities, namely: *Dissemination and Exploitation* and *Management* activities, while the other work packages will be devoted to the design, the development, the integration and the evaluation of the complete Rohome2.0 System.

***WP1, Functional Specifications***: will be carried on the basis of the needs and requirements of end-users: clinicians (SAS, PCL), caregivers (KORIAN and KOMMUN) and elders (PCL, SAS and KOMMUN). The Roohome2.0 platform will be designed to support the elder at home and to allow the caregivers and clinicians a reliable supervision. To this aim, **a clear picture of the functionalities required for monitoring** (the elder lifestyle, his/her psycho-physical status and the environment), for **assistance in every day life tasks, for activities and for evaluation** will be drawn and documented in D1.3. Modality for functional evaluation through the pilot (WP8) will also be defined, with case use scenarios (Task 1.6). Ethical submission documentation will also be prepared (Task 1.7).

***WP2, Implementation requirements***: will be carried out in pipeline with WP1 with the aim of defining the **technical specifications** of the system and of its components. The most suitable solution will be identified. Given the large number of components envisioned, particular attention is put on **modularity** and **interoperability:** diffused standards, hardware and software, will be used. The modality of evaluating the components and the whole system will be set as well as the requirements in terms of availability, dependability, accuracy and latency (Task 2.6).

***WP3, Virtual caregiver and service robot***: Infrastructure specifications will be defined. Autonomous navigation of Giraff will be developed and elder tracking with 3D camera implemented. The virtual caregiver that controls the entire system **through state-of-the art AI functionalities** will be developed. Functionalities that assist the elder in everyday tasks will be also implemented (Task 3.8, 3.9). Teleoperated clinical tests will be realized (Task 3.7).

***WP4, Activity center:*** provides activities under the form of adequate exer-games. Automatic narration is developed **as a gluing elements** of mini exer-games (Task 4.3). Personalized educational exer-games are developed (Task 4.4). **Gaming results will be made available to the community** to increase socialization (Task 6.3) and **interaction data will be made available to the Virtual Caregiver** for evaluation, assessment and tuning (Task 3.3, Task 3.6).

***WP5, Monitoring systems***: through networks that monitor the environment (Task 5.3) and collect physiological measurements (Task 5.6). A transparent monitoring system will be implemented in Tasks 5.1 and 5.2. **The voice distributed command system used to call Giraff** will be implemented in Task 5.5 and social monitoring in Task 5.4.

***WP6, Community of users:*** Realization of a **dynamic community** in which the elders can find a suitable group of pairs with whom to interact. **Motivation to use the community by elders will be addressed since its design** (Task 6.1 and 6.3). The community allows the carers to access data from monitorings and activity center and will receive warnings from the Virtual Caregiver (Task 6.5).The Apps that allow access to Robohome2.0 functionalities through a smart phone will be implemented in Task 6.6.

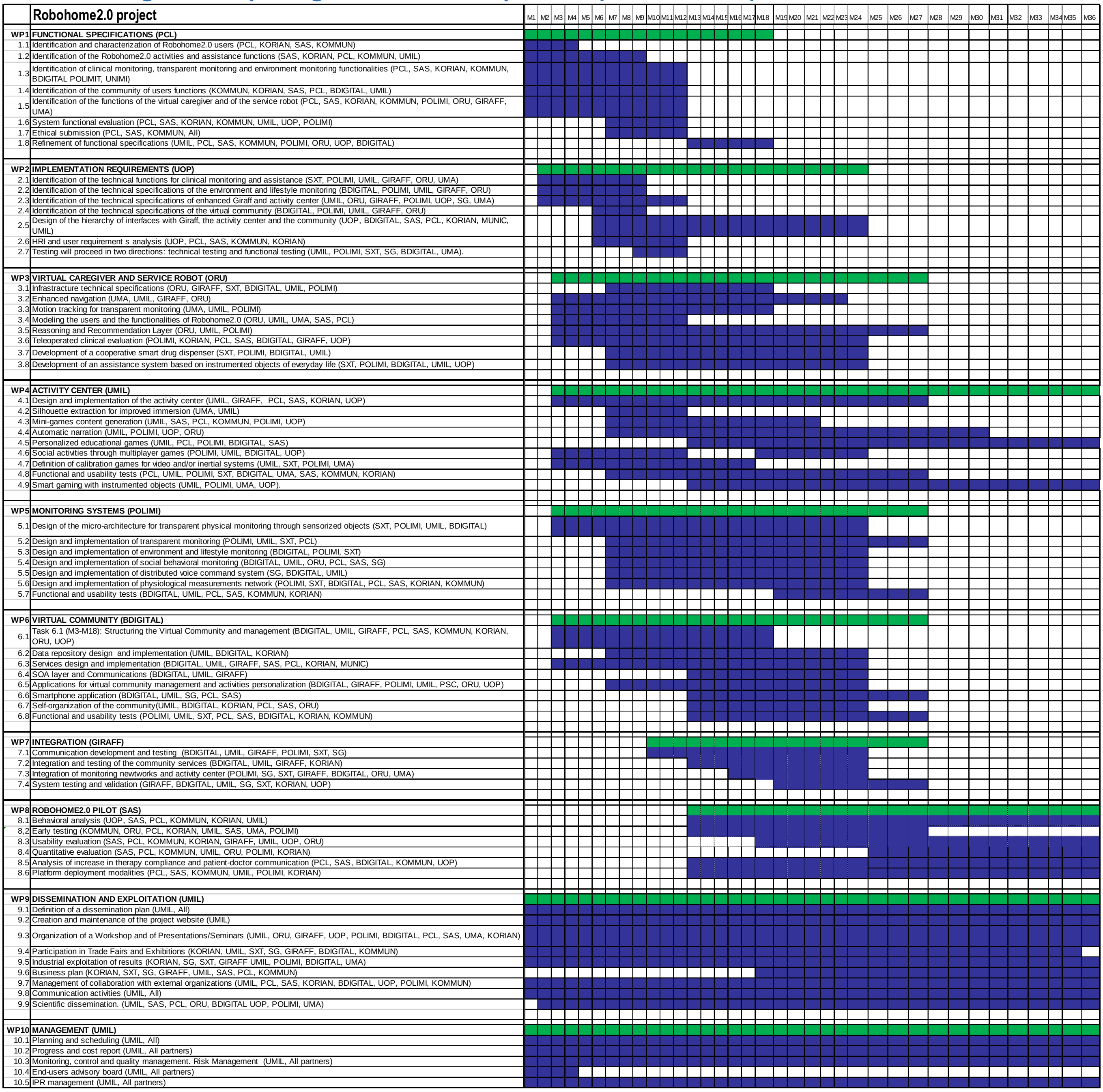
***WP7, System integration:*** takes care of the final integration of all components identified above. To achieve most effective integration **components early testing is carried out, from the technical and functional point of view,** in living labs in ORU and SAS to derive feed-backs from all users and suggestions to improve. UMIL set-ups progressively Robohome2.0 integrating and testing the components developed in increasing stages in WP3,WP4, WP5, WP6 under the guidance of GIRAFF, that tests and validates the final platform on its premises. D7.1 provides the **final specifications of Robohome2.0** and D7.2 a **Report on technical and functional tests of Robohome2.0.**

***WP8, Robohome2.0 pilot***: It will allow the testing of the system in real conditions and tuning it according to the feedback collected from elders, caregivers, family members, physicians and therapists. This WP will allows us to come with quantitative comprehensive evaluation of Robohome2.0 and the new modality of assistance offered by it. **Functional and behavioral analysis will be a fundamental part of this evaluation**.

***WP9, Dissemination and exploitation*****:** Conventional channels, like exhibitions, meeting, as well as non-conventional ones, like LinkedIn, YouTube, Facebook, will be exploited to diffuse the project results. Most effort will go towards private and public structures that offer support to elders.

***WP10, Management:*** provides all support to the project, promoting a shared view to minimize risks. A strong emphasis will be devoted to ethical issues, through a dedicated ethical review board and to IPR management through a direct involvement of UMIL technology transfer office in the evaluation of project's results.

### 3.1.2 Timing of work packages and their components (GANNT Chart)



### 3.1.3 Detailed work description

WP1 – Functional specifications

| Work package number | 1 | | | | | Start date or starting event: | | | | M1 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Work package title | Functional Specifications | | | | | | | | | | | | |
| Participant number | 1 | 2 | 3 | 4 | 5 | **6** | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Participant short name | UMIL | ORU | GIRAFF | UOP | SXT | **PCL** | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMUNN |
| MM per Participant | 5 | 7 | 0,5 | 4 | 0,5 | **9** | 5 | 2 | 8 | 9 | 2 | 2 | 4,5 |

**Objectives:**

- To identify users and use cases of the Robohome2.0 system.
- To define all the functionalities required to Robohome2.0 and define user-case scenarios.
- Prepare the ethical submission document.

**Partners role:** PCL leads this WP for its large clinical experience with elders and strong tights with social services. SAS and KOMMUN have a similar profile, thus combining the experience of 3 different countries. KORIAN provides the vision of a service provider. UMIL brings the experience in developing e-Health platforms for rehabilitation and fosters interaction between clinical and technological teams. BDIGITAL provides possibilities offered by virtual communities. Solutions that will be usable by the elder will be preliminary evaluated by UOP. Technological offer on monitoring, robotics and vision is provided by POLIMI, UMA, GIRAFF and ORU.

**Description of work.** User specifications and functional requirements will be written in a comprehensive technical report (D1.1), publicly available, that lays the ground for the future development of the Robohome2.0 system modules. Two approaches are followed. In the first approach, **bottom-up**, **end users expectations** are solicited by questionnaires, created specifically for each group of users,interviews and focus groups according to different needs and organizations in the different pilot sites, starting from the functionalities identified in the DoW. The second approach, **top-down**, is based on identifying functionalities and their operation modality through Unified Modeling Language (UML) or conceptual maps. Data gathered from these two approaches are integrated into a coherent and complete set of functions. In parallel, a few meetings are organized in clinical sites in which the technology that can be used in the project is shown with videos, mock-ups prototypes and discussed with caregivers and clinicians for its suitability for their approach to care. Clinicians illustrate the current care modalities. A set of **multiple applicability scenarios**, spanning from the old independent adult to the chronic disabled person living at home is designed and guidelines and metric for functional testing are defined. These include acceptability by the users and their caregivers. Refinement of functional specifications is obtained from the analysis of implementation requirements and from the early stages of the development of the components.

***Task 1.1(M1-M4) Identification and characterization of Robohome2.0 users (PCL, POLIMI, KORIAN, SAS, KOMMUN)*** Robohome2.0 groups of users are: 1) the elder, 2) people with a technological role 3) people with a functional role: clinicians, care-givers, relatives and so forth. For each of these categories required functions are identified along with the relationships between the functions. UML and conceptual maps can be used to clarify such processes and roles. **Main users are elderly subjects who are at risk of frailty, cognitive impairment, dependence and social exclusion**. Beyond the 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**. Inclusion/exclusion criteria are defined on the basis of physical and mental conditions, availability and willingness to be involved and on their living environment. Compliance with technology is appreciated. **A plan (including insurance cover) for emergency situations** that might occur during the pilot is designed in collaboration with the EBR. **Assessment measures are identified** and used before entering in the Pilot and the end. **Primary outcome is the evaluation of the fraility condition**. According to the principles of a Comprehensive Geriatric Assessment, the following specific outcomes will be measured at baseline and at the end of the pilot study: Measures of physical performance that can be Tinetti scale[158], Short Physical Performance Battery (SPPB)[159], 4-m walking speed, balance and chair-stand tests[160]; 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/ institutionalization; adherence to therapy;

[158] Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. JAGS 1986; 34: 119-126

[159] Puthoff M. (2008) Outcome measures in cardiopulmonary physical therapy: SPPB. Cardiopulmonary Physical Therapy J. 19 (1): 17-22

[160] 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

quality of life and satisfaction of the caregiver. Additional specific outcomes might be added according to the phenotype of the elder and his lifestyle (for example, HbA1c for a diabetic elder; number of daily naps).

***Task 1.2(M1-M12) Identification of the Robohome2.0 activities and assistance functions (SAS, KORIAN, PCL, KOMMUN, UMIL, POLIMI)*** A wide range of exercises aimed to counteract physical and cognitive decline are defined according to current geriatric practice[161]. Additional suggestions are: a) Themes suitable to narration for the largest elder population, taking also into account gender difference. b) Parameters that determine the exercise difficulty and that are tuned to elder state (e.g. amplitude, accuracy or speed of the movement). c) Parameters to monitor the elder's performance quality in terms of intensity, time and correctness. d) Possible constraints on the design associated to elder characteristics, for instance elements size and contrast. e) Definition of the elements that concur to motivation. An effective and balanced reward system is defined as well as several possible ways of defining levels of difficulty of the exercises in front of the elder residual capabilities. Most suitable card games to improve socialization will be defined. **Assistance functions** A set of objects that can be lost are identified and the requirements of the smart drug dispenser defined. Groups of diets are also identified in this task. Functional specifications of these services will be identified along with real case scenarios for testing.

***Task 1.3(M1-M12) Identification of clinical monitoring, transparent monitoring and environment monitoring functionalities (PCL, SAS, KORIAN, KOMMUN, BDIGITAL, POLIMI, UNIMI)*** Aims of clinical monitoring is clearly identified and use case defined and reported in D1.3. Possible implementation modalities will also be described having in mind the whole spectrum of aspects to be monitored: **A) Monitoring Cognitive and physical performance through exer-gaming provided by the activity center.** The activities offered by Robohome2.0 and defined in Task 1.2 allow collecting data that are useful for monitoring the elder. 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, and so forth. Design of scenarios to administer classical psycho-physical tests with remote supervision of the clinicians are designed. **B) Monitoring cognitive and physical decline through transparent monitoring.** Suitable scenarios and associated objects and modalities are defined along with data accuracy Possible parameters suitable as Degradation Indexes are defined according to physiological knowledge on normal functions. Most suitable parameters that can be derived from the analysis of phone conversations are identified. **C) Monitoring the elder lifestyle through environment sensors.** Functions are defined along with scenarios such us number of hours of sleep, number of times the user goes to the toilet or sits in front of TV. **D) Monitoring social interaction.** A baseline of social attitude of the elder is measured at pilot start with relatives and caregivers. Functions to measure deviations will be defined, like log book, use of the community, frequency of going out, input from caregivers provided from instance through on-line forms provided by the community (Task 1.4). Additional information is derived profiling phone calls. **E) Monitoring Health Conditions.** Physiological parameters that are required to monitor health conditions will be identified according to modality and frequency: e.g. blood pressure, heart rate, glucose concentration or saturation. Conditions that have to trigger an alert to the elder GP will be defined on the basis of the parameters measured and the elder clinical profile (Task 1.6).

***Task 1.4(M1-M12) Identification of the community of users functions (KOMMUN, KORIAN, SAS, PCL, BDIGITAL, UMIL)*** **A role will be defined for each type of user and each role will have its own assigned permissions and specific functions**. In particular, the relationship between the caregivers, the clinicians, the elders and the other possible users of Robohome2.0 platform is identified. Functions required to provide virtual interaction between community members, as also to run and review personalized activities adapted to the elder status will be identified with a tight cooperation between technological and clinical partners.

***Task 1.5(M1-M12) Identification of the functions of the virtual caregiver and of the service robot (PCL, KORIAN, SAS, KOMMUN, POLIMI, OUR, GIRAFF, UMA, UOP)*** A clear definition of: a) the recommendations required from the Virtual Caregiver as output of Task 3.5; b) modalities of tuning of the exer-games and activities to the elder profile and state and c) situations detected from monitoring and activity data that need caregivers or GP assistance. Clear definition of situations in which Giraff autonomus navigation is triggered, and constraints that have to be considered when planning the path. A definition of compliant approaching path is defined and interaction modalities with Giraff (gesture, voice).

***Task 1.6(M7-M12) System functional evaluation (PCL, KORIAN, SAS, PCL, KOMMUN, UMIL, UOP)*** Given the interplay between the elder and the robot and hat the type of assistance provided is multi-dimensional, the evaluation task will be complex and based on a set of indexes. Overall, the system activity is evaluated using questionnaires for three comprehensive aspects: 1) elder's compliance with the intervention; 2) measures for

[161] 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)

elder's satisfaction with the intervention; 3) customized measures for the achievement of the cognitive, physical, social and clinical objectives set at the beginning of the intervention. Measures for elder's compliance with the system are frequency of use of the system and rate of completion of activities proposed. The elder's satisfaction is evaluated using the **Technology Assessment Model (TAM)** aimed to assess the impact of the technology[162], [163], according two main aspects: the perceived usefulness and the perceived ease of use. The questionnaires are administered before and at the end of the pilot to all actors, including family/non-family caregivers involved in the intervention. Moreover, since the specific typology of intervention, among the range of functions that Robohome2.0 can provide, is customized to the characteristics and the needs of each elder, users are asked to define their own metrics and modalities to evaluate the **overall effectiveness** of the intervention, which might involve the cognitive, physical, social and clinical sphere. Finally, adequate clinical tests are defined to assess the elder; data are collected before and after Robohome2.0 usage and can be used for designing a later randomized controlled trial that will compare Robohome2.0 technology with standard assistance provided by socio-health services. Such tests are used in Task 8.4 for assessment.

***Task 1.7(M7-M12) Ethical submission (PCL, KORIAN, SAS, KOMMUN, All partners)*** Being volunteers and patients involved in the intervention, the pilot description is submitted for approval to the competent Ethical Committee of SAS, PCL and KOMMUN. Together with the Ethics Review Board a consent form for participants will be elaborated. It has at least the following fundamental components: it describes all the information concerning the characteristics of the intervention, including the possible expected risks; it protects data confidentiality; it guarantees subject's freedom to refuse to participate to or to withdraw from the study at any time without affecting the preceding management plan. The consent to participate is sought from the elder, but also from other possible users involved in the intervention (e.g. family/non-family caregivers).

***Task 1.8(M13-M18) Refinement of functional specifications (UMIL, PCL, SAS, KOMMUN, POLIMI, ORU, UOP, BDIGITAL)*** The specifications set in D1.1 will be reanalysed taking into account the constraints posed by technical offer and early implementation. The final functional specifications have still to match users requirement although with different modalities. For instance, a given physiological measurement turns out not reliable with available technology and the presence of a nurse or of a caregiver becomes required. The final specifications are collected inside D1.3, publicly available, that will offer the state of the art in assisted robots in smart environments.

**Deliverables:**

D1.1 [R, CO] Preliminary functional specifications (PCL, M12). Elders inclusion / exclusion criteria will be defined. Required functionalities for monitorings: environment, psyho-physical, social and lifestyle, assistance both in everyday tasks and in therapy adherence, activity center and evaluation will be defined. Specifications of clinical tests will also be provided. All specifications will be supported by use-case scenario design.

D1.2 [R, CO] Documentation for ethical commission submission (PCL, M12)

D1.3 [R, PU] Final functional specifications. The functional specifications in D1.1 are refined according to implementation requirements set in WP2 and to early testing in WP8 D1.3 represents therefore a complete document of the functionalities of a service robotic platform that can support the elder at home and will be fully exploited in WP9, as a scientific publication and as a publication targeted to policy makers.

## WP2 – Implementation requirements

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package number** | 1 | | | | **Start date or starting event:** | | | | | M2 | | | |
| **Work package title** | Implementation requirements | | | | | | | | | | | | |
| **Participant number** | 1 | 2 | 3 | **4** | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | UMIL | ORU | GIRAFF | **UOP** | SXT | PCL | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMUNN |
| **MM per Participant** | 3 | 6 | 1 | **11** | 3 | 5 | 6 | 4 | 1 | 4 | 2 | 6 | 2 |

**Objectives**

- Define the technical specifications of the Robohome2.0 platform and identify the most suitable components in terms of reliability, costs, availability.
- To identify and design the main HRI interfacing modalities to maximize compliance and effectiveness.
- To identify and design the main GUIs that will be displayed on the different displays used (Giraff monitor, TV monitor, smart phone and PC).
- To design technical evaluation tests of the system components and of the whole platform.

[162] 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.
[163] 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

**Partners role:**
The WP is aimed at finding the best technology and implementation that matches the requirements set in WP1. UOP for its experience in working with robots and users is the ideal candidate to lead the work. BDIGITAL mainly contributes in defining the implementation specifications of the virtual community and of environmental monitors, POLIMI for designing the assistance system and with SXT and UMIL in designing the psycho-physical transparent monitoring. UMIL provides its experience in designing game centers acquired in the Fitrehab and Rewire projects. UMA and GIRAFF will provide experience in working adeveloping Giraff. Clinical partners, PCL, SAS, and KORIAN will provide the users point of view.

**Description of work** WP2 defines the technical specifications of Robohome2.0 and of its components to comply with the functional specifications set in WP1. A tight coordination with activities in WP1 is needed and is guaranteed by the PC. Cost, reliability, dependability, usability are considered. The SW/HW specifications of all the components are identified: robot, virtual caregiver, activity center, assistance, community and the different monitoring systems (environment, physiological parameters and lifestyle). Devices and applications that already match given functionalities will be considered. Modalities of integration of off-the-shelf and specifically designed components are defined within a modular architecture suitable to be expanded already during the project. Given the fast pace of development of new sensors and physiological devices, Robohome2.0 will reserves the opportunity to integrate novel sensors that are made available in due course.

***Task 2.1(M2-M9) Identification of the technical functions for clinical monitoring and assistance (SXT, POLIMI, UMIL, GIRAFF, ORU, UMA)*** The components of the micro-architecture that constitutes the sensing module that provides pressure and motion of everyday life objects is identified. Pressure and motion range and accuracy, sampling rate, maximum delay, drift, non-linearity and all the other characteristic parameters are defined as well as synchronization modalities. Recharging modalities and data transmission are also specified. When monitoring is carried out by Giraff camera, the joints and degrees of freedom that have to be tracked are identified. Specifications on size, style and graphical format of questionnaires for cognitive monitoring is defined. The micro-architectures for remotely controlling the smart drug dispenser is identified,. A proper miniaturized design is produced and for the sensing module and the transmission protocol defined. The components that allow measuring the physiological parameters with clinical validity are identified.

***Task 2.2(M2-M9) Identification of the technical specifications of the environment and lifestyle monitoring (BDIGITAL, POLIMI, UMIL, GIRAFF, ORU)*** The off-the-shelf components that are assembled to produce a reliable and accurate sensing embedded inside the environment, according to specifications set in WP1, are identified and characterized. Temperature, luminosity, humidity, gas alerts, opening entrance door, presence in the rooms, will be among the monitors of choice. Sofa and bed pressure mattress as well as mattress humidity are among the possible measurements taken on lifestyle. For each of these measurements range, frequency, accuracy are defined. The most diffused networking systems, like z-wave, is analyzed and reported in D2.1.

***Task 2.3(M2-M12) Identification of the technical specifications of enhanced Giraff and activity center (UMIL, ORU, GIRAFF, POLIMI, UOP, SG, UMA)*** The autonomous navigation system of Giraff is defined by UMA to meet specifictions set in Task 1.5. Reacting navigation planning is fully explored. The most suitable framework to implement the reasoning engine based on DL will be identified, taking into account its speed and scalability. The conditions required by the distributed voice control system, are defined in terms of microphones aperture, signal to noise ratio and the words that have to be recognized. Languages differences will be addressed. The solution based on local DSP processing, envisaged in Robohome2.0, will be compared with a centralized solution based on Microsoft APIs for voice recognition, made available since Windows 7 OS. The most suitable platform to develop the activity center is identified, taking into account the compatibility with Windows OS mounted on Giraff, and the requirement to exercising using several display and input devices.

***Task 2.4(M2-M9) Identification of the technical specifications of the virtual community (BDIGITAL, POLIMI, UMIL, GIRAFF, ORU)*** The characteristics of the software and hardware elements that constitute the Virtual Community are defined in terms of workload, data storage and responsiveness. A high level architecture based on open source standards and accessible technologies is designed starting from the Integrated Continuous Care telemedicine platform) provided by BDIGITAL. A set of interconnection interfaces between the different Virtual Community components is defined. All technical requirements captured in this task will be used as input for the WP6 during the Virtual Community components development, deployment, testing and production tasks.

***Task 2.5(M3-M24) Design of the hierarchy of interfaces with Giraff, the activity center and the community (UOP, BDIGITAL, SAS, PCL, KORIAN, KOMMUN, UMIL)*** A flexible graphic user interface (GUI) is designed to allow the different type of users to interact effectively with Ronohome2.0. Classical design rules set by Constantine and co-workers[164] will be followed: 1) The structure principle. Your design should organize the user interface purposefully, in meaningful and useful ways based on clear, consistent models that are apparent and recognizable to users, putting related things together and separating unrelated things, differentiating dissimilar things and making similar things resemble one another. The structure principle is concerned with your overall user interface architecture. 2) The simplicity principle. Your design should make simple, common tasks simple to do, communicating clearly and simply in the user's own language, and providing good shortcuts that are meaningfully related to longer procedures. 3) The visibility principle. Your design should keep all needed options and materials for a given task visible without distracting the user with extraneous or redundant information. Good designs do not overwhelm users with too many alternatives or confuse them with unneeded information. 4) The feedback principle. Your design should keep users informed of actions or interpretations, changes of state or condition, and errors or exceptions that are relevant and of interest to the user through clear, concise, and unambiguous language familiar to users. 5) The tolerance principle. Your design should be flexible and tolerant, reducing the cost of mistakes and misuse by allowing undoing and redoing, while also preventing errors wherever possible by tolerating varied inputs and sequences and by interpreting all reasonable actions reasonable. 6) The reuse principle. Your design should reuse internal and external components and behaviors, maintaining consistency with purpose rather than merely arbitrary consistency, thus reducing the need for users to rethink and remember. Interface elements, like text font size and colour, sprites dimension and scene apparent size, are made adjustable to the elder residual sight so that no effort is required for interacting through the chosen display. The GUI are designed and adapted for web browsers, smartphone applications, TV monitor and Giraff robot dsplay. Particular care is put in the **design of the virtual caregiver avatar**, such that it does not fall in the so called "**uncanny valley**"[165]. 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 (cf. Figure 4)[166]. We design and provide several avatars so that the elder can choose the preferred one according to his taste. Avatars are endowed with a repertoire of movements and simple facial animation with approximated lip synch among which the most suitable animation congruent with voice feed-back will be produced.

*Figure 4* - Two possible Virtual Caregivers from the IGER system: a) a humanoid avatar, Hannah, b) a mascot, Piggy: some users preferred a puppet, that stresses the game nature of the interaction, while others felt more reassured seeing on the screen an avatar resembling a doctor.

***Task 2.6(M2-M12) HRI and user requirement s analysis (UOP, PCL, SAS, KOMMUN, KORIAN)*** This task concerns the design of the multimodal HRI interfaces to facilitate natural interaction between the robot and the users. The interface combines various interaction modalities as speech, touch screen, movement. Focus is placed on interface facilities to manage the user's explicit and implicit feedback[167]. Such interfaces are used in combination with a speech dialog system to facilitate interaction. The interface have also to provide speech-based feedback to ask questions, to solve pragmatic ambiguities, to motivate and encourage the elder. This informs the design of the interaction features, the HRI multimodal interface, and the design and analysis of the experimental sessions. The task combines the use of questionnaires to reach a larger group of potential users at the partners' sites. In addition, individual interviews and focus-group sessions will be conducted to investigate specific design interaction issues in more depth. These methodologies 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 that will be evaluated in Task 8.1.

**Scenario:** Giraff approaches Ann this morning and says to her: "Come on Ann, today is a beautiful and sunny day, why don't you call your nephew Jane to bring her to the park?". Ann, was a bit said; she finds this a beautiful idea, called Jane and spent a wonderful morning. She was really greatful to Giraff.

***Task 2.7(M9-M12) System testing (UMIL, POLIMI, SXT, SG, BDIGITAL, UMA).*** A set of technical tests are designed

[164] L Constantine and H. Windl "Usage-Centered Design: Scalability and Integration with Software Engineering." In C. Stephanidis and J. Jacko (Eds.) Human-Computer Interaction: Theory and Practice. Proceedings of the 10th International Conference on Human-Computer Interaction, Crete, Greece, 22-27 June 2003. Mahwah, New Jersey: Lawrence Erlbaum Associates, 2003. L.Constantine, . Software for Use: A Practical Guide to the Models and Methods of Usage-Centered Design, Addison-Wesley, 1st ed. 1999.

[165] 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

[166] M. Pirovano, R. Mainetti, G. Baud-Bovy, P.L. Lanzi, N.A. Borghese, IGER – Intelligent Game Engine for Rehabilitation, IEEE Trans. CIAIG, submitted.

[167] Broz F., Di Nuovo A., Belpaeme T., Cangelosi A. Multimodal Robot Feedback for Eldercare. Workshop at IEEE ROMAN IEEE International Symposium on Robots and Human Interactive Communications. 2013.

for testing the functionalities of the whole platform and of each component. They verify the communication between the components and their functioning according to the specifications set. Software will be developed in a high modular fashion, therefore unit testing methodology[168] will be preferentially be used. This will allow the possibility to adapt easily the tests to specific sections of software that change throughout the development.

**Deliverables**:
D2.1 (R, CO) Technical specifications of the platform and its components (POLIMI, M12)
D2.2 (R, CO) HRI analysis and definition of robot-users interfacing modalities (UOP, M12)
D2.3 (R/OTHER, CO) GUI design. Design of the major GUI of Robohome2.0 inspired to modularity (UMIL, 24).
D2.4 (R, CO) Design of testing the system and its components. The tests used and the data obtained at the end of the development of the components: WP3, WP4, WP5 and WP6 (POLIMI, M12).

## WP3 – Virtual Caregiver and service robot

| **Work package number** | 3 | | | | **Start date or starting event:** | | | | M3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Virtual Caregiver and service robot | | | | | | | | | | | | |
| **Participant number** | 1 | **2** | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | UMIL | **ORU** | GIRAFF | UOP | SXT | PCL | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | 5 | **15** | 1,5 | 2 | 1 | 7 | 9 | 2 | 2 | 3 | 0 | 22 | 3 |

**Objectives:**
- To provide Giraff with autonomous navigation compliance with the elder.
- To enable Giraff to provide elder tracking for monitoring;
- To develop tele-monitored clinical tests to be performed by the elder at home;
- To profile the user and update the profile according to data provided by activity center, environment, lifestyle monitoring and psycho-physical monitoring, and from inputs from the community of users;
- To infer changes in the user condition from the whole information gathered by the sensorized home and the activity center;
- To provide assistance in finding objects and to design and realize a smart drug dispenser.

**Role of the partners:** ORU leads this WP for its competences in AI. UMA coordinates the research on navigation and work with UMIL in tracking the elder with Kinect for exer-gaming. SXT leads the work on building assisting devices. BDIGITAL brings its expertise in designing and processing environmental data and GIRAFF the knowledge on robot infrastructure. PCL, SAS and KORIAN bring the view of robots users and on the definition of critical situations and the different warning levels required when monitoring the elder. UOP supports the development of telemonitoring and assistance to made them most compliant.

**Description of work** Aim of this WP is to transform Giraff from a teleoperated platform into an autonomous service robot that can provide assistance, advice and monitoring of the elder upon the work of the Virtual Caregiver embedded in Giraff. Computational engines based on DL are developed. Profiling of the elder is based on ontologies. Search of lost objects and smart drug dispenser will be realized.

***Task 3.1(M7-M18) Infrastructure technical specifications (ORU, GIRAFF, SXT, BDIGITAL, UMIL, POLIMI)*** To effectively develop the system, it is made clear that all components have to be developed such they can be easily and effectively integrated. It is important that the different parts of the system were communicating from start and therefore the definition of a proper software architecture is required: a middleware installed on Giraff PC, defined in this Task. We are aiming at OSGi architecture[169] that is widely diffused for AAL applications, it allows integrating heterogeneous devices and it scales with new devices/services at need. This task defines also the software services that the infrastructure should support. The middlware should be able to support the acquisition of sensors data periodically or upon request. Some data require negligible delay, like gas alarms or voice commands, others, like presence sensors pose less tight constraints. Z-wave appears the best match for environment network, but other standards that would become available at project starts will be evaluated as well. Bluetooth connection seems the most effective transmission modality to acquire data from sensorized objects because of its tread-off between power and latency. Indeed Bluetooth connection has already been implemented in devices for clinical use, like the Tymo balance boards[170].

***Task 3.2(M3-M24) Enhanced navigation (UMA, UMIL, GIRAFF, ORU)*** is required for Giraff to move around autonomously without crashing over objects and finally, it is used to gentle approaching the elder. This task

[168] Kolawa, Adam; Huizinga, Dorota (2007). Automated Defect Prevention: Best Practices in Software Management. Wiley-IEEE Computer Society Press.
[169] http://www.osgi.org/
[170] http://tyromotion.com/en/products/tymo/overview

capitalizes on the experience on navigation and SLAM of UMA[171,172]. We start from the 2D plant of the house that in enhanced through enhanced through the data acquired by Giraff while moving inside the house to create a 3D static map of the house. Possible risky areas can be defined (e.g. precious vases or furniture). We provide the robot the capacity to move from one place of the house to another, selecting the best route (global navigation) and avoiding any obstacle encountered along its way (local navigation). As for global navigation, houses present a highly structured topology, typically a corridor connecting rooms. Global navigation between two locations of a house (in general, from two different rooms) we proceed as follows: first, planning a sequence of intermediate places (from the topological map) from the start to the destination, and then to concatenate a series of reactive navigations between them extending to 3D the previous work of the UMA group on 2D reactive navigator. Apart from the geometrical and kinematics robot constraints, we will explore here how introduce additional proxemic constaints to path planning. We develop also an ecological approach for both the autonomous navigation of Giraff and its approach to the elder by identifying the path and velocity profile that are most suitable.

***Task 3.3(M3-M18) Motion tracking for transparent monitoring (UMA, UMIL, POLIMI)*** In this task a function that automatically determines the optimal location and orientation of Giraff to observe the elder to provide transparent monitoring (Task 5.2) is implemented. To obtain a clear view of the elder and his/her movement, the type of movement surveyed, its amplitude and position in space as well as the constraints provided by the room inside which the activity takes place, are considered. Elder motion is captured as a moving skeleton produced by Kinect SDK and described in quaternion notation.

***Task 3.4(M3-M12) Modeling the users and the functionalities of Robohome2.0 (ORU, UMIL, UMA, SAS, PCL)*** This task is concerned with creating semantic models (ontologies) that depict information about the end users, domain, activities, functionalities of objects etc. The goal is to align the various high level models in order to link them for eventual reasoning on the data provided by monitoring and activities. This information is used to tune the activities inside the activity center; this task will be developed in tight connection with UMIL. The actual elder profile will be initialized according to information gathered from clincians and caregivers, and it will be updated according to informations gathered by monitoring and activity[173]. Elder's idiosyncrasies is also considered.

***Task 3.5(M3-M27) Reasoning and Recommendation Layer (ORU, UMA, UMIL, POLIMI)*** Based on the models in Task 3.4, eventual rules are constructed that link the models with the data from the sensors, the community and the activity center. Such rules are then used for providing recommendations. Features of the reasoning layer are formed based on the representational model of knowledge. The semantic model which unifies various types of knowledge provided by different sources, allows to structure the domain of interest in terms of concepts (classes) and roles (relations between classes), namely TBox, along with ABox which is bout assertions on individuals (instances of the class)[174]. Given the knowledge structured in form of TBox and Abox in Description Language, the next step is implementing rules examples of which are OWL expressions or SWRL. These rules which allows the reasoner to infer implicit knowledge are written based on the requirements of the application. Since (deductive) reasoners implemented for DL (such as Pellet, FaCT++, HermiT) are based on top-down logic, the reasoning process starts with premises of rules and leads to necessarily true conclusions. For instance, in order to enable the reasoner to suggest different things mentioned in the following scenario, it is needed concepts such as person, friend, activity, social activity, etc., along with their relations are modeled in Tbox. Abox also needs to contain Anna, her friend and playing card as instances of aforementioned concepts. The key point in developing systems with the rules having time-based conditions (e.g., suggesting to call a friend if Anna has not heard about since a long time) is modeling the concept of time. The reasoner needs to be called in different intervals to check passed time for those concepts or actions (calling friend) which are included in a rule with a time concept. Furthermore, due to the unreliability of systems most of whose observations are provided by sensors, the reasoner needs to be also equipped with bottom-up logic where the truth of conclusions based on the evidence is plausible rather than certain. For this, a plug-in accompanying the DL reasoner needs to be implemented so as to prepare axioms and rules of the knowledge base for the abductive reasoning. In this way, the reasoner will also be able to reason even upon incomplete knowledge (lack of observations). Recommendations are presented via the caregiver avatar that passes the actual utterances with recommendations to the elder. We will also implement a function that selects the best channel to interact with

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[171] J.L. Blanco, J. Gonzalez-Jimenez, J.A. Fernandez-Madrigal, **"Optimal Filtering for Non-Parametric Observation Models: Applications to Localization and SLAM"**, *The International Journal of Robotics Research (IJRR),* vol. 29, no. 14, 2010

[172] J. Gonzalez-Jimenez, C. Galindo, F. Melendez-Fernandez, J.R. Ruiz-Sarmiento, "Building and Exploiting Maps in a Telepresence Robotic Application", 10th International Conference on Informatics in Control, Automation and Robotics (ICINCO), Reykjavic, Iceland, 2013

[173] E Vargiu, L Ceccaroni, L Subirats, S Martin, and F Miralles. User Profiling of People with Disabilities - A Proposal to Pervasively Assess Quality of Life. In ICAART 2013 - Proceedings of the 5th Int. Conf. on Agents and Artif. Intelli. Vol. 2, J Filipe, ALN Fred (Eds) Barcelona Spain, SciTePress 2013.

[174] Gruber, Thomas R. (June 1993). "A translation approach to portable ontology specifications". Knowledge Acquisition 5 (2): 199–220, 1993.

the elder, according to his/her preferences and the devices status (e.g. it can be through an SMS or video message on mobile phone, through Giraff display or through TVscreen).

**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.

**SCENARIO.** Maria has started to use a walking stick, 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[175]" 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 walking stick.

***Task 3.6(M2-M24) Teleoperated clinical evaluation (POLIMI, KORIAN, PCL, SAS, BDIGITAL, GIRAFF, UOP)*** These assessment tests are complementary to the transparent tests developed in WP5 and they have both the aim of a clinical validation of the cognitive and physical status of the elder. A procedure to compute the evaluation is designed and implemented. For cognitive tests can be the collection of the answers provided pressing a given virtual button on the screen. For physical tests, tracking with Giraff camera can provide the data required.

***Task 3.7(M7-M24) Development of a cooperative smart drug dispenser (SXT, POLIMI, BDIGITAL, UMIL)*** Its structure is constituted of a chest of drawers, each with an electro-magnetic lock, a led, and a micro-controller wireless connected to the Virtual Caregiver. Upon command, the chest drawer will un-lock only the right drawer from which the right pill will be taken and will switch on its associated led. At the same time, the virtual caregiver warns the elder through the devices available: Giraff, mobile phone and TV.

***Task 3.8(M7-M24) Development of an assistance system based on instrumented objects of everyday life (SXT, POLIMI, BDIGITAL, UMIL, UOP)*** In this task an assistance system able to locate of everyday objects (reading glasses, keys, mobile phone) will be developed. Some solutions have been proposed on the market. These are based on sticks or key rings[176] to be used with specific Apps, but elderly people would have still 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. We explore here an approach based on new Bluetooth technologies (v 4.0) that allows extending the range of detection, even with reduced power consumption. An adequate receiver software / hardware module will be realized that can be integrated inside Giraff to that the Virtual Caregiver can trigger Giraff to navigate and find objects. Software APIs will be realized also to support this functionality through the smart phone. .

**Deliverables** (brief description and month of delivery)
D3.1 [R, PU] Methodology for profiling the elders and some real case scenarios (ORU, M12)
D3.2 [R/OTHER, CO] Improved navigation functionalities (UMA, M24)
D3.3 [R, PU] The reasoning and recommendation system (ORU, M24)
D3.4 [R/OTHER, CO] Tested prototype of everyday life assistance and therapy compliance (SXT, M24)

## WP4 – Activity Center

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package number** | 4 | | | | **Start date or starting event:** | | | | M3 | | | | |
| **Work package title** | Activity Center | | | | | | | | | | | | |
| **Participant number** | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | **UMIL** | ORU | GIRAFF | UOP | SXT | PCL | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | **27** | 7 | 0,5 | 4 | 4,5 | 6 | 16 | 4 | 2 | 5 | 0 | 8 | 1 |

**Objectives:**
• Realize the Activity Center with full functionalities and communication infrastructure with the Virtual Caregiver;
• Design, implement exer-games that can be adapted to the physical and cognitive status of the elder;
• Design and develop automatic narration for long lasting games;
• Explore the use of generic everyday physical objects as trackers;
• Provide support to social activities and to card games in particular.

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[175] http://en.wikipedia.org/wiki/Whac-A-Mole
[176] https://www.sticknfind.com/, http://www.thetileapp.com

**Role of partners:** UMIL will lead this WP for its specific experience on gamification developed in FITREHAB and REWIRE projects. POLIMI will also participate supporting mainly multi-player gaming dsign. UOP, SAS, PCL and KORIAN will contribute to the most suitable game design and gameplay. UMA contributes on processing 3D camera data and GIRAFF in the architectural support.

**Description of work:** The activity center is built around the **gamification** concept. All gamification elements are considered. Gaming with instrumented objects will be experimented in Task 4.9.

***Task 4.1(M3-M27) Design and implementation of the activity center (UMIL, GIRAFF, UOP, PCL, SAS, KORIAN)*** The most suitable software architecture will be designed to support a large range of cognitive and physical exer-games, according to specifications set in WP1 and WP2, that can guide the elders through social cognitive and physical activities. Basic functionalities will comprehend loading scenes and avatars, collision detection, rendering, and animation capabilities. Most accepted standards for data representation will be used (e.g. XML for definition of activities and configuration, quaternions for motion representation). The center will be based on the IGER game engine and it is **extended in several directions**. We explore **different visualization possibilities** introducing the concept of **device equivalence**. This is a concept well known in the technology domain[177] and it will be fully exploited here to allow the elder to exercise through the best display: Giraff display, computers display, mobile phones or the TV screen will be enabled. The middleware will be extended to provide this support, **formatting the output to the current display chosen by the Virtual Caregiver** as most suitable for a particular activity / message. A **wireless connection between the game center and the TV** will be realized using for instance miracast solution[178]. An extrinsic motivation framework, common to all activities, based on balanced **reward, game design of adequate cognitive complexity and gameplay at the proper level of challenge will be developed**. Controlled randomization of assets, targets, voice feed-back avatar choice, and facial animation are all aimed to increase compliance with the therapy[179]. Automatic mesh simplification algorithms, working on both geometry and viual appearance[180], will be adopted to create a sets of game assets of different LOD. Alternatively more simple heuristics based on objects count and on their dimensions will be used. An adequate **measure of cognitive load**, that takes into account both 3D geometry and texture, **will be defined** to match the elder profile.

***Task 4.2(M7-M12) Silhouette extraction for improved immersion (UMA, UMIL)*** In this task we aim to segment the body of the elder in front of the Giraff 3D camera from the background, and to use the obtained silhouette for visualizing the elder inside a virtual environment through alfa channel[179]. We start from the silhouette obtained segmenting the range image. Although this produces a robust identification of the user, the borders of the silhouette are jerky, and the silhouette is useless[181] for our aims. We improve segmentation exploring local total variation regularization[182] applied to the areas of RGB image corresponding to the silhouette border in the depth image. Regularization is used usually to filter noise preserving sharp edges, it will be used here to robustly identify the edges of the silhouette in RGB images thus improving segmentation.

***Task 4.3(M7-M21) Mini-games content generation (UMIL, ORU, UOP, PCL, POLIMI, SAS, KOMMUN)*** We begin from three starting points: the identified profiles of the elders, the associated mix of activities and a suitable theme (WP1): **personalized environments will constitute the containers inside which the activities will be accommodated.** We design mini-games, inside the theme chosen, that match the required exercises. We consider also that the mini-games will be assembled into a narration in Tasks 4.4. and 4.5. We design **physical exer-games** such that the elder can exercise alone or with her/his caregivers and friends either through the community (Task 6,1) or inside the house (Task 4.5). We also enable the elder to play in front of the TV. In this case Giraff will navigate besides the TV to survey the elder motion while playing. To avoid perspective distortion, correction for viewing angle of Giraff is implemented.

**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 Robohome2.0 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

[177] Berends, Johan H. and Veldhuis, Gerrit J. and Lambeck, Paul V. and Popma, Theo J.A. Device equivalence in integrated optics. Journal of Lightwave Technology, 13 (10). pp. 2082-2086. ISSN 0733-8724, 1995.
[178] http://www.wi-fi.org/wi-fi-certified-miracast%E2%84%A2
[179] Mainetti R, Sedda A, Ronchetti M, Bottini G, Borghese NA. Duckneglect: video-games based neglect rehabilitation. Tech Health Care 21 97–111 97, 2013.
[180] Rigiroli P, Campadelli P, Pedotti A, Borghese NA (2001), Mesh Refinement with Colour Attributes, Computers & Graphics. Vol 25(3), pp 449-461, 2001.
[181] Pirovano M, Ren CY, Frosio I, Lanzi PL, Prisacariu V, Murray DW, Borghese NA, Robust Silhouette Extraction from Kinect Data, In: Image Analysis and Processing–ICIAP 2013 (pp. 642-651). Springer Berlin Heidelberg, 2013.
[182] Rudin, L. I.; Osher, S.; Fatemi, E. "Nonlinear total variation based noise removal algorithms". Physica D 60: 259–265, 1992

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** are based mainly on touch screen interaction. Exer-games are realized on specifications set in WP2, like for instance, puzzle, Simon, or other memory games. Content is generated according to the elder idiosyncrasies. For instance, puzzle games can be based on pictures uploaded by the elders; memory games a competition with Giraff the sequence of instructions of a given recipe (e.g. the preferred cake of the elder's housband / wife), and so forth. Some popular games, like Ruzzle, can be incorporated inside training, promoting also socialization. Support for multiply is provided also for cognitive games. The **activity center provides also simple questions for assessing purpose**. For instance, when switching on the TV the virtual caregiver may ask a question from a cognitive test, picked up randomly, asking for instance the current day, season, month, the name of daughter or son and so forth. **Social activities.** Robohome2.0 takes advantage of multi-player support and audio-video interaction to provide **inside the same display window** a **real-time video-stream of all the elders playing together**, so that each elder sees the others and can interact with them (Task 4.6).

**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(M7-M30) Automatic narration (UMIL, POLIMI, UOP, ORU)*** These mini-games designed in Task 4.3 will be described through an ontology; this will highlight an initial and final state of the episode. Stochastic finite state machines are implemented to chain each next episode, with a probability transition that reflects the degree of compatibility of one episodes with respect to the next and the capability of that episode to support the activity prescribed (e.g. crossing a river can be implemented also through a puzzle game of through a memory game that assigns a reward that allows to accomplish the task). Drama curve will also be considering, alternating activity intense episodes to more quite ones. This methodology will provide the elder with an unpredictable sequence of episodes, thus creating a surprise element that is a fundamental ingredient for motivation. We will explore also reinforcement learning to make the activity center learn which can be the best next episode, for the elder, given his/her idiosyncrasies, by collecting her/his qualitative feedback at the end of each episode. We will also provide information that will be displaced inside the community (success rate, gaming time ….) that will be used to promote competition or cooperation and feed trust mechanisms.

***Task 4.5(M13-M36) Personalized educational games (UMIL, PCL, SAS, BDIGITAL, POLIMI)*** To realize effective educational games, all the functions and elements on which to build education: therapy, comorbidity, disease description and lifestyle have to be identified with clinicians and caregivers. Possible critical elements are defined as well as associated consequences. Throughout the game, the elder is guided to increase the knowledge about his/her condition, with a score mechanism that follows the degree of acquired knowledge and a gameplay that is tuned to the success rate.

***Task 4.6(M3-M24) Social activities through multiplayer games (POLIMI, UMIL, UOP, BDIGITAL)*** Two settings. Are provided. The first setting is based on multi-cast video streaming and most suitable technology to realize it will be analyzed. On the one side SkypeVideo APIs seem particularly suitable for this as they allow point to point video streaming, that can be manageable for allowing a few elders playing together. On another side WebRTC technology provides more secure video streaming because it offers a direct peer-to-peer streaming without having any other intermediary server. Moreover it is an open standard based on web technologies. The table, the card deck and the cards in the hand of the elder will be shown inside a virtual scene displayed on the screen. Merging video streams with virtual scene will take place at visualization time, resorting to alpha shading as shown in the Duckneglect system[183]: The same infrastructure is made available to do physical exercises in a vitual group, for instance with a virtual. Such setting will promote also discussion and speech between the elders themselves and will promote socialization. Lastly it will be explored also to support collaborative work. We will explore for instance this through puzzle games that can be made cooperatively.

**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

[183] Mainetti R, Sedda A, Ronchetti M, Bottini G, Borghese NA Duckneglect video-games based neglect rehabilitation. Tech. Health Care 21 97–111 97. 2013.

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 ORU. They are happy to make dance movements together and, at the end, they could restore the old friendhship. Since then they started meeting not only for the exercises, but also through video communication through Robohome2.0 platform. Eventually their nephews met each other and could meet one year in Italy and one in Sweden in summertime, enlarging the social dimension of their whole family. Michela and Lenita were very happy of this.

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).

***Task 4.7(M3-M18) Definition of calibration games for video and/or inertial systems (UMIL, SXT, POLIMI, UMA)*** This task is aimed at developing all the methods that allow fusing tracking data obtained from different sources. Initial calibration of the devices is carried out at the Service provider site before giving Robohome2.0 to the elder, but periodic refinement may become necessary and limited cognitive and physical residual capabilities of the elder should be fully taken into account. To simplify the process, ad hoc calibration objects that can be integrated in the room furniture will be studied. Alternative methods can be based on adequate games will be studied, like for instance for the calibration of the Kinect camera to provide registered RGB and range images[184]. We will explore also the same data used to track everyday life activities (Task 5.2) to calibrate motion sensors embedded inside the objects.

***Task 4.8(M7-M27) Functional and usability tests (PCL, UMIL, SXT, POLIMI, BDIGITAL, SAS, KORIAN, UMA, KOMMUN)*** The activity center and its exer-games will be tested starting early in the project, when simple features and infrastructure is made available (D4.1) to the end of development. Such tests will be organized for groups of users who will evaluate the usability and effectiveness of the functionalities from the early prototypes to the final system to verify that they match users expectations and needs.

***Task 4.9(M13-M36) Smart gaming with instrumented objects (UMIL, UOP, POLIMI, UMA).*** Calibration carried out in Task 4.7 and sensorized objects built in Task 5.1 will be combined to make everyday objects game tracker. Moreover, these objects will be able to **control gameplay with motion and pressure**. We will fully explore this possibility to guide the elders through specific movements defined with the clinicians that can provide specific information and motion control.

**Deliverables**:
D4.1 (R/OTHER, CO) A first nucleus of physical and cognitive games + silhouette tracking. A first user manual will be provided (UMIL, M12).
D4.2 (R/OTHER, CO) The full system for education (POLIMI, M18).
D4.3 (R/OTHER, CO) The full smart activity center with the final reference manual, user manual and installation manual (UMIL, 27).

## WP5 – Monitoring Systems

| **Work package number** | 5 | | | | | | **Start date or starting event:** | | | M3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Monitoring Systems | | | | | | | | | | | |
| **Participant number** | 1 | 2 | 3 | 4 | 5 | 6 | **7** | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | UMIL | ORU | GIRAFF | UOP | SXT | PCL | **POLIMI** | BDIGITAL | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | 9 | 4 | 0 | 0 | 30 | 9 | **20** | 12 | 3 | 5 | 7 | 0 | 2 |

**Objectives:**
- To design and implement the sensorized objects and the communication infrastructure with the virtual caregiver and the service robot;
- To design and implement environment, lifestyle and social monitoring;
- To design a physiological monitoring network;
- To design and implement a distributed voice control system;
- To realize the sensorized home monitoring system;
- To design and validate cognitive and physical transparent clinical tests.

**Role of partners:** POLIMI leads this WP for its specific experience in multimodal monitoring and assessment of users condition. POLIMI implements the physiological measurements network with the support of KORIAN, PCL,

[184] Pirovano M, Ren CY, Frosio I, Lanzi PL, Prisacariu V, Murray DW, Borghese NA, Robust Silhouette Extraction from Kinect Data, In: Image Analysis and Processing–ICIAP 2013 (pp. 642-651). Springer Berlin Heidelberg, 2013

SAS, and KOMMUN and collaborate with PCL and SAS in the validation of the novel transparent clinical tests. SXT develops the sensorized objects for physical and cognitive monitoring and the micro-architecture that integrates monitoring system within Giraff, in collaboration with GIRAFF. Environmental and social monitoring work is led by BDIGITAL. SG develops the voice processing system in Task 5.4 and leads the development of the distributed voice command system. UMIL brings in its experience in motion analysis, mainly to design the most effective transparent tests in Task 5.2.

**Description of work:** The aim of this WP is to provide a set of customized and off-the-shelf low cost devices and tools to monitor the elder behavior at home and his physical and cognitive condition. All the sensors are selected following the user and functional monitoring requirements (Task 1.3) and the technical specifications identified in Task 2.2, that define also the network connectivity. Modularity, flexibility and adaptability to the different use-case scenario is considered. Physiological sampling devices are also identified and connected with the Virtual Caregiver. We design and implement a novel cognitive and physical transparent system based on sensorized objects (Task 5.1 and 5.2). Identification of proper indexes and scales, and validation with standard clinical and instrumental evaluation indexes is carried out.

**Task 5.1 (M3-M24) Design of the micro-architecture for transparent physical monitoring through sensorized objects (SXT, UMIL, POLIMI, BDIGITAL)** Micro-architectures based on micro-sensors of pressure and acceleration (Figure 6.1) are realized. Novel flat **pressure sensors** with ultra thin sensing circuits to sense contact forces are considered so that they can be attached and adhere to objects surfaces in the contact area (Fig. 6A and B). This can be for instance the handle of a comb or of a walking stick. **Inertial sensors** can be integrated inside the body of the object (Fig. 6C). SXT has already developed inertial, wearable systems to analyze human movement at work, during sport activities or rehabilitation within the Protheo system. A **micro-controller** among ARM Cortex M0 or M0+ families can be used to acquire the analog data from the sensors, digitalize them and send them to a radio transmission module that transmits thorough low-power Bluetooth (class 4.0). Another possible solution, depending on the data transfer and the specific processing, is the use the free resources of the Bluetooth micro-controller (typically an 8051 architecture) to act as generic microcontroller, reducing even more power consumption and occupied space. Two modalities of data transfer will be made available: a) **real-time transmission of the data** in which the micro-controller will read the data from the sensors, process them and output in real-time the value through blue-tooth connection. It will be used for transparent monitoring. b) **on-board storage of the data.** This modality will be used to gather motion data during the day, both inside and outside the house. An automatical download procedure will be developed that is triggered when the object is put in its resting location. Particular care is reserved to **calibration,** which is the determination of gain and offset parameters. Both inertial and pressure sensors will be calibrated before releasing the sensorized object. However, calibration parameters may change over time and their value may need to be adjusted. Offset and gain of pressure sensors can be refined by measuring the reading associated to a given load. Simple objects and procedure aimed to caregivers will be developed to **periodically re-calibrate instrumented objects**. Inertial sensors, constituted here of tri-axial accelerometers required to calibrate at least six parameters (3 offset and 3 gain parameters). However, knowing that when no motion is detected, the square norm of the output should be the norm of the gravity vector, **auto-calibration can be carried out**[185]. This will be fully explored here to keep the motion sensors calibrated. In case, accelerometers will not provide the required accuracy, they will combined with gyroscopes to make measurements more robust. Psychological issues in accepting sensorized objects will be properly dealt with PCL and ORU partners as well as with PCL, SAS and KOMMUN psychologists.

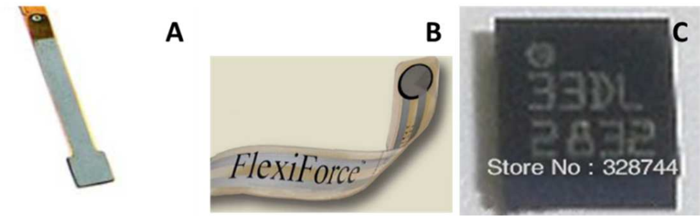



*Figure 6 –A) Digitacts sensors by PPS; B) Flexiforce sensors by Tekscan; C) LIS331 acceleration sensors by STM*

**Task 5.2 (M7-M27) Design and clinical evaluation of transparent monitoring (POLIMI, UMIL, SXT, PCL)** In this task psycho-physical monitoring of elder status will be performed by a novel approach that combines a robot to measure the elder movement by means of motion tracking (Task 3.3) in combination with the sensorized object realized in Task 5.1. The transparent monitoring is based on the principle that gestures are the expression of the motor and cognitive ability of the elder. We first identify start and end of a single gesture by identifying typical

[185] . Frosio, F. Pedersini and N. A. Borghese, Autocalibration of Triaxial MEMS Accelerometers with Automatic Sensor Model Selection, IEEE Sensors Journal, Vol. 2, No. 6, June 2012, pp. 2100-2108.

features on pressure and/or kinematic profile, like movement or pressure onset/offset. Time warping will them be applied to the data to enable a comparison with a baseline. Both statistical parametric models, like GLVM, or deterministic models like covariation patterns, will be fitted to the data to derive **Gesture Degradation Indexes** that can be of clinical relevance. Segmentation of motion and pressure data will allow also to evaluate the proper concatenation of actions that can be used for cognitive evaluation. We will implement PFSM[186] to describe the concatenation of actions associated to different situations as a **model of the elder behavior.** High probability patterns, termed eigenbehaviours[187], can be extracted from this model and compared with the actual pattern to detect possible cognitive decline. The proposed synthetic indexes will be evaluated in their significance and sensitivity and validated in cooperation with PCL and SAS. A similar approach will be applied for transparent cognitive monitoring, in which a set of questions will be asked to the elder by the Virtual Caregiver, in different times and days. Answers will be registered and analyzed collectively to derive **cognitive degradation indexes**.

**Task 5.3(M7-M24) Design and implementation of environment and lifestyle monitoring (BDIGITAL, ORU, POLIMI, SXT)** This network will chain several sensors that are associated to the home (Task 1.3). Different priorities is assigned to the different sensors Z-wave communication protocol for the ambient sensoring will be favored among other protocols due to its broad market share and open standards. The combination of presence, luminosity, humidity, temperature and cushion pressure data will be used to evaluate the user behaviour, and to detect abnormalities of daily habits. To illustrate, a particular case is the detection of insomnia and sleep abnormalities when presence is detected in different rooms at night, or a prolonged period in the bathroom with respect to his normal time can indicate a concealed pathology that can be detected by the Virtual Caregiver and then analyzed by the GPs. The same network will check for gas and smoke alarms that will immediately raise an alarm to the elder first and then to the carers. An architecture based on a Raspberry micro-server to collect and transmit the data the Virtual Caregiver is envisaged.

**Task 5.4(M7-M24) Design and implementation of social behavior monitoring (BDIGITAL, UMIL, ORU, PCL, SAS, SG)** Social behavior will be tracked through heterogeneous information. First source information will be made available through a log book of activities compiled by the elder caregiver, for instance on a weekly basis. Such documentation will be provided preferentially through the community or through a smart phone app (Task 6.6). Access to the community and profiling of the phone conversations is computed to provide additional information. In this task an pitch analysis of the elder voice in phone conversation is carried out with the aim of identifying possible consistent changes of emotional state. To this aim, cepstrum analysis or Short Time Fourier Transform[188] of audio signal with vocal folds opening and closing rates. The task will end with technical and functional testing.

**Task 5.5 (M7-M24) Design and implementation of distributed voice command system (SG, BDIGITAL, UMIL)** A plug&play acoustic sensor will be designed and developed. This is constituted of a microphone with a low-level speech processing software implemented through DSP dedicated processing. Its aim is to enable specific voice command execution. Such component shall be connected to sockets and transmit the signal through a wireless protocol (z-wave and BlueTooth Low energy will be considered first depending on their acceptance, bandwidth and latency). Possible post-processing inside the Robot or the Raspberry Pi microserver will be evaluated. Various speech analysis and recognition approaches based mainly on the cestrum coefficients and HMM models will be examined. The main objective to have stand-alone acoustic sensors plugged on sockets is the range limits the microphones have, so basic commands could not be detected if the robot is in a different room.

**Task 5.6 (M7-M24) Design and implementation of physiological measurements network (POLIMI, SXT, BDIGITAL, PCL, SAS, KORIAN, KOMMUN)** We aim at low cost devices already available in the market that comply with all the medical equipment safety and quality standards are required (EN 1060-1, EN 1060-3, EN 1060-4 and ISO 8106). An initial detailed analysis of the state of the art and of the devices 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 miniaturized OEM modules[189]. These are cost-optimized and can offer accurate measures meeting all the medical equipment safety and quality standards. Specific modules are selected according to the needs of each elder and integrated inside Robohome2.0, so that a **personalized physiological monitoring network is realized.** Novel applications, like retinal imaging to measure oxygenation[190] in a non intrusive way, will be considered in the early stage of the project to select the most friendly and still reliable solutions.

[186] Vidal E, Thollard F de la Higuera C Casacuberta F Carrasco RC. Probabilistic finite-state machines - part I and II, IEEE Trans. PAMI, 27(7) 1013-1035, 2005
[187] N Eagle and A Pentland, Eigenbehaviors: Identifying Structure in Routine. Proc. Ubicomp 2006.
[188] E. Jacobsen and R. Lyons, The sliding DFT, Signal Processing Magazine vol. 20, issue 2, pp. 74–80 (March 2003).
[189] E.g. http://www.medlab.eu/english/modules/, http://www.casmed.com/files/documents/OEM_SellRev00.pdf
[190] http://www.google.com/patents/US6477394

**Task 5.7(M19-M27) Functional and usability tests of the sensorized home (POLIMI, SXT, BDIGITAL, UMIL, PCL, SAS, KORIAN, KOMMUN)** Each of the component developed in Tasks 5.1-5.4 will undergo extensive usability and technical tests. Modality of use of each sensor and components has been set in WP3. The actual implementation will be made available to PCL, SAS, KORIAN and KOMMUN that will verify the adequacy of the implementation and may suggest refinements. In parallel testing of the each monitoring network and of the whole network is carried out with particular attention on possible conflicts among the different components or bottlenecks at the Virtual Caregiver level.

**Deliverables**:
D5.1 [R, CO] Design and development of the monitoring networks; a first report will be provided (BDIGITAL M12)
D5.2 [R, CO] The full monitoring systems ready for usability testing (POLIMI, M18)
D5.3 [R, PU] Validation of the clinical transparent clinical tests (POLIMI, M27)
D5.4 [R, PU] Report on the functional and usability tests of the monitoring systems (POLIMI, M27)

## WP6 – Virtual Community

| **Work package number** | 6 | | | | | **Start date or starting event:** | | | M3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Virtual Community | | | | | | | | | | | | |
| **Participant number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **8** | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | UMIL | ORU | GIRAFF | UOP | SXT | PCL | POLIMI | **BDIGITAL** | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | 6 | 2 | 0,5 | 3 | 0 | 2 | 5 | **32** | 3 | 3 | 5 | 0 | 2 |

**Objectives:**
- Implement a Virtual Community based on web technologies conneting all users of Robohome2.0;
- To provide a set of specific services oriented to elderly people and formal/informal caregivers to promote socialization and communication between them, and to offer a social and healthcare support to the elders;
- To provide an interaction point for Virtual Community users;
- To create an environment to increase elderly motivation, adherence, cognitive and physical stimulation.

**Partners role:** BDIGITAL will lead this WP for its wide experience in designing web-based communities inside the projects, Rewire, Backhome and Saapho and leads the design and implementation of the infrastructure. UOP supports interfaces development according to specifications set in Task 2.5. POLIMI provides the support for data recording. UMIL will lead the integration of gamification inside the community and provide analysis instruments. PCL, SAS and KOMMUN bring in the psychological, sociological and psychological view to obtain the most compliant implementation. ORU will bring in its expertise in designing functionalities mediated by Giraff robot.

**Description of Work:**

***Task 6.1(M3-M18) Structuring the Virtual Community and management (BDIGITAL, UMIL, PCL, SAS, KOMMUN, KORIAN, ORU, UOP)*** Goal of this task is to provide a low level architecture of Virtual Community platform taking into account both functional and technical specifications identified in WP1 and WP2. An adequate client and server architecture will be designed using web services technology that will communicate through the Robohome2.0 infrastructure. Apache Tomcat, Java programming language, Spring framework, jQuery, Apache Tiles among others. The most suitable database type will be chosen, selecting between SQL or noSQL databases, taking into account the type of data produced by monitoring systems, activity center and community. The interfaces defined in WP2 are incorporated. Multi-user interaction is implemented with the same technology identified in Task 4.3.

***Task 6.2(M7-M24) Data repository design and implementation (POLIMI, UMIL, BDIGITAL, KORIAN)*** The data collected by Robohome2.0, provided by transparent monitorings and activities will be stored inside the database designed in Task 6.1. Functionalities to transfer data from the Giraff PC on a regular basis are implemented. A repository of live stories narrated by the elders is built to generate **collective knowledge of close past of the elderly that would get otherwise lost**.

***Task 6.3(M6-M18) Services design and implementation (BDIGITAL, UMIL, GIRAFF, SAS, PCL, KORIAN, KOMMUN)*** The set of services defined in Task 2.4 are integrated by a continuous osmosis from most popular social networks and from thematic networks of interest for the caregivers and the elders. The content will be filtered through adequate indexing, to provide the elder with personalized knowledge and annotations and comments will be collected, using classical threads technology. Aim is to **increase the collective knowledge of the users**. Additional services, like reminders, calendar, notifications will also be provided.

**_Task 6.4(M12-M24) SOA layer and Communications (BDIGITAL, UMIL, GIRAFF)_** The Virtual Community is developed as a web application and installed on a dedicated server, which will have access to the internet in order to accept, validate and send communication requests between Virtual Community components. Communications among them will be implemented using a service oriented architecture (SOA) developed with Open Software components. Confidentiality will be analyzed and guaranteed in all communications. The output of this task will be integrated in development carried out in Tasks 6.5 and 6.6.

**_Task 6.5(M12-M27) Applications for virtual community management and activities personalization (BDIGITAL, GIRAFF, POLIMI, UMIL, PSC, ORU, UOP)_** In this task all administrative GUI and functionalities are implemented. New elders or caregivers can be inserted. Tools for profiling the elder before installing Robohome2.0 will also be provided. GUI for the different main users categories: elder, formal and informal caregivers will be integrated. Tools for a cluster analysis of all the users will be provided. This task will design also the most suitable support for motivational elements like leader boards or other feed-back identified in Task 2.4.

**_Task 6.6(M12-M27) Smartphone application (BDIGITAL, UMIL, SG, PCL, SAS)_** The Virtual Community will allow interaction beyond the use at home through the Virtual Caregiver. Therefore an interface specific to smart phones is developed. This will be preferentially used by caregivers. In this task the apps associated to the assistance function (Task 3.8) and to suggest recipies adequate to the elder diets will also be provided. Finally, the app that analyzes the voice pitch during elder conversations will be provided.

**_Task 6.7(M13-M24) Self-organization of the community (UMIL, BDIGITAL, KORIAN, PCL, SAS)_** The analysis of the network of social ties among users, defined by symmetric or asymmetric relationships, is implemented and it is used to derive self-organized clusters of users[191]. Such clusters will be characterized by homogenous interests and similarity in other parameters derived from the profile like interests, age, familiar status and so forth. These clusters will be used in Task 3.4 to refine patients profile, to provide better recommendation and to provide better filtering of knowledge delivered.

**_Task 6.8(M13-M27) Functional and usability tests (BIDIGTAL, SAS, KORIAN, KOMMUN)_** The community and its components will be tested starting early in the project, when simple features and basic infrastructure will be made available up to the end of development. Such tests will be organized for groups of users who will evaluate the usability and effectiveness of the functionalities from the early prototypes to the final system to verify that they match users' expectations and needs.

**Deliverables**:
D6.1 [R/OTHER, CO] Virtual Community design. Report on the initial virtual community design and implementation of the basic features. Description of the structure of services planned to be included in the final version of the platform Robohome2.0 will be described. Questionnaires to evaluate the design of community at the functional and usability level will be defined (M15, BDIGITAL)
D6.2 [R, CO] Virtual community final design and implementation. The complete final design and architecture of the community will be presented as well as the full list of services along with their description and user manual. The implementation process as well as the technical specifications of the platform on which virtual community is based will be described (M24, BDIGITAL)
D6.3 [OTHER, CO] Virtual community software package. The associated software of the virtual community will be packaged in this deliverable. The installation manual will be presented along with the code. (M24, BDIGITAL)

## WP7 – Integration

| **Work package number** | 7 | | | | | | **Start date or starting event:** | | M13 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Integration | | | | | | | | | | | |
| **Participant number** | 1 | 2 | **3** | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | UMIL | ORU | **GIRAFF** | UOP | SXT | PCL | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | 8 | 5 | **8** | 2 | 4,5 | 0 | 4 | 8 | 0 | 1 | 3 | 6 | 0 |

**Objectives**:
• To coordinate the integration of the modules developed in WP4, WP5, WP6 and WP7 into a complete first prototype of Robohome2.0 system;
• To validate the functioning of the prototype.

**Role of the partners:** Integration will be carried out by partners who have developed the components under the lead of UMIL. BDIGITAL will supervise the integration of the community, POLIMI of the monitoring systems and

[191] M. C. González, C. A. Hidalgo, A.-L. Barabási Understanding individual human mobility patterns. Nature 453, 779-782 (2008). Mark S. Handcock and Adrian E. Raftery Model-based clustering for social networks J. R. Statist. Soc. A (2007) 170, Part 2, pp. 301–354.

assistance functionalities and UMIL of the activity center. GIRAFF will carry out extensive testing for validation. KORIAN will participate to the integration of the community to provide its view of final service provider and possible channel of commercialization of Robohome2.0.

**Description of work**: Aim of this WP is the validation of the platform producing all the documentation required to allow using the platform in the pilot tests. Validation results will be assembled in a comprehensive report that will be made publicly available.

***Task 7.1(M7-M24) Communication development and testing (BDIGITAL, UMIL, GIRAFF, POLIMI, SXT)*** This is a critical task for integration. In this task the communication between all Robohome2.0 components: the game center, Giraff, the virtual community and the monitoring system will be developed and tested. This task will start early to develop a coherent view of development and communication. Data types, possible conflicts, technological requirements (bandwidth, protocols and transmission media) as well as the functional requirements (data anonimization, organization) are taken into account. Data confidentiality and safety is a main concern in the design phase and is properly addressed using OASIS web service security specifications (WS-Security protocol).

***Task 7.2 (M18-M27) Integration and testing of the community services (BDIGITAL, UMIL, GIRAFF, KORIAN)*** All the services developed in WP6 are integrated in the Robohome2.0 platform. Suitable tests are performed to evaluate the provided functionalities according to the users and technical specifications defined in WP1 and WP2. Several tests, based on use cases, will be performed with the purpose of ensuring the full integration of all the components that are part of the community.

***Task 7.3 (M7-M27) Integration of monitoring networks and activity center (POLIMI, SG, SXT, GIRAFF, BDIGITAL, ORU, UMA)*** All the selected and developed devices will have most different transmission capabilities and cabling the entire house cannot be feasible. A structure based on a set of networks based on WiFi transmission is the most reasonable. A Hub, for instance based on a Raspberry microprocessor, that integrates all environment sensors, manages them and communicate with the virtual caregiver, will be explored. Sensorized devices will have their own network as the delay required in transmission has to be short. We will start in subsequent steps, from early prototypes supporting few devices to the full set of networks and the activity center. Such progressive approach is fundamental to early detect possible conflicts and software / hardware incompatibilities.

***Task 7.4 (M21-M27) System testing and validation (GIRAFF, BDIGITAL, UMIL, SG, SXT, KORIAN, UOP)*** Quantitative experiments and tests are carried out on the whole platform according to functional specifications set in WP1 and to technical specifications set in WP2. Tests are carried out in protected environments, the living labs of ORU and SAS, to identify any bugs and/or functional limitations. An exhaustive testing at technical level will be performed before delivering the Robohome2.0 system for use and evaluation. Particular attention will be devoted to the characterization of the performance of the integrated system in terms of robustness, reliability, usability, and dependability. A specific focus will be paid to **user safety**. Furthermore, during integration of the Robohome2.0 system, consistency with international medical regulations and communication standards will be pursued by the Ethical Advisory Board. Full documentation of integration is provided in D7.3.

**Deliverables**:
D7.1 [R, PU] Description of the hardware and software infrastructure of Robohome2.0. Interfacing specifications and SW and HW specifications of the components and of the whole system will be reported in a comprehensive way (BDIGITAL, M24).
D7.2 [R, PU] Report on functional tests on the final integrated platform (UMIL, M27) Results on functional tests developed in collaboration with the different groups of users will be extensively reported.
D7.3 [OTHER, CO] Integrated SW / HW prototype to be used for the pilot (UMIL, M27).

## WP8 – Robohome2.0 pilot

| **Work package number** | 8 | | | | | | | **Start date or starting event:** | | | M13 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Robohome2.0 pilot | | | | | | | | | | | |
| **Participant number** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | **9** | 10 | 11 | 12 | 13 |
| **Participant short name** | UMIL | ORU | GIRAFF | UOP | SXT | PCL | POLIMI | BDIGITAL | **SAS** | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | 3 | 3 | 1 | 10 | 0 | 8 | 7 | 2 | **24** | 19 | 0 | 2 | 6 |

**Objectives**
To evaluate the Robohome2.0 technology in a real home setting, for the following aspects:
• usability by the elder, the caregivers and the physicians;
• efficacy in assisting the elder in everyday living, therapy compliance, monitoring, evaluation and stimulation;

**Partners role:** SAS will be the leader of WP8 for its extensive expertise in this field. It will collaborate intensively with PCL and KOMMUN in all the aspects of testing. KORIAN and GIRAFF will look also closely to aspects involved in industrial exploitation, KOMMUN from the public and KORIAN from the private point of view. UMIL, POLIMI, BDIGITAL, UMA, BDIGITAL and ORU will contribute on information gathering on the use of the components and of the whole platform and assist in any issue with the technology. Intensive experimentation of robot interaction is carried out under the lead of UOP in Task 8.1.

**Description of work:** Robohome2.0 is tested with at least 16 elders, selected by SAS (6), PCL (6) and KOMMUN (4) among the elders who meet inclusion criteria set in WP1. Each of them will be using the platform for at least 4 months: each partner enroll two elders for each platform assigned to them. Enrollment follows the rules of the reference center. A system personalized to elder needs will be installed in the elder's house and he/she will be briefly trained. Full support is provided through phone or through the platform itself. **In this pilot study not only the elder will be involved but also the network of his/her carers**. The clinical partners will collect all the events associated to the pilot: hazards, criticalities, observations, suggestions, that will be compiled into a comprehensive report (D8.4). The sample size of 16 elders is the number that can realistically be treated for the 9 months training period that can be allocated for the trials. Keeping in mind that our primary aim is to assess the technical feasibility and usability, we cannot provide a power-based sample size estimation. Nevertheless, 21 subjects with different pre-frailty characteristics will allow us to obtain a generalizable evaluation of feasibility. We will also focus on the safety of the technology, on the elder's compliance and satisfaction with the technology, and on the customized objectives as defined in Task 1.6. In particular, we will have enough man months (16*5 = 80) to register adverse events if there are any caused by Robohome2.0 training, and to acquire a large set of feed-back on compliance, usability, effectiveness and flexibility of the system and of its components.

***Task 8.1(M13-M36) Behavioral analysis (UOP, SAS, PCL, KOMMUN, KORIAN, UMIL)*** In this task we design experiments to evaluate interaction modalities of the elder with Giraff and the Virtual Caregiver. Long-term interaction and acceptance, matching perceived and actual ability, readability and responsiveness are among the factors that make the interaction with a robot successful[192]. **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 focus on incrementally improving these HRI qualities through implementing the latest insights in the field of HRI and field testing with naive users. In particular, the choice of the open experimental scenarios and of controlled interaction experiments considers (i) the quality and effectiveness of long-term interaction and acceptance of the robot, (ii) matching of perceived and actual ability; (iii) feedback and readability of the interaction partners; (iv) responsiveness of the robot. For the qualitative and quantitative HRI behavioural analyses, in addition to video analyses of the human-robot interaction strategies, dialog transcripts and non-verbal behavior (gestures), questionnaire-based measurements will be collected after the experiments. This is based on the scales on Trust, Likability and Source Credibility used by Rau et al. (2009) and the Bartneck et al. (2009), questionnaires to measure a range of HRI factors (Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety). The experimental interaction tasks are based on the use case scenarios identified in Task 1.5. Results are used to refine the specifications, the components and the interfacing modalities to maximize robot compliance with the elder.

***Task 8.2(M13-M27) Early testing (KOMMUN, ORU, PCL, KORIAN, UMIL, SAS, UMA, POLIMI)*** ORU sets up a preliminary version of the system constituted of the Robohome2.0 components at different stages of completeness produced in WP3, WP4, WP5 and WP6. Such early prototype will be deployed in the living labs made available by ORU and SAS, updating the components with major updates provided by the WP leaders. This working platform is tested on different types of end users: therapists, clinicians, caregivers and elders themselves in collaboration with KOMMUN and PCL. The components will communicate with a simple network and the data collected will be made available for the analysis. This would allow to early identify criticalities in the interaction, compliance and usability and provide refinement of the specifications and of the final implementation.

***Task 8.3(M27-M36) Usability evaluation (SAS, PCL, KOMMUN, KORIAN, GIRAFF, UMIL, UOP, ORU)*** During and after the pilot trial all involved carers will answer a standardized questionnaire on system usability. This will be possibly based on TAM approach and will look on several aspects: easiness of use, compliance, pleasantness, perceived usefulness, looking at the point of view of the different users. Particular care is put on the adaptation

[192] 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.

mechanism and the evaluation of their suitability from the motivational and effectiveness point of view, as evaluated by the different users.

***Task 8.4(M25-M36) Quantitative evaluation (SAS, PCL, KOMMUN, UMIL, ORU, POLIMI, KORIAN)*** Given the number of elders studied and the time horizon of the project, the assessment of efficacy will remain preliminary. But, these preliminary data are necessary to design a future randomised controlled trials that will yield a valid assessment of efficacy. Efficacy here will be assessed with proper tests according to the specific main assistance goals with measures taken before and after entering the pilot. We will collect data on daily usage of monitoring, activity center, assistance and community by the elders and the other users. These will be regressed on several parameters related to elders like clinical status, age and gender, physical and cognitive deficits, to gather preliminary knowledge on whether certain subgroups of elders can accept the system better than others. Information on technical failures, operation errors, system abuse and hours spent with implementation and instructions will be recorded. These data will be reported to and discussed with the other partners to further improve and refine the Robohome2.0 components. The data will also be used to derive a preliminary estimation of the cost of implementation.

***Task 8.5 (M13 - M36) Analysis and assessment on the improvement in therapy adherence and elder-doctor communication (PCL, SAS, BDIGITAL, KOMMUN, UOP)***
Robohome2.0 provide to the elders several tools to cope with their own health management: physiological sampling, feed-back on activities, recommendation by the Virtual Caregiver, information from the community, a smart drug dispenser and video-communication with his/her GP. We expet that all these possibility will have a positive effect on the relationship between elder and doctors and on therapy compliance, both increasing by 15%. The evaluation would take into account the elder's involvement his own lifestyle program, knowledge and management of diseases as well as satisfaction, acceptability level, adherence to the lifestyle program and to the therapy and usability. This will be done through specific questionnaires that address all these elements that will be compiled by the elder and by his/her carers. Other elements worthwhile to be considered will possibly emerge during the project and, in particular, from the early trials carried out in the living labs of SAS and KOMMUN. Further information on this issue will be obtained by means of the analysis of the use of the activity center and of the community. The summary of this work will be contained in D8.3.

***Task 8.6 (M13-M36) Platform deployment modalities (PCL, SAS, KOMMUN, UMIL, POLIMI, KORIAN)*** A survey on the platforms for remote elder assistance in Europe is carried out at project start and reported in D8.1, with the aim of identifying critical points and actual practices. Thie will serve as the basis for defining Robohome2.0 platform deployment modalities. Knowledge and expertise acquired through the project execution will be carefully analyzed to identify and describe possible winning elements. T**he most appropriate model to seamlessly connect at home assistance to hospitals, GP and elder service providers networks, appropriate service settings** needed to guarantee a realistic implementation, adjusted to the needs of the elders and the reality and possibilities of service providers, will be studied and a business plan defined on these data in Task 9.5. Feedbacks obtained from the pilot test outcome is used to create best practices, guidelines and policy recommendations for the successful deployment of such platforms within the national health systems of the EU zone. Our reasonable goal would be to prolong the period in which elders can stay safely at home, still monitored and supervised in a way that is transparent to them. Besides increasing their quality life, we expect to reduce the cost of the National Health Service of at least 10% in primary and secondary recoveries and clinical visits.

**Deliverables** (brief description and month of delivery)
D8.1 [PU, R] Analysis of assistance platforms on the market and their deployment modalities (KORIAN, M24)
D8.2 [CO, R] Refinement of functional and technical specifications (UMIL, M24)
D8.3 [PU, R] Report on deployment modalities and patient-doctor communication improvement and therapy compliance with Robohome2.0. will contain also possible scenarios and metrics to evaluate mainly the increase in therapy compliance and patient doctor relationship. (PCL, M36)
D8.4 [PU, R] Assessment of Robohome2.0 effectiveness, compliance, usability and reliability in assisting the elders at home (SAS, 36)

## WP9 – Dissemination and exploitation

| **Work package number** | 9 | | | | **Start date or starting event:** | | | | M1 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Dissemination and exploitation | | | | | | | | | | | |
| **Participant number** | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | **UMIL** | ORU | GIRAFF | UOP | SXT | PCL | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | **11** | 3 | 2 | 4 | 1 | 3 | 3 | 1 | 2 | 4 | 0,5 | 1 | 3 |

**Objectives**

- to disseminate project results to the relevant target groups;
- to promote best practice and/or further exploitation and to to facilitate the up-take of results by the market;
- to assess sustainability and harmonise links of Robohome2.0 with related EC and international initiatives.

**Partners role:**
UMIL, leader of this WP, will work in tight collaboration with POLIMI, head of the technical committee and PCL, head of the functional committee, to promote dissemination among the different stakeholders of the project. All the other partners will contribute with suggestions and material for the different domains and to the different diffusion actions according to their specific expertise.

**Description of work**: Main goal of this task is to ensure **effective and wide spread diffusion of project results**, channeling the diffusion of the different results to the proper audience to raise globally the perception of the new possibilities offered to the elder for assisted living through grounded results. The unique mix of the consortium, made of ICT experts, clinicians, caregivers, companies and service providers allows the discussion and the presentation of the results from different points of view. Conventional channels like exhibitions, meetings, and non-conventional ones like LinkedIn, YouTube, Facebook, are exploited to diffuse project results. The EC communication Officer will be kept informed in due time of any diffusion activity. Dissemination effort is directed mainly in improving elder care, main focus of the project: Health and Social service providers at different levels, private and public, will be contacted throughout the project to demonstrate the project results and receive a valuable feed-back. The project is expected to have a strong outcome also in the ICT domain. Industrial exploitation modalities of the whole system and of single components will be discussed throughout the project. A **right of first refusal** is granted to the consortium industrial partners that will be privileged in exploiting technology developed. A use and dissemination plan is prepared in the first year of the project (D9.1) and continuously updated until the end (D9.2). Fundamental for project exploitation will be the feed-back from the stakeholders. To this aim, workshops, small meetings and exchange visits will be organized, in which Robohome2.0 members and stakeholder will come together to discuss how the developed system should be assessed and against what criteria increase in the duration and quality of life at home should be evaluated.

***Task 9.1(M1-M36): Definition of a dissemination plan (UMIL, All partners*)** A dissemination plan is designed by UMIL together with all partners during the first 6 months of the project, identifying the communication objectives, activities and tools for dissemination, and distributing the work among partners. This will be discussed during the Kick-off meeting. Updates of the dissemination plan will be provided at months 12, 24 and 36.

***Task 9.2(M1-M36): Creation and maintenance of the project website (UMIL)*** UMIL will take care of designing, populating, and publishing the project website within the first 3 months, aiming to outline the project aims, share technical information among partners, make the project deliverables and results available online, and activate a discussion forum for the scientific community interested in Robohome2.0. A restricted access section will give partners the opportunity to access drafts of documents and to provide input to the development process.

***Task 9.3(M1-M35): Organization of a Workshop and of Presentations/Seminars (UMIL, ORU, GIRAFF, UOP, POLIMI, BDIGITAL, PCL, SAS, UMA, KORIAN)*** Dissemination activities will be carried out by all partners throughout the whole project duration and include: a) information about the project and its aims to stakeholders; b) presentation of interim results and of the final ones in national and international specialized publication organs and peer-reviewed journals in the relevant areas; c) presentations of interim and final results at national and international conferences in the area, in the form of papers/posters; d) organisation of workshops, presentations and seminars to sustain awareness about the project and its results; e) a Final Workshop will take place at the end of the project in which live demos will be shown. Relevant stakeholders will be invited. (Month 36).

***Task 9.4(M1-M36): Participation in Trade Fairs and Exhibitions (KORIAN, UMIL, SXT, SG, GIRAFF, BDIGITAL, KOMMUN)*** Robohome2.0 industrial partners will participate in relevant European and International Trade Fairs and Exhibitions held inside and outside Europe by hiring stands at which hands-on technology demonstrations will be held. Moreover, all participants will attend major European and International conferences and/or workshops to demonstrate Robohome2.0 achievements, such as AAL Forum, Bucharest, 9-12 September 2014.

***Task 9.5(M1-M36): Industrial exploitation of results (KORIAN, SG, SXT, GIRAFF UMIL, POLIMI, BDIGITAL, UMA)***
An **Exploitation plan** is prepared during the project and finalized at the end of the project. The plan presents how the partners involved in Robohome2.0 intend to exploit the results of the research and development activities. The plan takes into account the different regions/countries and their specific features and priorities identifying actual and potential industrial and sales partners. Possible risks and hurdles which need to be tackled before starting the exploitation of project results are identified and measured in order to minimise their impact and

corrective actions recommended. Appropriate alliances for the deployment of project results are investigated. Negotiation and contracting with potential industrial and commercial partners will be started as soon as possible.

***Task 9.6(M18-M36): Business plan (KORIAN, SXT, SG, GIRAFF, UMIL, SAS, PCL, KOMMUN)*** A **business plan** will be prepared for the end of the project substantiated with the data gathered during the pilot. We will summarize inside a business plan a set of possible business goals, the reasons they are believed attainable with the development of Robohome2.0, and the plan for reaching those goals. Financial and technological content will be highlighted as well as competitive advantage with respect to similar systems will be highlighted.

***Task 9.7(M1-M36): Management of collaboration with external organizations (UMIL, PCL, SAS, KORIAN, BDIGITAL, UOP, POLIMI, KOMMUN)*** The goal of this task is to manage the collaboration with external organisations. PCL, a National center for Geriatry and SAS, the reference node for Socio-Health public services in Andalusia have developed a long term follow up and a continuous elder care assistance with screening of frailty. Due to this, they have the possibility to follow the elders in different stages of pre-fraility functional development and they will be able to maintain a strong connection with elders groups through GPs on the territory.

***Task 9.8(M1-M36): Communication activities (UMIL, All partners)*** In this task all the communication activities planned will be carried out (Section 3.2b). In particular, during the lifetime of the project, contributions to technical roadmaps and standardisation of modular, multi-modal pro-active assisted living will be analyzed. Continua Health Alliance (CHA)[193] and Assisted Ambient Living joint program (AAL)[194] are particularly suitable and participation of Robohome2.0. **Synergies with other projects of Horizon2020** is explored to make provisions to complement or adopt existing standard interfaces and network protocol, and components and to favor interoperability and scalability. The goal would be to pursue the idea of Robohome2.0 experimental testing platform as a living lab in which novel components can be tested and integrated.

***Task 9.9(M2-M36): Scientific dissemination. (UMIL, SAS, PCL, ORU, BDIGITAL UOP, POLIMI, UMA)*** Potential conferences relevant to the project content will be continually updated on the web-site and a web-based conference calendar to alert the relevant project partners to deadlines for submissions of papers and conference registrations. A minimum of 5 peer-reviewed journal articles and 8 publications on major conferences are expected. The results shown may increase the interest of the different research communities involved to invest into improving elder assistance levels. Coordination of the scientific dissemination will be carried out by UMIL. PCL will play the role of shaping the information related to the project for the National Health Providers and of producing the material adequate to diffuse, and sensibilize the Health Provider of the EC countries.

**Deliverables**:
D9.1 [PU, DEC] Project Website (UMIL, M3)
D9.2 [PU, DEC] Project leaflet, poster (UMIL, M6)
D9.3 [CO, R] Preliminary exploitation and dissemination plan (UMIL, M12)
D9.4 [CO, R] Refined exploitation and dissemination plan, with refined poster (UMIL, M24)
D9.5 [CO, R] Final exploitation and dissemination plan, with final leaflet and poster (UMIL, M36)

## WP10 – Management

| **Work package number** | 10 | | | | | **Start date or starting event:** | | | M1 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work package title** | Management | | | | | | | | | | | |
| **Participant number** | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| **Participant short name** | **UMIL** | ORU | GIRAFF | UOP | SXT | PCL | POLIMI | BDIGITAL | SAS | KORIAN | SG | UMA | KOMMUN |
| **MM per Participant** | **12** | 1 | 0,3 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 0,5 | 1 | 1 |

**Objectives:**
The WP aims to ensure that the project remains on track and a successful completion of the Robohome2.0 project providing administrative and scientific co-ordination. **Objectives of the scientific coordination are:** to manage the overall scientific and ethical activities of the project according to approved plans; to monitor, track and control deviations due to progress, costs, financial and scheduling changes; to ensure that the required reporting is prepared and delivered in a timely manner; to implement an administration and communication infrastructure to establish a basis for efficient and easy communication within the project. Also to ensure that external communication (project website, dissemination and exploitation) is undertaken and controlled by the project management, **to raise the proper level of expectation; without any hype, but with a realistic shared evaluation**: to perform a procedure for updating and revising the plans due to changes and new knowledge; to communicate

[193] http://www.continuaalliance.org/
[194] http://www.aal-europe.eu/

with the Commission, with the Consortium and with other project bodies; 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.

**Partners role:** All partners are involved in this WP since each organisation has to provide the mandatory financial and administrative documents requested by the EC. UMIL will act as coordinator. All other partners will nominate a member in the PSC and will participate in steering the progress of work. Management will take advantage of a reserved area set-up in the Web-site installed and developed in WP9. UMIL will be in charge of IPR management.

**Description of work:** The main objective of the project management work package is to ensure a successful completion of Robohome2.0 providing **administrative and scientific co-ordination**. This WP is aimed at scientific and strategic project management including project meetings and internal reviews, strategic discussions and the technical coordination among partners. Basic aim is to keep the project correct dynamics by setting the appropriate mechanisms to achieve objectives. It works 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 results. Particular attention is paid to the management of risks and issues and to their early detection with a **pro-active attitude in solving them**, already experimented in coordinating the projects Fitrehan and Rewire.

***Task 10.1(M1-M36): Planning and scheduling. (UMIL, All partners)*** provides accurate planning of different actions during the project's lifetime. Activities performed in this task are: a) form the PSC and the technical and functional committees. Install EAB (UMIL, All partners); b) provide inputs and needs for changes (All partners); c) define and check consequences according to budget, schedule and objectives (UMIL); d) communicate and arrange meetings (UMIL); e) define management meetings agenda (All partners based on UMIL proposal); f) collect partners inputs on meeting Agenda (UMIL); g) circulate meeting agenda and logistic information. Prepare minutes of each meeting (UMIL) h) prepare updated plans for final approval in the PSC (UMIL). This might include the request of amendments to the EC. In this case, partners involvement is the following: a) amendment requested for technical issues (UMIL and all partners); b) amendment requested for entrance or withdrawal of beneficiaries (UMIL and all partners); c) communicate updated plans to consortium members. Large use of IT-based communication platforms, like Skype, is used to cut the costs and increase the responsiveness.

***Task 10.2(M1-M36): Progress and costs reporting. (UMIL, All partners)*** Robohome2.0 brings together researchers from different institutes and different countries. In order to establish common operational procedures and taking into account the enlarged Robohome2.0 partnership, UMIL prepares written guidelines and operational instructions to be followed by the partners for carrying out their research activities, that have to be approved by the PSC. This task focuses on **project's reporting starting from the individual reports provided by the partners**. Periodic reports for the EC 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. Activities that have to be performed in this task are: a) providing administrative/financial data and relative explanations requested for each reporting period: table including detailed explanation of the use of the resources for each partner, Form C and if applicable Certificate on Financial Statement. The procedure includes the preparation of draft documents and then once the EC approves the costs, signature of the Form C (All partners); b) providing customised templates for reporting to all concerned participants (cf. Task 1.1, UMIL); c) assistance on the use of the on-line tools for the completion of the financial reporting, and on how to complete the templates and revision of their first draft documents (UMIL); d) first control on the administrative/financial documents provided by partners (UMIL and All partners). Once the PC approves the financial report of each partner the latter can proceed with the final draft to be up-loaded in the on-line system (All partners); e) maintaining a document repository for reporting (UMIL); f) submitting on time reports deliverable, milestone reports and cost claims of the required quality (UMIL); g) creating periodic reports (UMIL). The periodic report for each period, will regroup in one single report both the technical report and financial reporting. The latter will include also the Financial Statements and the Certificates. The final report will comprise a final publishable summary report, the plan for use and dissemination of foreground and a report covering the wider societal implications of the project, in the form of a questionnaire. UMIL as Coordinator is in charge and responsible to create the final version of reports.

***Task 10.3(M1-M36): Monitoring, control and quality management. Risk Management (UMIL, All partners)*** This task will ensure that **approved plans are monitored and controlled**. Progress control will be done at WP level by measuring resources and costs. Activities to be performed include: a) research and development progress control (UMIL); b) cost control (UMIL, All partners). In this context each partner prepares periodical estimates on expenditure from which UMIL will produce a lumped estimate. These figures will be discussed within PSC to evaluate possible deviations and correction actions. c) checking schedules, deliverables and milestones (UMIL); d) risk analysis (UMIL, All partners); e) Risk management is fundamental to keep the project on track and to tackle early any hazard in which the project might incur. **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.

***Task 10.4(M1-M4): Set-up of the end-users advisory board and of the project committees (UMIL, All partners)*** Robohome2.0 consortium believes that a continuous, effective and reliable feed-back of users is fundamental for the project success. Beside the functional committee that will bring the end-users point of view, we aim also to have an external independent advice. **In the first stage of the project key figures will be identified for each type of end-users** (informal caregivers: relatives, elders, formal care-givers: nurses, physiotherapists, Psychologists and clinicians, and ICT personnel) and will be invited to be part of an end-users advisory board. This will meet at M6 of the project with the PSC and, afterwards, at M12 M24 and M36. Their role will be a pro-active evaluation of the project and suggestions of improvements that will fully discussed with the PSC of Robohome2.0.

***Task 10.5(M1-M36) IPR management (UMIL, All partners)*** Knowledge developed in Robohome2.0 will be secured as early as possible by the consortium as a whole and each partner individually. PSC and single partners will evaluate which results are suitable to be patented and identify the best options to protect SW and HW aspects of the results; patenting will be the method of choice in most cases. A continuous patent survey throughout the project will ensure the priority to the IPR. UMIL will lead this task, with the contribution of the director of its TTO, with the role of **scouting the solutions developed and secure the results as early as possible to avoid that early disclosure would make patenting not possible**. A report will summarize the IPR activities and achieved patents at the end of the project (M36).

**Deliverables** (brief description and month of delivery)
D10.1 [OTHER, PU] Set-up of the end-users advisory board (UMIL, M4)
D10.2 [R, CO] Project management and quality plan. Report on ethical guidelines and regulations (UMIL, M6)
D10.3 [R, CO] Periodic Report I (UMIL, M12)
D10.4 [R, CO] Periodic Report II (UMIL, M24)
D10.5 [R, CO] Periodic Report III (UMIL, M36)
D10.6 [R, CO] Final Report (a public section is provided) (UMIL, M36).

## List of Workpackages

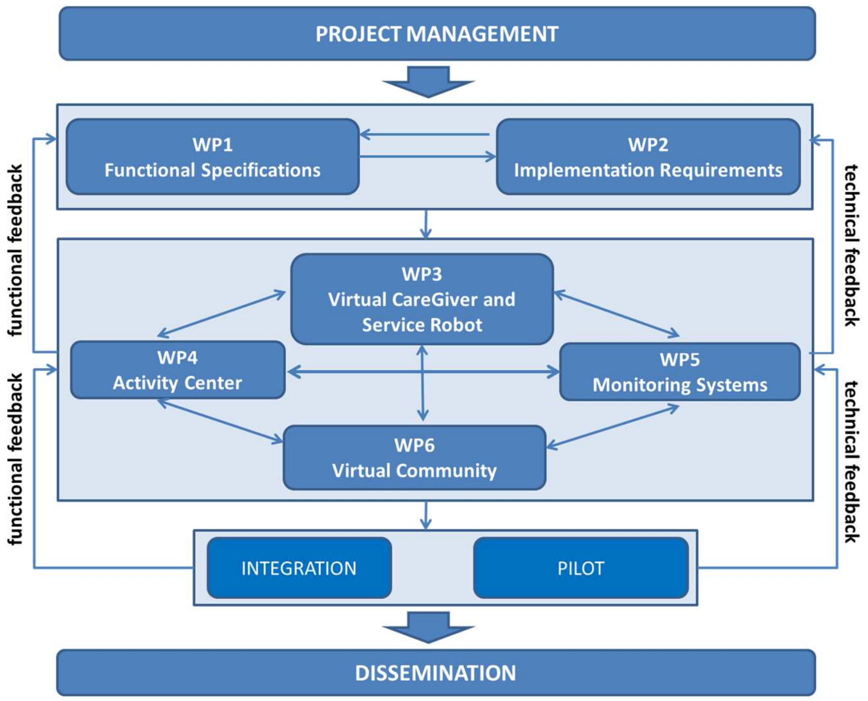
| Work package No | Work Package Title | Lead Particip ant No | Lead Participant Short Name | Person-Months | Start Month | End month |
|---|---|---|---|---|---|---|
| 1 | Functional Specifications | 6 | PCL | 58,5 | 1 | 18 |
| 2 | Implementation requirements | 4 | UOP | 54 | 2 | 24 |
| 3 | Virtual caregiver and Service robot | 2 | ORU | 72,5 | 3 | 27 |
| 4 | Activity center | 1 | UMIL | 85 | 3 | 36 |
| 5 | Monitoring Systems | 7 | POLIMI | 101 | 3 | 27 |
| 6 | Virtual Community | 8 | BDIGITAL | 63,5 | 3 | 27 |
| 7 | Integration | 3 | GIRAFF | 49,5 | 10 | 27 |
| 8 | Robohome2.0 pilot | 9 | SAS | 85 | 13 | 36 |
| 9 | Dissemination and Exploitation | 1 | UMIL | 38,50 | 1 | 36 |
| 10 | Management | 1 | UMIL | 24,8 | 1 | 36 |
| | | | | 632,3 | | |

### List of major deliverables

| Deliverable (number) | Deliverable name | Work package number | Short name of lead participant | Type | Dissemination level | Delivery date |
|---|---|---|---|---|---|---|
| 9.1 | Project Website | 9 | UMIL | DEC | PU | M3 |
| 10.1 | Set-up of the end-users advisory board | 10 | UMIL | OTHER | PU | M4 |
| 9.2 | Project leaflet, poster | 9 | UMIL | DEC | PU | M6 |
| 10.2 | Project management and quality plan. Report on ethical guidelines and regulations | 10 | UMIL | R | CO | M6 |
| 1.1 | Functional specifications | 1 | PCL | R | PU | M12 |
| 1.2 | Ethical submission | 1 | PCL | R | CO | M12 |
| 2.1 | Technical specifications | 2 | POLIMI | R | CO | M12 |
| 2.2 | HRI analysis and definition of robot-users interfacing modalities | 2 | UOP | R | CO | M12 |
| 2.4 | Design of testing the system and its components | 2 | POLIMI | R | CO | M12 |
| 3.1 | Methodology for profiling the elders and the functionalities and some real case scenarios | 3 | ORU | R | PU | M12 |
| 4.1 | A first nucleus of physical and cognitive games + silhouette tracking | 4 | UMIL | R/OTHER | CO | M12 |
| 5.1 | Design and development of the monitoring networks; a first report will be provided | 5 | BDIGITAL | R | CO | M12 |
| 9.3 | Preliminary exploitation and dissemination plan | 9 | UMIL | R | CO | M12 |
| 10.3 | Periodic Report I | 10 | UMIL | R | CO | M12 |
| 6.1 | Virtual Community design and structure | 6 | BDIGITAL | R | CO | M15 |
| 1.3 | Final functional specifications | 1 | UMIL | R | PU | M18 |
| 4.2 | The full system for education | 4 | POLIMI | R/OTHER | CO | M18 |
| 5.2 | The full monitoring systems ready for usability testing | 5 | POLIMi | R | CO | M18 |
| 2.3 | GUI Design | 2 | UMIL | R/OTHER | CO | M24 |
| 3.2 | Improved navigation functionalities | 3 | UMA | R/OTHER | CO | M24 |
| 3.3 | The reasoning and recommendation system | 3 | ORU | R | PU | M24 |
| 3.4 | Tested prototype of everyday life assistance and therapy compliance | 3 | SXT | R/OTHER | CO | M24 |
| 6.2 | Virtual community final design and implementation | 6 | BDIGITAL | R | CO | M24 |
| 6.3 | Virtual community software package | 6 | BDIGITAL | OTHER | CO | M24 |
| 7.1 | Description of the hardware and software infrastructure of Robohome2.0. | 7 | BDIGITAL | R | PU | M24 |
| 8.1 | Analysis of assistance platform available on the market and their deployment modalities | 8 | KORIAN | R | PU | M24 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8.2 | Refinement of functional and technical specifications | 8 | UMIL | R | CO | M24 |
| 9.4 | Refined exploitation and dissemination plan, with refined poster | 9 | UMIL | R | CO | M24 |
| 10.4 | Periodic Report II | 10 | UMIL | R | CO | M24 |
| 4.3 | The full smart activity center with the final reference manual, user manual and installation manual | 4 | UMIL | R/OTHER | CO | M27 |
| 5.3 | Validation of the clinical transparent clinical tests | 5 | POLIMI | R | PU | M27 |
| 5.4 | Report on the functional and usability tests of the monitoring systems | 5 | POLIMI | R | PU | M27 |
| 7.2 | Report on functional tests on the final integrated platform | 7 | UMIL | R | PU | M27 |
| 7.3 | Integrated SW / HW prototype to be used for the pilot | 7 | UMIL | OTHER | CO | M27 |
| 8.3 | Report on deployment modalities and patient-doctor communication improvement and therapy compliance with Robohome2.0 | 8 | PCL | R | PU | M36 |
| 8.4 | Assessment of Robohome2.0 effectiveness, compliance, usability and reliability in assisting the elders at home | 8 | SAS | R | PU | M36 |
| 9.5 | Final exploitation and dissemination plan, with final leaflet and poster | 9 | UMIL | R | CO | M36 |
| 10.5 | Periodic Report III | 10 | UMIL | R | CO | M36 |
| 10.6 | Final Report (a public section is provided) | 10 | UMIL | R | CO | M36 |

### 3.1.4 Graphical presentation of the components and how they inter-relate (Pert chart)



## 3.2 Management Structure and procedures

### 3.2.1 Organizational structure and the decision-making

When establishing the consortium, great attention was placed to fully cover the different aspects involved in Robohome2.0, by choosing partners capable of dealing as effectively as possible with their tasks. We found an enthusiastic feedback to the participation both to the consortium and to the advisory board. The Management structure consists of: 1) The Project Co-ordinator (PC) Nunzio Alberto Borghese from UMIL; 2) the Project Steering Committee (PSC), formed by the Principal Investigators (PIs) of the 13 partners. Each member of the PSC is entitled to nominate a substitute to attend any meeting when a member is unable to attend. The PSC will be the organ of the consortium **entitled to make decisions**. Given the size of the consortium and the type of project, two committees are formed, with the aim of making internal discussion easier. The **functional committee**, led by PCL, and participated also by PCL, KOMMUN, SAS, KORIAN, UOP and UMIL, discusses specific issues related to functional aspects and their implementation, coordinates relevant information. The **technical committee**, led by POLIMI, and participated by POLIMI, UMIL, ORU, GIRAFF, UOP, SXT, BDIGITAL, SG and UMA, discusses **technical aspects** and their implementation. Other partners can adhere to the committees or to their initiatives. The two committees discuss specific issues, possibly keeping trace of the discussion, and **report the conclusion to the PSC.** A committee specifically devoted to manage the Ethical issues is set-up: the **Ethical Advisory Board** of the project, led by PCL. It will be participated also by PCL, KOMMUN, SAS and UMIL and has the responsibility for monitoring the conformity of the project to the ethical standards, analyzing all the ethical issues of the project: data protection, privacy, ethical submission (cf. Task 1.7), gender issues, proper level of communication. The WP leaders are responsible to assure the successful completion of their relevant work packages. At every level, decisions will be made by consensus whenever possible, to keep the maximum collaborative atmosphere inside the consortium. However, if over a reasonable length of time the conflicting parties have fully described and defended their conflicting positions but without resolution, then in order to avoid deadlock in the project's operational progress, the approval of a two-thirds majority of the partners will be considered conclusive. P1 will have the casting vote. The Robohome2.0 administrative headquarters will be located at UMIL premises in Milano. Concerning the suitability to the tasks of the participants, the Principal Investigators (PIs) of each partner have long experience in his/her field and holds senior positions of responsibility within his/her own organisation. **The role of the PC is mainly a coordinating role, while that of the PSC is of decision maker**. Therefore, the ***PC is responsible for:*** *a)* supervising and controlling the research programme, including control of research progress towards milestones; b) representing the REWIRE Consortium in the communication with the EU; c) communicating and negotiating with the EC after approval of the PSC; d) distributing funds among partners; e) preparing common formats and templates to be used by the partners for reporting activity; f) collecting and preparing the mandatory reports and submitting them to the EU; g) managing ethical issues, in collaboration with the EAB; h) organizing, convening and participating in the PSC meetings; i) managing technological risks by identifying and classifying them and by putting them in contingency plans; j) performing detailed planning and co-ordination of the work, taking the responsibility for the completion and quality assurance of each WP; k) providing a trimestral update on project development. The ***PSC will have the responsibility for making all the decisions in the project,*** among which: a) setting the scientific priorities, within the existing objectives and budget framework; b) maintaining and implementing the CA; c) discussing the most adequate potential solution to risks and, in case, implementing them; d) monitoring and reporting processes and results, based on deliverables accomplished; e) proposing and approving corrective actions, when any problems occur that might affect achievements or delay activities and deliverables, thus ensuring the adherence to the project timetable. As Robohome2.0 is deeply concerned of end-users need, an **End-Users Advisory Board** is set-up early in the project. This body will include high profile members in the following areas: informal caregivers: relatives, elders, formal care-givers: nurses, physiotherapists, Psychologists and clinicians, and ICT personnel. They will be chosen by the PSC at the kick-off meeting, taking into account partners suggestions, match to Robohome2.0 aims and nationality. The EUAB meets just before or after PSC meetings to discuss and advice about functionalites and their implementation to guarantee maximum compliance with the ender. Some of the information generated during the development of Robohome2.0 system has to be considered as **confidential**. In this regard, partners will be asked to sign a non-disclosure agreement as a specific article of the CA.

### List of milestones

| Milestone number | Milestone name | Related work package(s) | Estimated date | Means of verification |
|---|---|---|---|---|
| 1 | Set-up of end-users advisory board | 9,10 | M4 | All members have provided written agreement |

| | | | | |
|---|---|---|---|---|
| 2 | Functional description of Robohome2.0 | 1,2,9,10 | M12 | Document containing the complete platform technological and functional specification |
| 3 | Running prototypes of the components endowed with a limited set of functionalities | 3,4,5,6,9,10 | M18 | Tests report on running prototype of the components endowed with a limited set of functionalities. |
| 4 | Running components of Robohome2.0 | 3,4,5,6,9,10 | M24 | Functional and technological documentation of the components and their testing that show that the components implement the specifications in WP1 and WP2 and run flawless. |
| 5 | Running Robohome2.0 platform | 7,9,10 | M27 | Functional and technological documentation of field testing the whole Robohome2.0 platform, documenting that it runs flawless. |
| 6 | Final report | 8,9,10 | M36 | Report on applying Robohome2.0 to single elders at home Report on results obtained from the analysis of all the patients. |

### 3.2.2 Explain why the organizational structure and decision-making mechanisms are appropriate to the complexity and scale of the project

The management structure and operational functions guarantee the proper and prompt implementation of activities, as indicated in the contract terms with the EU. These are similar to those adopted successfully for the Rewire project. From a functional point of view, management will deal with the following two sub-processes: a) implementation of the project's components; b) innovation management & reporting. The management structure envisaged is functional to exploit these two sub-processes. A brief description of the main objectives, activities and responsibilities associated with managing **implementation** is described in the following Table.

| Objectives | Activities & responsibilities |
|---|---|
| To establish common operational procedures | P1 develops common templates and forms to be used by each participant in order to document the project's progress (both scientific and administrative/financial). For example: common format for all the project deliverables, cost statement forms, risk analysis templates, task activity evaluation forms, etc. Non-paper deliverables will be always completed by a short paper description of their contents and aims (Task 10.2). |
| To ensure integration of the different research teams | Meetings at the health providers sites will be organized early in the project to build a shared view of Robohome2.0, and of its aims. Trimestral updates on project progress will be provided to all partners. The PSC establishes the rules for the day-to-day activities of the different research groups and defines the proper tools and infrastructures for implementing the co-operation between the different research groups. The constitution of a functional and technical committee will help the discussion among homogenous groups of partners. |
| To prepare and agree on the IPR and access rights. To maintain the Consortium Agreement (CA) | The PSC agrees on IPR, exploitation rights of the projects results, common knowledge access rights, etc. The partners adhere to the CA. A careful analysis of the deriving IPR issues will be carried out by the PSC and the rules for the management of IPR are agreed within the Consortium and included in the CA. The CA will also regulate any previous know-how |
| To organise periodic meetings of the PSC | P1 takes care of the organisation of periodic meetings to verify the development of the various project components and tune further development. |
| To monitor the project financial status | Every period, each partner prepares a cost statement, which declares the sustained costs broken down by type of activity; a justification of its overall costs incurred, linking these costs to the resources deployed and to the activity performed during the period. Each partner transmits to P1 the information. P1 evaluates and agrees with the cost statements received. P1 is responsible to collect the information and prepare the financial report for the EC. In the reserved area of the website, |

| | |
|---|---|
| | resources tables will be shared for internal monitoring of the overall resources consumed. An open source tool, like dotProject.net, might be used. |
| To assure complete and timely reporting to EC | Every period P1 prepares a periodic report that contains an overview of the activities undertaken during the period; a summary of the S&T results achieved during the period; a list of the deliverables published and of the milestones reached during the period; a description of the actions carried out in the "Monitoring" process, i.e. the measurement / evaluation / corrective actions carried out to ensure adherence to the project workplan; a financial statements provided by each participant; a summary financial report. After the end of the project, P1 prepares a final report including a final publishable summary report and the DUP. The PSC will agree the above documents and P1 submits them to EU. |

### 3.2.3 Describe how effective innovation management will be addressed in the management structure and work plan

Regarding **management of innovation**, it is worth distinguishing between: a) internal" knowledge, i.e. consortium access to the information needed to carry out the research programme; b) study on the best ways to diffuse the tools developed through the Robohome2.0 project; c) spreading of knowledge toward the scientific and industrial community, i.e. enlargement of the researchers base and dissemination activity; d) knowledge transfer to the EU, i.e. reporting activity; e) intellectual protection provisions; f) exploitation plan.A brief description of the main objectives, activities and responsibilities associated with managing **knowledge** is described in the following Table.

| Objectives | Activities & responsibilities |
|---|---|
| To guarantee that information is available where and when it is needed. | The PSC defines and implements access rights provisions to the documentation and the results achieved during the project. Within these provisions, P1 is responsible for deciding what information is needed and for collecting it from the partners. P1 is then responsible for publishing these internal documents, deliverables and reports on an electronic workspace that can be used by each partner of the Consortium to download documents and run discussions. |
| To support the dissemination / exploitation of the project results | The PSC approves the dissemination activities defined within the WP9 "Dissemination/Exploitation. PSC is responsible for revising draft Exploitation plan (Task 9.1). P1 is responsible to ensure the full functionality the project web site. To this aim, the partners submit their contributions to P1 and P1 structures and spreads the information / reports / deliverables received from the partners. |
| To prepare and organize diffusion material. | Each deliverable will be analyzed and eventually edited to become suitable for diffusion through conventional (press-release, newsletters and so forth) and non conventional (LinkedIn, YouTube, Facebook, and so forth) channels. Given the comprehensive nature of the project, major deliverables associated to milestones could be grouped to provide chapters to be published in major books of the area. |
| To assure complete and timely information to EC of dissemination activities | P1 will inform in due time the Communication Officer of all the Communications and Dissemination activities (Press Releases, website launch, articles, etc.) to enable a proper relay of these activities within Europa, the eHealth newsletter, Healthtech Wire platform, etc. |

### 3.2.4 Describe any critical risk, relating to project implementation

A continuous monitoring of risks emerging during project development will be carried out.The Consortium will ensure an internal control of the project development to early identify critical issues and operational bottlenecks. The proposed methodology is based on a three-stage approach, the Risk Identification, the Risk Assessment and the Mitigation Plans. First, all risks will be identified (cf. "Table on critical risks for the implementation") and evaluated on a qualitative scale. After the first risk identification, all risks will be plotted into a risk analysis matrix (Figure 7a). This will highlight the two parameters used to characterize each risk: the **probability** and its but also their possible **impact** on the project. These two parameters provide to the PC all the information needed for a risk prioritisation. Furthermore, the Critical Risks Matrix will provide a sound basis to highlight the most significant potential risks and lead to the development of corrective mitigation action planning. The risk mitigation planning four-stage process described in Figure 7b guarantees that corrective actions are chosen after a meticulous analysis of alternative options. WP leaders will constantly monitor identified critical risks associated to their WP. The results of these risk mitigation actions will be implemented only upon the approval by the PSC.

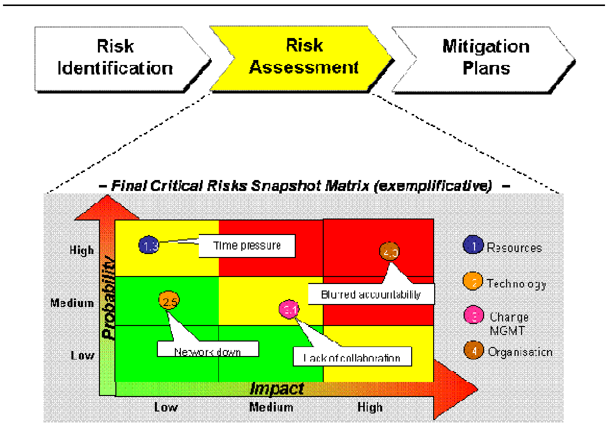



Figure 7a: Example of Risk Assessment matrix.

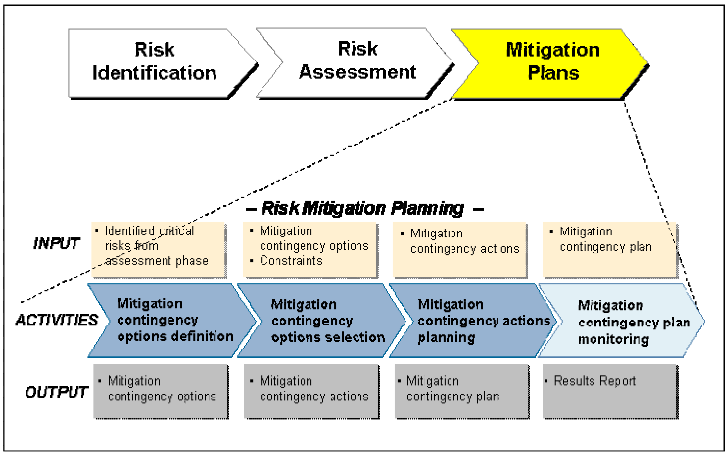



Figure 7b: Mitigation planning

## Table of critical risks for the implementation

| Description of risk | WP(s) | Proposed risk-mitigation measures |
|---|---|---|
| **Technical risk**: Robohome2.0 features do not match expectations of the end users. ***Probability low:*** WP1 is completely devoted to transfer users' needs into clear technical requirement. Futher, the adoption of participatory design in the development of the modules allows a continuous matching of Robohome2.0 features to users' expectations and needs. ***Impact high:*** the system will have little use. | 1, 8 | *Additional resources will be allocated to designing tasks to better accomplish users expectations. Early checking through living lab experiments, will allow to include them in the second cycles of refinement (cf. Pert diagram)*. *The end-users advisory board will also help Robohome2.0 to avoid this.* |
| **Technical risk**: The technologies used to implement Robohome2.0 prototypes are not the most suitable for the project purposes. ***Probability low:*** WP2 allows choosing the best technological solutions for Robohome2.0 functions. ***Impact Medium:*** specific modules can be substituted later in the final prototype. | 2, 8 | *The architecture design is modular and flexible allowing an easy addition or substitution of technological components throughout the development project phase.* |
| **Technical risk**: The developed system has limits in usability and accessibility. ***Probability Low***: Usability and accessibility rules are taken in account in design and development phases, with specific behavioral testing (Task 3.4, Tasks 8.1 and 8.2). ***Impact Medium:*** limit in usability will allow use only to particular groups of users. | 3, 8 | *A continuous feedback from the end users, starting from early pilot in living labs, and from the End-Users Advisory Board will allow modifications of the weak interfaces all along project development* |
| **Consortium risk:** Divergence among partners on project direction. ***Probability Low:*** Consortium agreement rules every conflict situation. The research of consensus is the first objective. ***Impact Medium:*** Goals of Robohome2.0 are clearly described in this document. No major deviations can take place. | All | *PC will put a strong effort in finding a solution most suitable to all involved parties. After illustration and defence of conflicting positions, in order to avoid deadlock in project operational progress, the approval of simple majority of Partners will be verified.* |
| **Management risk**: Unexpected delay in project development. ***Probability Medium:*** Due to the high complexity of the project, a few components may not be realized within the expected time. ***Impact Medium:*** A delay in the project may take place. | 3, 4, 5, 6, 7 | *Robohome2.0 management is structured to maintain a continuous monitoring on all administrative and technical aspects. In case criticalities are detected, re-evaluation of the task duration is carried out. Last resort would be to discuss with the PO project prolongation beyond M36* |
| **Management risk:** Risks related to the protection of involved users data. ***Probability Low:*** All data collected | 8, 9 | *Robohome2.0 clinical partners are well experienced and will monitor all along* |

| | | |
|---|---|---|
| within Robohome2.0 project are anonymous and the project is carried out in compliance with the Directive 95/46/EC about data protection. Moreover the Ethical Advisor Board will supervise all the project activities. ***Impact High***. | | *project's life with regards to ethics and privacy issues. Respective Ethical Committees will be consulted and ethical approval requested before any experimentation involving patients.* |
| **Technical risk:** One PC will not support both the game engine, the video processing required for tracking and the interfaces to the monitoring systems. ***Risk very low.*** The highest computational load is on the game engine. UMIL IGER platform currently runs in real-time on a wide range of computers, also less power than the Core i7 mounted on Giraff. ***Impact High.*** Latency in the graphics would destroy amusement, key element for gamification | 4, 7 | *In this situation we will consider either a new generation PC to be integrated inside Giraff or an embedded PC for acquisition and processing data from Kinect camera that communicates in real-time (e.g. via GigaEthernet network) with the PC on Giraff.* |
| **There will be not enough exer-games to cover the needs specified in WP1. Risk very low:** Exer-games will be developed upon IGER system that has allowed developing a total of 17 exer-games for REWIRE in one year. **Impact medium:** The impact depends on the criticality of the exer-games that could not be implemented. | 4 | We will allocate extra-resources to exer-games development during the second year of the project. |
| **Technical risk:** We will not be able to recruit enough elders for the pilot study. ***Risk low:*** PCL, SAS and KOMMUN serve yearly a very large number of elders. ***Impact medium:*** Pilot duration needs to be prolonged. | 8 | *We will reconsider the conditions set to enroll the patients and possibly contact other centers / hospitals.* |

## 3.3 Consortium as a whole

### 3.3.1 Describe the consortium

Robohome2.0 consortium is composed of 13 partners from 5 European countries (Italy, Spain, United Kingdom, France and Sweden). It gathers experts from the technological sector (UMIL, ORU, GIRAFF, UOP, SXT, POLIMI, BDIGITAL, SG, UMA), the clinical, psychological and assistance sectors (PCL, SAS, KOMMUN), the public administration (SAS, KOMMUN) and a large service provider (KORIAN). It joins the big industry (KORIAN), the small industry (SXT, SG, GIRAFF), universities (UMIL, UOP, POLIMI, UMA), a private research center (BDIGITAL). Indeed, the consortium includes all the different perspectives involved in remote elder assistance. The technological development is led by UMIL. POLIMI will lead the research on Monitoring systems, BDIGITAL of the virtual community, ORU of the virtual caregiver, UMA of Giraff, UMIL of the activity center and UOP will take care of realizing meaningful interaction between the elder and the robot. Technological development will be continuously supported by the end-user partners: KOMMUN, SAS and PCL. These will lead the design of the Robohome2.0 functionalities and they will do the pilots tests. All the three parties have already been involved international projects and are reference centers in their country. Technology assessment and exploitation evaluation will be carried out by KORIAN supported by PCL, SAS and KOMMUN. Looking at the specific competencies, a multidisciplinary project always needs a “link partner” expert in enhancing dialogue and collaboration among clinical and technological experts. This role is covered by UML who has covered this role successfully in the projects FITREHAB and REWIRE. Two living labs will be set-up, one in Malaga and one in Orebro in which early testing will be carried out. Looking at the dissemination of the results, all the academic partners are strongly committed to spread their research results while KORIAN will supervise the exploitation with the help of SXT, SG and GIRAFF.

### 3.3.2 Describe the industrial / commercial involvement in the project

KORIAN is aiming to incorporate Robohome2.0 technology to enlarge its range of assistance services to the elder at home (cf. Section 2.2a). SXT and SG are interested in developing innovative solutions in their specific domains and GIRAFF will be the natural node through which provide the technology to KORIAN. SG and SXT will bring specific competence in signal processing and sensing micro-architectures. With Robohome2.0 they will exploit their competence for potential new attractive market. GIRAFF is extremely interested in further developing Giraff robot. It totally adhere to the open source approach and it will exploit applications that show potentiality for the market.

## 3.3 Resources to be committed

The project cost is of 3,199,756 € to which 799,939 € of overheads has to be added. This cost is well justified by the amplitude of Research and Development. The largest share goes into staff (2,771,256 €). Travel costs are 177,500 €, Equipment 174,200 €, Consumables 49,800 Euros and Other Direct Costs 27,000 €.

### 3.4a Number of person / months required

| | WP1 | WP2 | WP3 | WP4 | WP5 | WP6 | WP7 | WP8 | WP9 | WP10 | Total Person/ Months per Participant |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1/UMIL** | 5 | 3 | 5 | **27** | 9 | 6 | 8 | 3 | **11** | **12** | **89** |
| **2/ORU** | 7 | 6 | **15** | 7 | 4 | 2 | 5 | 3 | 3 | 1 | **53** |
| **3/GIRAFF** | 0,5 | 1 | 1,5 | 0,5 | 0 | 0,5 | **8** | 1 | 2 | 0,3 | **15,3** |
| **4/UOP** | 4 | **11** | 2 | 4 | 0 | 3 | 2 | 10 | 4 | 1 | **41** |
| **5/SXT** | 0,5 | 3 | 1 | 4,5 | 30 | 0 | 4,5 | 0 | 1 | 1 | **45,5** |
| **6/PCL** | **9** | 5 | 7 | 6 | 9 | 2 | 0 | 8 | 3 | 1 | **50** |
| **7/POLIMI** | 5 | 6 | 9 | 16 | **20** | 5 | 4 | 7 | 3 | 2 | **77** |
| **8/BDIGITAL** | 2 | 4 | 2 | 4 | 12 | **32** | 8 | 2 | 1 | 1 | **68** |
| **9/SAS** | 8 | 1 | 2 | 2 | 3 | 3 | 0 | **24** | 2 | 2 | **47** |
| **10/KORIAN** | 9 | 4 | 3 | 5 | 5 | 3 | 1 | 19 | 4 | 1 | **54** |
| **11/SG** | 2 | 2 | 0 | 0 | 7 | 5 | 3 | 0 | 0,5 | 0,5 | **20** |
| **12/UMA** | 2 | 6 | 22 | 8 | 0 | 0 | 6 | 2 | 1 | 1 | **48** |
| **13/KOMMUN** | 4,5 | 2 | 3 | 1 | 2 | 2 | 0 | 6 | 3 | 1 | **24,5** |
| **Total** | **58,5** | **54** | **72,5** | **85** | **101** | **63,5** | **49,5** | **85** | **38,5** | **24,8** | **632,3** |

The following staff figures will be possibly on staff for the partners: UMIL: 2 Senior researcher for 27 MM total + 2 post doc for 30 MM each + 1 TTO manager for 2 MM; ORU: 1 PI for 11MM + 1 PhD Student for 24 MM + 1 Post-doc for 18 MM; GIRAFF: 2 Senior researchers for 15,3 MM; UOP: 1 PI for 5 MM + 1 Post-doc for 36 MM; SXT: 3 Senior engineers for 45.5 MM total; PCL: 1 PI for 1 MM, 1 Senior Researcher for 2MM, 1 senior neuropsychologist 1 MM; 1 sociologist for 1 MM; 2 Post-Docs for 22 MM each; POLIMI: 2 Senior researchers for 23 MM total + 1 Post-doc for 24 MM + 1 Assistant professor for 30 MM; BDIGITAL: 1 PI, 2 Senior Researchers + 1 Junior researcher part time for a total of 68MM; SAS: 1 PI (Medical doctor, 6MM) + 2 nurses (19MM); 1 Junior doctor +1 Psychologist + 1 sociologist for a total of 20 MM; 1 Project Manager (2MM); KORIAN: 1 PI (10 MM); 1 Junior researcher (7 MM); 1 Junior geriatrist (13 MM); 1 junior physiotherapist (13 MM); 1 psyhologist (8 MM); 1 nurse (3 MM); SG: 2 senior engineers for a total of 20MM; UMA: 2 Senior Researcher for 18 MM total + 1 Post-doc for 20 MM + 1 Senior Engineering / CS for 10 MM; KOMMUN: 1 Senior clinician (PI – 3,5 MM); 2 junior clinicians (12 MM); 1 sociologist (1 MM); 1 Psyhologist (2MM); 1 Physiotherapist (6 MM).

### 3.4b Other relevant direct cost

| **3/GIRAFF** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 11.000 | 4.5K for project meetings, 6.5K for short visits and development / testing on partners site |
| **Equipment** | 9.700 | 1 robot Giraff: 9.7K |
| **Other goods and services** | 2.000 | Small mechanical components, electronics and cables |
| **Total** | 22.700 | |

| **4/UOP** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 17.000 | 4.5K for project meetings, 7K for Scientific meetings, 5.5K for short visits and development / testing on partners sites |
| **Equipment** | 9.700 | 1 robot Giraff: 9.7K |
| **Other goods and services** | 13.000 | 5K for students projects and 3K for external auditing<br>5K for material and software for testing. |
| **Total** | 39.700 | |

| **5/SXT** | **Cost (€)** | **Justification** |
|---|---|---|

| | | |
|---|---|---|
| **Travel** | 11.000 | 4.5K for project meetings, 6.5K for short visits and development/testing on partner sites |
| **Equipment** | 12.800 | 4.2K for specific SW licenses for the time dedicated to the project. 4.2K for SDK and licenses for new generation low-power CPUS and Bluetooth 4 Smart device SDK. 0.9K for 1 PC for development end test on field (three years and further demonstration). 3.5K for special plants and equipment for the production for the prototypes. |
| **Other goods and services** | 12.000 | Small mechanical components, electronics and cables. Small subcontracting for assembly and testing. |
| **Total** | 35.800 | |

| **6/PCL** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 13.000 | 4.5K for project meetings, 5.5K for scientific meetings; 2K for short visits and development/testing on partner sites |
| **Equipment** | 29.100 | 3 robots Giraff: 29.1K |
| **Other goods and services** | 3.000 | Clinical material for tests |
| **Total** | 45.100 | |

| **7/POLIMI** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 11.000 | 4.5K for project meetings, 4.5K for Scientific meetings, 2K for short visits and development / testing on partners sites. |
| **Equipment** | 30.000 | 12 full sets for clinically validated instrumentation for: blood pressure and heart rate physiological measurements (4800K), Equipment for multiparameters physiological measures (HR, BP Glucose, Oxygenation, 14400K), Glucometers (8400K). 2 laptop (2400K) |
| **Other goods and services** | 7.500 | 3,5K for external auditing, 4K for small mechanical components, electronics and cables |
| **Total** | 48.500 | |

| **9/SAS** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 14.000 | 7k for project meetings, 4k for WP training meetings, 3k for dissemination events attendance |
| **Equipment** | 29.100 | 3 robots Giraff: 29.1K |
| **Other goods and services** | 4.500 | 1.5K for pilot material, 3K for auditing and meeting organization |
| **Total** | 47.600 | |

| **11/SG** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 14.000 | 5.5K for project meetings, 8.5K for short visits and testing on partners site. |
| **Equipment** | 0 | - |
| **Other goods and services** | 9.000 | DSP and FPGA development boards, hardware components, development software for 9K Euros. |
| **Total** | 23.000 | |

| **12/UMA** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 18.000 | 9 K for project meetings, 6 K for scientific events (conferences, workshops, etc.), 3 K for supporting the pilot test site and for short visit to partner sites |
| **Equipment** | 9.700 | 1 robot Giraff: 9.7K |
| **Other goods and services** | 3.500 | 1.5K for PSC meetings organization, 2K for Kinect, webcam, calibration structures and objects |

| | | |
|---|---|---|
| **Total** | 31.200 | |

| **13/KOMMUN** | **Cost (€)** | **Justification** |
|---|---|---|
| **Travel** | 10.000 | 4.5 K for project meetings, 5,5 K for scientific events (conferences, workshops, etc.) |
| **Equipment** | 9.700 | 1 robot Giraff for 9.7K |
| **Other goods and services** | 2.000 | Clinical material for tests |
| **Total** | 21.700 | |

## Abbreviations

AAL – Ambient Assisted living
ADL – Activity of Daily life
AI – Artificial Intelligence
CA – Consortium Agreement
CHA – Continuous Health Alliance
COPD - Chronic obstructive pulmonary disease
DB – DataBase
DL – Description Language
DoW – Description of Work
EAB – Ethical Advisory Board
EUAB – End-Users Advisory Board
EC – European Commission
FP7 – 7th FrameProgram
FTD – Fronto Temporal Dementia
GLVM - Gaussian Latent Variable Models
GP – General Practitioner
GUI – Graphical User Inteface
HRI – Human Robot Interfaces
HW – Hardware
ICER – Incremental Cost Effectiveness Ratio
ICT – Information Communication Technology
IGER – Intelligent Game Engine for Rehabilitation
IPR – Intellectual Property Right
IT – Information technology
KOMMUN – Orebro Municipality (Orebro Kommun)
NUI – Natural Users Interfaces
OS- Operating System
OWL – Ontoloty Web Language
PC – Project Coordinator
PCL – Fondazione IRCCS Cà Granda Ospedale Maggiore Policlinico
PFSM – Probabilistic Finite State Machines
PO – Project Officer
PSC – Project Steering Committee
QMCI - Quick Mild Cognitive Impairment score (test)
RFID – Radio Frequency Identification Device
RGB – RedGrenBlue, a digital color image code
TAM – Technology Assessment Model
TRL – Technology Readiness Level.
SMS – Short Message Service
SOA – Service Oriented Architecture
SQL – Structured Query Language
SXT – SXT srl
SW - Software
SWRL – Semanting Web Rules Language
TUG – Timed Up and Go, test used for physical assessment
UML - Unified Modeling Language
VC – Virtual Caregiver
VCA – Virtual Caregiver Avatar
WP – Work Package