Collaborative R&D program: **Ambient Assisted Living services**

A. Project Identification

Project Title:
Open **P**latform and **T**ools for **I**ntelligent **M**onitoring of **A**ctivities of Elder People at Home

Project acronym: OPTIMA

Project Description:
Healthy ageing is about enabling elder people to enjoy a good quality of life. Analyzing and understanding the elderly needs (in general, but also in relation to their disabilities due to age) is a key prerequisite to building added value assistive technology, which could have a substantial impact on the end-users' daily life.

OPTIMA's main aim is to design, develop and evaluate a "Smart and self-adaptive Personal Assistance System" for elder people, which integrates different complementary technologies to provide early detection of changing individual needs, and which uses Collaborative Reasoning principles to provide advanced reasoning functionalities to predict and analyse behavioural data, finally interacting with the surrounding of the user, enabling a holistic and adaptive support for independent living.

OPTIMA platform will support a list of key services, corresponding to the main domain of assistive technologies: Personal Emergency Response Systems, smart devices to facilitate computer access, augmentative and alternative communication, assistive technology for cognition and other accessible technologies, mainly by offering people with disabilities unprecedented opportunities to access information and services and even a more accessible and flexible work environment.

As a main novel product, OPTIMA will offer a Virtual Caregiver at Home (VCH) framework, implemented on an Open Platform. The following facilities are integrated on the platform: personal assistive devices, adaptive monitoring devices, high-confidence medical devices, mainstream communication technologies. The main activities developed in this scope are:

1. Elaboration of an information platform that offers a Virtual Caregiver at Home (VCH) framework on which applications (in this case personalized services for active ageing) may run.
2. Design and implementation of an interactive Cyber-Physical System (CPS) that integrates evolved sensor network technology to provide proactive services in a smart space, as Activities of Daily Living (ADL).

3. Integration of data from a Body Area Network (BAN), for permanent monitoring of physiological parameters, which include also a personal emergency response system
4. Elaboration of a Collaborative Situation Recognition System (CSRS), based on collaborative reasoning (CR), that provides the early detection, prevention and support to individual needs, with a multi-agent system based on ontology description and case-based reasoning.
5. Design and implementation of a software interface for natural-like interaction of humans with personal robots
6. Development of an Open Accessibility Framework (OAF) consisting of open source accessible interfaces and accessibility toolkits for assistive technologies for elder people

OPTIMA framework technology can also provide opportunities for social interaction and education—something that adults with disabilities too often miss out on. The solution addresses the educational and social needs of the elderly persons who require long-term medical care.

B. Development Consortium (University - R&D Institute)

Institution names:

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B. Project description

B1. High-level architecture

The functional model of the architecture defined according to OPTIMA's objectives has five layers identified to be taken into account for fulfilling project requirements. Those five layers are:

1. Data acquisition
2. Information abstraction and inference.
3. Applications and services.
4. Data communication.
5. User interaction.

Fig. 1 shows the high-level architecture diagram and internal functional blocks identification:

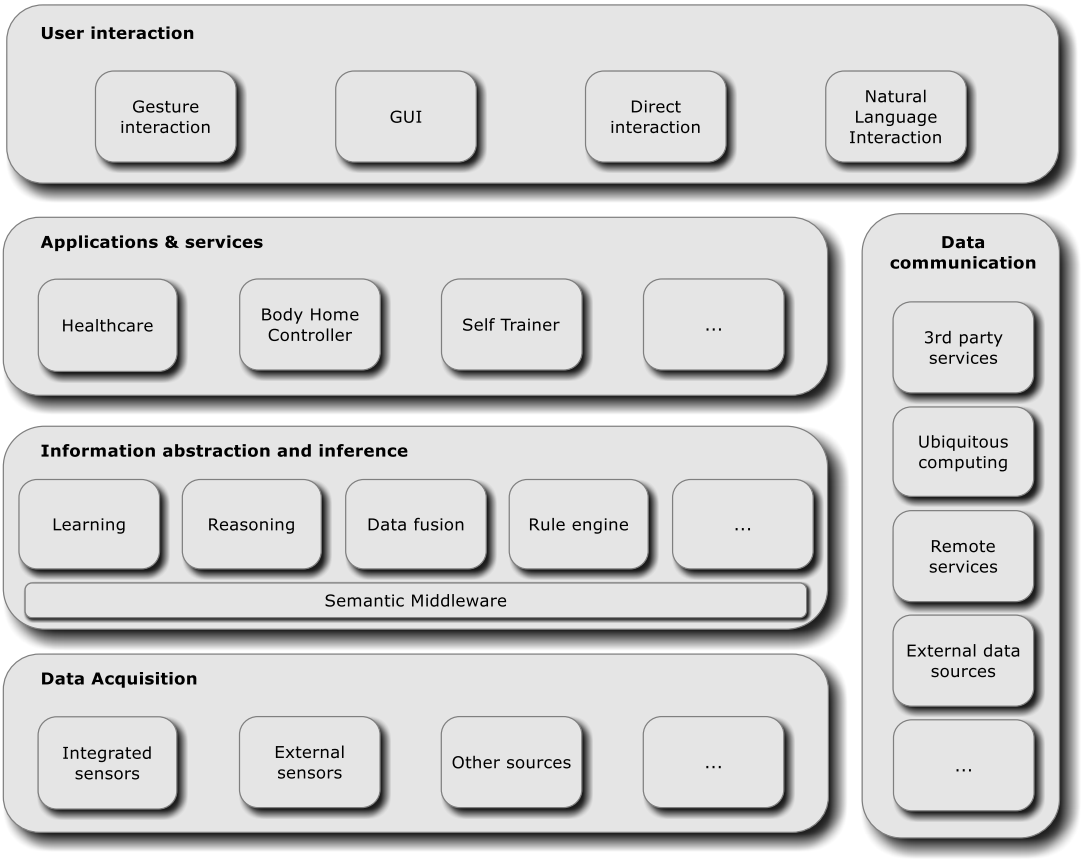

Fig 1. Architectural model

In the following are shown brief explanations for each one of the blocks of the architecture.

Data acquisition. This layer is in charge of providing to the platform each relevant data source to be taken into account by the system. Such data sources must at least take into account both, integrated sensors (for example body sensor network) and also external sensors (which may provide relevant information from the user's environment and situation context). In addition to that, any other data source which could be identified as relevant along project execution will have to be analysed. It should be taken into account that, in order to include data sources which are not directly integrated in the platform, this layer should be aligned with data communication

layer, since a communication interface will be needed to communicate with external sensors or data sources.

Information abstraction and inference. Once data has been collected by data acquisition layer, information abstraction and inference is in charge of understanding, combining, and adding significance to unprocessed data. Firstly, a semantic middleware is designed for an initial data pre-processing, so that more complex data processing procedures are enabled. Once syntactic unprocessed data have been semantically annotated, a number of data processing procedures are to be considered, including: Data fusion (considering heterogeneous data sources, data fusion processes may result in a richer knowledge than independent sources themselves); Machine learning processes (in order to adapt, personalize or contextualize services and applications); Rule engine (which may be useful for rule definition and decision-making processes considered for certain services or applications); Inference and reasoning processes (according to certain ontological data models, inference and reasoning processes are enabled).

Data communication. As a cross layer, data communication should take into consideration every need from other layers (data acquisition, inference, services and applications and user interaction) regarding data communication among external devices. That is the case of: external sensors or external data sources; Remote services and applications; Back-end functionalities (ubiquitous computing); functional services provided by other modules.

Applications and services. Upon support functionalities provided by lower layers of the architecture, domain-specific services and applications will add the real value to the OPTIMA platform, making the most of the whole architecture (considering not only embedded functionalities, but also back-end and external ones).

User Interaction. On top of the platform architecture, user interaction has to take into account not only traditional interaction (button-like interaction, GUI, etc), but also gesture recognition, natural language interaction and multimodal interaction paradigms in general.

The addition of a semantic feature to the obtained data from portable devices allows a low coupling interconnection among different devices, improving their interoperability and making easier the addition of heterogeneous devices. Those commercial sensors or actuators that will be added to the final platform should be provided of an additional semantic layer that can be implemented in the device itself (if they have programming features). On the other hand, portable devices such as smartphones or tablets are more and more provided with heterogeneous sensors, so they can also supply semantic information to the whole platform; data that can be managed by other services to compose more complex services.

B2. Expected achievements

The project's expected results are summarized in the following table and a brief description is given for each of them:

Table 1 Expected Results

Expected Result	Relevance of the problem to be solved
Design and implementation of the experimental model of an Open Platform for ambient assisted living support (OPTIMA)	The platform will provide the basis of the tele-assistance environment for elder people, supporting timely involvement of carers and family. It will be used not only for the actuation of the system but also for the human-in-the-loop reasoning in the detection of ageing problems. For the target architecture, five layers have been identified to be taken into account for requirement compilation task
Design and implementation on the Virtual Caregiver at Home (VCH) framework on which applications of personalized services for active ageing people may run	Upon support functionalities provided by lower layers of the architecture, domain-specific services and applications will be developed in the VCH framework, which offers also the support for information abstraction and inference, being in charge of understanding, combining, and adding significance to unprocessed data. The following data processing procedures are to be considered: data fusion (considering the origin from heterogeneous data sources), machine learning processes (in order to adapt, personalize or contextualize services and applications), rule engine (which may be useful for decision-making processes), reasoning processes (according to certain ontological data models).
Design and implementation of an interactive Cyber-Physical System (CPS) that integrate evolved sensor network technology to provide proactive services in a smart space	Basically CPS is a smart and self-adaptive sensor and actuator network, able to integrate already existing or soon available electronic devices at user homes, such as TVs, mobile phones or tablets, smart objects in the form of pet-like friendly devices, personal information devices, personal assistive devices, adaptive assistive devices, high-confidence medical devices. The idea is the CPS will also be integrate-able with existing or forthcoming devices in home environments.
Design and implementation of the interface with a Body Area Network (BAN), for permanent monitoring of physiological parameters.	The use of innovative sensors (e.g. wearable biosensors) will be studied to retrieve data from elderly people in a non-obtrusive way and integrated as a Body Area Network (BAN). An experimental model of a BAN will be implemented for the detection of behavioural events or physiological data of elderly people, as well as a biometric key establishment protocol to secure the communication between every sensor of the BAN and the platform before the physiological data is transferred to external networks for remote analysis or diagnosis, possibly as a personal emergency response.
Elaboration of a Collaborative situation recognition system (CSRS), based on collaborative reasoning (CR), that provides the early detection, prevention and support to individual needs, with a multi-agent system based on ontology description and case-based reasoning.	Collaborative reasoning principles will be used in the network, based on ontology descriptions and Case-Based-Reasoning, to provide early detection of individual needs related to ageing (risk of falls, depression, emergencies, sleep deprivation, cognitive decline, etc). A multi-agent system will be built, to provide different types of answers (automatic, semi-automatic and with the help of human-in-the-loop reasoning), through a networked system of actuators (emergency calls, alarm messages, reminders, videoconference connections, etc) adapted to the end users and their present situation.

Design and development of a module for people activity recognition by integrating data from different sources and for gesture recognition	The module for aggregation of monitoring data (AMD) offers a robust framework for enhanced activity recognition by integrating supplementary motion or fall sensors (of accelerometer type) with ambient vision sensors. Additionally, a vision system using a computer-mounted video camera as the sensor allows one-handed gesture recognition. A significant improvement in performance is the outcome of three factors: 1. The *general engineering* of the system (the pre-processing is reliable on every frame). 2. The *exemplar-based classifier (*ensures that recognition of the gesture label from a pre-processed image uses a rich, informative model), allowing a large gesture vocabulary to be employed. 3. The basic exemplar-based recognition is significantly sped up both by conventional exemplar clustering, and by a novel variant of the pattern-recognition technique of *boosting.*
Development of an Open Accessibility Framework (OAF) consisting of open source accessible interfaces and accessibility toolkits for assistive technologies for elder people	OAF will identify and justify selection of key services with high impact such as activities of daily living, safety, mobility, social inclusion with seamless support in and outside the home, and will build on progress in enabling ICT combined with behavioural and social science. It should deeply embed accessibility into future ICT for the open desktop, rich Internet applications, and mobile devices. OAF will support also users learning in order to develop specific skills, particularly tailored to their individual and employability needs.

B3. Progress beyond the State of the Art

As a conclusion about the presumed developments in AAL over the next few years, it beholds those charged with the engineering of AAL systems to be acutely conscious of this and ensure their designs provide for flexibility, scalability and evolution during the aging process. AAL must cater for two constituencies – those who are currently elderly and are more likely to be technology averse, and those who will be elderly in the next decade but who may be technology friendly. OPTIMA **focuses on the needs of the later constituency**, and argues that AAL systems must evolve to meet the needs of individuals as they became older. In particular, the issue of evolution must be considered both from the elderly or user perspectives, as well as from a systems perspective. One approach, outlined in this project, proposed the harnessing of embedded agents as a potential mechanism for enabling open, scalable and adaptive infrastructures upon which evolutionary AAL services can be delivered. The main novel contributions are summarized in the following.

- **Reducing maintenance costs through continuous user adaptation**

Conventional assistive systems suffer from low adaptability to the user's needs and high maintenance costs. OPTIMA aims at significantly reducing these costs and enhancing the quality of system response by continuous user adaptation. The ability of integrating new

services and aligning the system responses to continuous feedback over the lifetime of the system is key to the acceptance and economic success.

OPTIMA will provide mechanisms for performing continuous and automatic system learning by updating the underlying technical infrastructure. New requirements that can emerge and fed into the system are as follows:

- Introduction of new services: The system capabilities might be enhanced or reduced; knowledge gathered about new features has to be spread among all installations.
- Introduction of new sensors: New recognition features of the vision system sensors or also new sensors that might have become available have to be included into an installation.
- Discovery of new behavioural patterns: As implicit input of the attendees, new behavioural patterns have to be identified and made known among the system.
- Recommendation of appropriate action: As explicit input by attendees, relatives and care givers, appropriate services will be proposed by one party and spread all over the system, enhancing the service quality.

- **Collaborative Reasoning System.**

Placed at the top of the structure the reasoning system is the mind of the whole system, supervising and listening to each of the sensors connected to the system. Its main task is to store and analyse the information issued for each of the devices of the system, evaluating if the current situation is abnormal in the daily life of the elder people. As stated before, the OPTIMA Advanced Reasoning System introduces two major innovations:

- A new approach to the recognition of long-term behavioural patterns is introduced.
- A collaborative approach to swarm-like collective intelligence is chosen in order to accelerate system learning, reduce cost and enhance the acceptance by end users.

The following table illustrates the advantages of the OPTIMA approach of collective reasoning over conventional case based reasoning and ontology-based reasoning by Bayesian networks.

- **Smart networked sensors and actuators**

OPTIMA will provide a complementary system supporting the information from a video system. The complementary system will be made up from a sensor and actuator network spread over the room/house or even easy-wearable sensors carried by the user. This smart sensor and actuator network will contribute to the state-of-the-art of sensor networks with a multilevel sensor data fusion framework, use of a reliability factor to enable more trustworthy and energy-efficient systems and a level-of-detail enabled data model with privacy support.

Single sensor systems base their operation on the data gathered by only one sensor for each property they need to measure. This approach normally has the following problems:

sensor deprivation (the information provided by a sensor cannot be obtained if the sensor breaks down); limited spatial coverage (the measure is only valid for a restrictive region); limited temporal coverage (the system is limited to the maximum frequency of the sensor), imprecision (the measures taken are dependent of the precision of a concrete sensor); uncertainty (it arises when the sensor cannot measure all the relevant attributes of the observed object).

To avoid these problems, this work will use sensor data fusion techniques. Sensor data fusion combines the data collected by a set of sensors to obtain improved information. The resulting information is improved with regards the data obtained individually from the same sources. In the OPTIMA project a combination of sensor data fusion techniques will be used: the competitive sensor fusion (used when some sensors deliver independent measurements of the same property) for direct data and decision level fusion and, complementary and cooperative sensor fusion for feature level fusion. Note that complementary type sensor fusion is used when the sensors do not directly depend on each other, but they can be combined in order to obtain more complete information and cooperative type sensor fusion is used when the information provided by two or more independent sensors derives information that would not be available from the single sensors. The fusion will be performed via a multi-tiered process: redundant sensors (sensors of the same type will be deployed in the environment to reduce the errors in capture); feature extraction (with the data obtained from the first step, a higher-level information will be extracted using a cooperative feature level fusion); enrichment of camera's features (with a subset of the information extracted in the second step, the features extracted from the cameras will be refined, using a competitive direct data fusion approach).

On one hand, the sensors will gather information from the person under surveillance in the simplest way, for instance, monitoring its vital signs; small sensor markers wearable over the person clothes and helping to track its position an sending it to a processor; stickers easily recognizable for the TOF cameras increasing their efficiency in detecting the human shape and motion. On the other hand, the actuators will take measures when the information analysis results in a positive alarm of an accident, fall, or problem.

- **The Open Accessibility framework and the communication facilities platform**

User-configurable Open-Source interface AAL enhancements (foreground & background) will be created to promote tele-assistance and communication of elder people in a personalizable and adaptable way. The user interface is completely adapted and suited to the care and assistance of elder people. The possibility of providing video and voice communication perfectly suits the requirements of an application related to e-health and wellbeing due to the fact that visual

communication provide a more realistic contact between an elder person and some of their relatives or carers than a mere phone call. This means that the elder person can communicate immediately with those people; therefore assistance can be provided by this mean to the person who is under OPTIMA surveillance. More of that, OPTIMA will extend and make available any new Internet enabled technology and will integrated any new software for enhancement of Ambient Assisted Living in the areas of socialisation, wellbeing and healthcare, including application opportunity for the elderly.

B4. Project objectives and outcomes

Specific objectives

OPTIMA's **main outcome** will be an AAL-enabling platform offering personalized services for active ageing people. In order to accomplish this general objective, several **specific objectives** are considered:

- Finding potential end-users and including their needs into the facilities offered by OPTIMA platform
- Design of the framework architecture and the technical specifications for the components
- Development of user interfaces and service design for ambient assisted living software applications accessed through a range of mobile and portable devices both within and outside the home environment.
- Development on the functional model of the Virtual Caregiver at Home (VCH) framework
- Select and adapt existing sensor networks to provide inputs for the detection of behavioural events or physiological data.
- Identify and enhance existing actuator systems to interact with elderly people, either with automatic responses or as tele-assistance services.
- Development of a semantic reasoning system for long-term trend analysis of basic daily behavioural and physiological data, building on unobtrusive sensing.
- Development of an Collaborative Situation Recognition Middleware
- Design and implementation of a module for aggregation of monitoring data (AMD)
- Design and implementation of a software interface for interpreting gesture commands provided by a vision system
- Development of an Open Accessibility Framework (OAF) for integrating accessibility toolkits for current and future assistive technologies.

Original and innovative contributions of the project

- On the technical level, the continuous user adaptation is accomplished by a seamless integration of the ontology-based actuator middleware and the case-based behavioural pattern reasoned. A continuous mutual exchange of newly revealed user behaviour as well as enhanced system capabilities allow for a new quality in user adaptation and help reducing maintenance costs drastically.
- The fine granularity of pattern recognition and long-term event detection provided by OPTIMA imposes the requirement of new ways of sensor fusion and advanced reasoning. The vision system is expected to provide data on a person's condition and activities in unprecedented quality. In synergy with the smart sensor and actuator network, the visual event detection will enable the recognition of complex behavioural patterns composed of a wide range of minor indicators, whose combined incidence within a certain time frame may be interpreted as significant and trigger some corrective action.
- OPTIMA will combine the advantages of ontology-based Bayesian Networks and overcome the drawbacks of previous solutions mentioned above by additional case based. Similarity measures for case based reasoning can be inferred from different sources, including input from human entourage, as well as from peer systems. This is where the innovation of the proposed Advanced Reasoning System comes into play.
- The application of evolved connectivity standards will mean an important breakthrough in the ambient assisted living area, what means that the OPTIMA performance will fill the gaps and solve the problems of other tele-care systems attempts.
- Web services will also facilitate for greater social inclusion of the home-bound to reduce the long-term negative effect of social isolation and to help combat the emerging evidence that links social isolation to early onset of negative mental faculty via a truly integrated Assisted Ambient Living and Wellbeing Inclusive Technology.

B5. **Exploitation of OPTIMA project results throughout the project development**

The key exploitation activities consist of:

- Setting up experiments in which the algorithms developed will be tested and validated and their performance evaluated.
- Setting up tests of the system components for evaluation of their performances and reliability.

- Integration of relevant algorithms in the development framework and monitoring of their performance level.
- Validation of searching logic in order to locate the algorithm or algorithms relevant to a certain function.
- Setting up tests with the final system demonstrator for validation of performances and proof of concept of the developed strategies.

C. Applications with market potential

The main scientifically and technological results of the project will have an important impact for the decision factor at the governmental level and will contribute also to the progress of Romanian IT&C community. The collaborative platform used from the beginning to host the entire life cycle of the project from development to exploitation will give the capability to offer new and innovative commercial services on the market, starting with the consultation of data bases and arriving to control daily activities in any smart space.

One of the key objectives is to develop a robust, highly usable system that can be successfully exploited in the market and can be easily extended to a wide number of final services, being able to fulfil the needs of different end users belonging to groups formed by elder people.

In order to achieve this, the following will be pursued:

- A readily adopted integrated and expandable system, with proven flexibility and feasibility for a wide number of end users.
- Innovative sensor fusion and collaborative reasoning approach that enables moving OPTIMA results into downstream RTD in other application areas.
- An affordable solution and devices, and support availability, which enable wide exploitability for the industry.
- Practice user and stake-holder involvement in delivering compelling initial results from trials.

The accumulated knowledge will open to each partner the opportunity to offer consulting and engineering services for applying assistive and adaptive technologies

D. Intellectual Property Protection

The appropriate handling of Intellectual Property Rights (IPR) is critical to the success of the project. The Consortium’s decisions on the matter of IPR are based on two main principles:

- **Fairness:** IPRs belong to the entities that achieved the technical development.

- **Functionality:** IPRs are protected with the aim to obtain return on investment by means of their commercial exploitation. The distribution of the exploitation rights on the IPR will obey to facilitate an agile commercial exploitation, avoiding complex decision making structures that can act in detriment of times to market.

Within this context, IPR related to project results will be shared amongst the partners based on their position in the future added value chain and their implication in R&D activities for obtaining those results.