engAGE

Managing cognitivE decliNe throuGh theatre therapy, Artificial intelligence and social robots drivEn interventions

D2.2 User requirements and system specifications

Deliverable Id:	D2.2
Deliverable Title:	User requirements and system specifications
Related Work Package:	WP2
Related Task(s):	T2.2
Related Milestone:	MS2
Version:	V1.0
Status:	Final
Dissemination Level:	PU
Deliverable Type:	R
Due date of deliverable:	M9 (August 2022)
Actual submission date:	September 12, 2022
Deliverable lead partner:	TUC
Main author(s):	Ionut Anghel, Tudor Cioara, Cristina Pop (TUC)
Contributing authors:	Lars Thomas Boye (TLU), Terje Grimstad and Gisle Hannemyr (KRD), Andrei Marin (IRIS)
Peer-reviewers:	Lars Thomas Boye (TLU), Andrei Marin (IRIS)
Keywords:	Requirements, conceptual architecture, system specifications

*Project partially funded by AAL Joint programme and Unitatea Executiva pentru Finantarea Invatamantului Superior, a Cercetarii, Dezvoltarii si Inovarii (UEFISCDI) (RO), The Research Council of Norway (NO), Federal Department of Economic Affairs, Education and Research / State Secretariat for Education, Innosuisse (CH) and Italian Ministry of Health (IT) under the Consortium Agreement number **aal-2021-8-159-CP**.*

Version history

Version	Authors	Date	Description
0.1	Ionut Anghel (TUC)	16.03.2022	ToC
0.2	Cristina Pop (TUC)	09.05.2022	First draft with deliverable structure and TUC initial contribution
0.3	Lars Thomas Boye (TLU)	07.07.2022	Requirements and architecture of Monitoring and Big Data Proc.
0.4	Tudor Cioara (TUC)	19.07.2022	TUC contributions to Sections 2, 3 and 4
0.5	Terje Grimstad and Gisle Hannemyr (KRD)	27.07.2022	Karde contributions
0.6	Andrei Marin (IRIS)	22.08.2022	Added IRIS contributions
0.8	Tudor Cioara (TUC)	26.08.2022	Integrated and refined version
0.9	Ionut Anghel (TUC)	29.08.2022	Peer-review ready version
0.95	Lars Thomas Boye (TLU)	01.09.2022	Peer review
0.96	Andrei Marin (IRIS)	08.09.2022	Peer review
0.97	Ionut Anghel (TUC)	08.09.2022	Refined quality check ready version based on peer-review feedback and technical discussion
0.98	Ionut Anghel (TUC)	09.09.2022	KRD review and feedback implementation
1.0	Ionut Anghel (TUC)	12.09.2022	Final version

Contents

List of acronyms

Acronym	Description
AAL	Ambient Assisted Living
API	Application Programming Interface
CMU	Central Management Unit
CPIP	Communication Platform and Intelligent Personalization
DoW	Description of Work
FHIR	Fast Health Interoperability Resources
HCI	Human Computer Interface
HRI	Human-Robot Interaction
HTTP	Hypertext Transfer Protocol
IoT	Internet of Things
JSON	Javascript Object Notation
MCI	Mild Cognitive Impairment
ML	Machine Learning
MLCDA	ML-based Cognitive Decline Assessment
MoSCoW	Must, Should, Could and Won't
MSRBD	Monitoring, Self-Reporting and Big Data Processing
NLP	Natural Language Processing
REST	Representational State Transfer
SDK	Software Development Kit
SMCI	Seniors with mild cognitive impairment
SRCCS	Social Robot Coaching and Cognitive Stimulation
TTS	Text-to-Speech
STT	Speech to text
UI	User Interface
UX	User Experience
WP	Work Package

Executive summary

This deliverable presents the 1st version of the system architecture together with the building services, the envisioned functionalities by means of functional or non-functional requirements and technologies to be used and integrated in the engAGE solution. A study of the state-of-the-art literature in terms of social robots and care applications is provided in Section 2. The engAGE requirements are summarized in Section 3. These requirements will serve as a basis for the analysis and design phases and have been categorized using the MoSCoW (Must, Should, Could and Won't) prioritisation technique.

The first version of the engAGE conceptual architecture is described in Section 4. It comprises four main services/components that take advantage of various techniques and technologies such as IoT sensors, artificial intelligence, intelligent dashboards, and social robots: Monitoring, Self-Reporting and Big Data Processing (MSRBD), ML-based Cognitive Decline Assessment (MLCDA), Social Robot Coaching and Cognitive Stimulation (SRCCS) and Communication Platform and Intelligent Personalization (CPIP).

MSRBD will provide non-invasive monitoring of older adults with MCI using easy-to-collect variables on their ability to conduct ADL, perceived health, and wellbeing state using off-the-shelf commercial IoT sensors integrated with the TelluCloud infrastructure. The collected data will be used as input for MLCDA to analyse and corelate by means of machine learning algorithms the information with the goal of determining insights onto the cognitive state and potential decline. The insights can then be used by the formal care givers in day care centres to fine tune and personalize the robot-based intervention and will be displayed in the CPIP service that consists of several dashboards to show care status information concerning the cognitive baseline, ADL monitoring, self-reporting, and cognitive decline assessment and to enable interaction and communication of all types of interested actors with the system. SRCCS aims to provide personalized brain training for the older adults by using the Pepper social robot as a companion. Pepper will be enhanced in engAGE to provide a wide spectrum of assistive functions such as cognitive stimulation (i.e. drama storytelling), reminding or step by step instruction on conducting ADL (washing, eating, taking medication, drinking water, etc.), and facilitation of social interaction.

1 Introduction

The goal of deliverable "D2.2 User requirements and system specifications" is to investigate the existing technologies in the project areas, identify and list the main functionalities of engAGE services in terms of functional / non-functional requirements and define the initial system architecture. The deliverable is based on the findings of Task 2.1 (deliverable D2.1) and further transforms the user needs and requirements, scenarios and use cases into more specific system level functional and non-functional requirements.

1.1 Intended Audience

The intended audience of D2.2 is the engAGE consortium and the AAL Central Management Unit (CMU) representatives tasked with reviewing the project and its progress towards meeting the specified milestones and raised awareness. The dissemination level of the present document is marked as public, thus all interested parties and stakeholders will be able to read it and understand what engAGE proposes in terms of system components and services.

1.2 Relations to other activities

WP2 main objectives is the involvement of end-users in all phases of system design, development, and testing. As illustrated in Figure 1, WP2 is directly connected with the technological WP1 and with the testing and evaluation WP3.

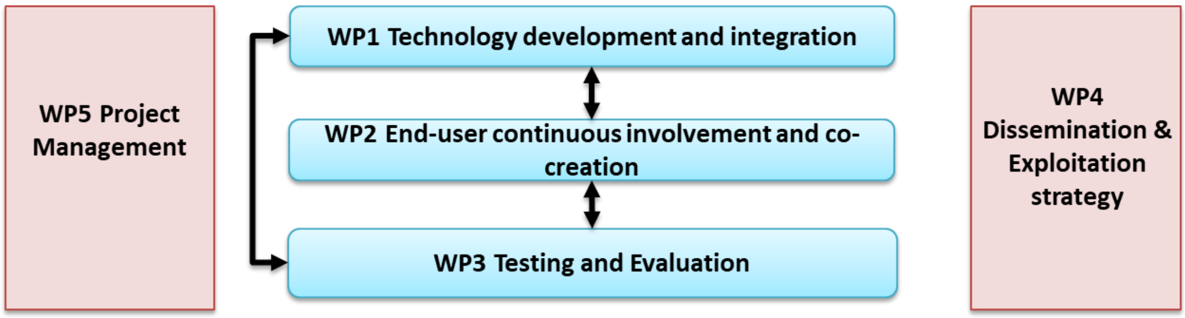

Figure 1: WP interactions in engAGE.

Deliverable D2.2 is an output of WP2 - "Task 2.2 End-users requirements analysis and engAGE conceptual model design" and will be used as basis for driving the system development in WP1.

1.3 Document overview

The remainder of the deliverable is organized as follows:

- Section 2 presents an overview of social robots and care applications
- Section 3 summarizes the engAGE requirements
- Section 4 focuses on presenting the design of the engAGE platform
- Section 5 concludes the document.

2 Social robots and care applications

In the last decades, robots have been becoming interactive, and they now offer the software and hardware support to be adapted to meet the requirements of domains such as care of persons in need. This chapter offers an overview of the current state of the art in the research literature for social robots' integration into care scenarios and applications. It served as a starting point for designing the engAGE platform architecture in terms of social robot interactions for serving the overall project goals.

In the healthcare domain, robots represent a new resource to offer better assistance, care, and interventions being able to ensure good skilled and personalized communication with humans by using voice recognition, facial recognition technology, and a defined system to mediate and interact with the users. The design and the physical presence of the robot [1] bring more confidence to the interlocutor even though in the beginning the older adults may be sceptical. After several interactions, users may be delighted by the presence of such a companion, but this depends on and is correlated with the functionality offered. In [2] the authors discuss the adoption of social robots in elderly care services and modalities in which their human-like affect and cognition influence users' social perceptions.

To develop a social robot, the researchers need to combine multiple disciplines like computational approaches, social and cognitive psychology, social neuroscience, developmental psychology, and developmental robotics [3]. To build computational models of social cognition, social neuroscience needs to be integrated with artificial intelligence. To ensure a good communication and interaction between robot and human user computational linguistics needs to be integrated.

During the Covid-19 pandemic, robots [4][5] have been used more often in the healthcare domain for functions like disinfection and sterilization of facilities (using ultraviolet lights, vaporization techniques), handling and delivering drugs, food and waste, telemedicine, and remote assistance. Other robot solutions were developed as emergency response for robotic manipulation of a dialysis machine for patients [6].

The abilities and characteristics of social robots are discussed in several literature works:

- Morphology. Social robots' physical bodies have an important role to gain users' trust and tend to be designed closely to realism and can take various forms such as anthropomorphic (human-like), zoomorphic (animal-like), caricatured (cartoonish) and functional (it can be designed based on his functionality).
- Autonomy. The ability of the robot to work properly without human intervention or with a little human help, or none of these. To gain the abilities like affective and cognitive values, the robots must function as much as possible autonomously.
- Assistive role. Robots tends to acquire psychosocial assistance like emotional, psychological, and social needs.

The social robots can be used monitor the possible risks that may be exposed a person under medical treatment and to encourage them to stick to the medical plan [7]. The robot role is to assist and perform tasks that the users can't perform because of their health condition, or to manage the cognitive or mental health [8]. Social robots are easy to use, can interact in a simple and clear way with users and their main role is to improve users' daily life. This type of robots is designed to support people living alone and this role is to provide users assistance and monitoring [9].

Pepper [10] is a good example of such a social robot. It features a humanoid form and is capable of exhibiting body language, perceiving and interacting with its surroundings and moving around. It can analyse and detect people and people's expression and voice tones. His autonomy can be up to 12 hours, with possibility to return to its charging station. This robot was developed with the goal of creating a daily-life assistant robot capable of providing physical and cognitive assistance for people.

From an architectural point of view, the care applications integrating social robots have been developed using multiple approaches, depending on the purpose in which they are used. In [12] is presented a systematic review for Visual Programming Environments aimed at enabling a paradigm fostering the so-called End-User Development of applications involving robots with social capabilities. The most recent tools are adopting distributed and Component-Based Software Engineering approaches and web technologies [11]. The solutions discussed related to the intelligent modelling of robot behaviours consisted of script-based like if-then-else conditional statements, for-loops, creating variables and functions and using low-level mathematical and logical operations; rule-based – method that can be intuitively used by non-programmers; state-based – using finite state machines; behaviour-based – using behaviour trees - considered a "two-way" control transfer. In [13] the authors focus on three main application areas: cognitive architectures, behavioural adaption and empathy establishment between social robots and users. They remarked the limit of holistic experimental studies most of publications being focused only to some aspects of Human-Robot Interaction. In [14] a behaviour control system for social robots in different therapies is presented, with a focus on personalization (the behaviour of the robot to have a personable character) and platform-independence (that can be used on multiple robot platforms). The architecture was designed by the following design principles:

- multi-layer behaviour – includes reactive, deliberative, and reflective implementations for robot characteristics. These functionalities are responsible for generating social, track-based and behaviour's correctness.
- personalization - generated behaviours are mapped on user needs and is responsible for ensuring a real interaction between user and robot.

Robot's personality and affective behaviour was created using Ortony Claire Collins model (OCC) [15] and it was tested on multiple scenarios like autism therapy and elderly care and physical exercise. In [16][17] the authors have generalized a software architecture that feature a template and a common vocabulary for improving a robot's behaviour, social skills, and decisions. Software architecture was grouped in 4 concentric layers like:

- Knowledge base layer - was used to store robot's language into a structured format and to maintain a reasoning engine that was able to infer logical rules for the robot. To permit the access to the layer Object-Ontology Mapping API was used.
- Semantic bus layer - is used to exchange or to generate the asynchronous messages or to react to the events that may occur on the robot. The exchange communication paradigm is the publish-subscribe type using a message broker. The broker can map software functionalities to a robot's hardware capabilities.
- Capabilities layer - is declared as software components that can be reused in different robotics applications. They represent the robot's human-like functionalities such as: speaking, understanding, moving, converting speech to text, converting text to speech,

approaching/following the user; or ensuring human control interface like buttons that exist on the robot, tablet display, camera, laser to identify objects.
- Behaviour layer - is responsible for establishing the interaction between users and robot. It consists of robot's behaviours (the software artifacts that aims to realize a specific goal that implies the user) and behaviour manager that is able to coordinates the sequence robot's behaviours based on user interaction and robot capabilities.

This layered architecture used in MARIO [18] project that investigated the use of autonomous companion robots as a cognitive stimulation tool for people with dementia. In [19] the authors present an architecture used for controlling autonomous social robots allowing the creation of distributed graphs and behaviour trees in combination with finite state machines. The Behaviour-based Iterative Component Architecture [20] was developed in a bottom-up strategy starting from a defined finite state machine and defining on it a set of actions and reaching to the development of hierarchical finite state machines. The authors have added a new component into the architecture, a planner component where it was able to calculate a plan as a sequence of actions. The language used for this approach was Planning Doman Definition Language [21] where can be defined actions, conditions, and goals for different planners. In [22] an interaction social robot framework was developed, capable of generating sentences and to recognize users' responses according to a state transition-model and to implement some non-verbal behaviours (gestures) based on speech context. For speech recognition they used crossword context constrained word graphs and for face recognition they developed an application in OpenCV. The proposed framework consists of:

- Robot driver layer - the robot hardware modules.
- Information processing layer – contains sensing and actuation modules related to environment recognition and activities that the robot must perform (localisation, human tracking, face detection).
- Behaviour layer – consists of social knowledge, the actions that the robot need to perform based on different user inputs.
- Application layer – consists of a graphical robot interface that is able to ensure the communication between human and the robot and an interaction Composer for creating behaviour blocks as a sequence of tasks that the robot needs to perform.

In [24] the developed architectures for social robots used in healthcare domain, especially therapy, are presented. They divided the social robots in 3 major categories (companion, therapeutic play partner or peer or coach robot) and they presented a detailed analysis for each of them like behaviour generation mechanisms, learning mechanisms or example of projects where the robots have been used. In [25] the authors designed a cognitive architecture for social robots which is based on user emotions and motivations allowing the robots to interact naturally with normal people. The authors designed an architecture which consists of:

- Long Term Memory – set of social contexts were defined and new ones are added using genetic algorithms.
- Short Term Memory – detect the useful features to classify and detect social context.
- Drives - the robots receive as inputs signals from camera, sensors, sonar or microphones and these signals are sent to be manipulated by memory modules.

There are many types of application in which social robots can be used [26]. In [27] the authors present a Human-Robot Interaction system architecture which uses an AI framework and individual smart sensor. It consists of data acquisition, device-based human identification, visual identification, audio-based interlocutor, and interaction (for communication) and localization subsystem using Bluetooth technology. In [28] the socially assistive robots are used in cardiac rehabilitation. The system integrates a set of sensors used to monitor physical exercise that is performed on a treadmill and a social robot. The sensors were used to measure heart rate, weight and blood pressure, treadmill inclination, and speed. Based on these monitored data, the robot can offer three types of behaviours like motivation. In [29] [30] social robot is used for gait rehabilitation of patients with neurological disorders in combination with Lokomat [23], one of the most used devices for gait rehabilitation. The task of the robot is to provide feedback on patient posture during exercise (cervical posture feedback, thoracic posture feedback), to give motivational feedback and alert the therapist when the patient's heart rate is high. In [31] the social robots are used in the paediatric field, in hospitalized children using social robots like teddy bear, tablet-based avatar version of the bear and plush teddy bear with human presence. The result of the study reported more positive impact to the emotional status of the children. In [32] the authors present an overview of social robots used in therapy and healthcare of children or adults by offering support for dealing with disease, autism spectrum disorder, support for well-being during hospital stay, entertainment during a medical procedure, companions, or service for elderly care. They present the need to take care of acceptability and perception metrics to evaluate the HRI performance and the need for a multidisciplinary team such as engineers, healthcare, and caretakers.

3 engAGE requirements

D2.1 "User co-creation phase report" presented the results of the analysis, study and interviews for gathering end-users' requirements in the co-creation phase. Based on these findings and considering the Description of Work (DoW) engAGE technological view, we have defined a clustered and prioritized list of engAGE design requirements, which combine the user requirements with the technical ones to offer a comprehensive view for building the platform conceptual architecture. The design requirements will serve as a basis for the analysis and design phases of the engAGE platform development process.

We have used the MoSCoW (Must, Should, Could and Won't) prioritisation technique which is an effective way of defining requirements in an Agile style[1]. MoSCoW helps to understand and manage priorities and helps overcoming the problems associated with simpler prioritisation approaches which are based on relative priorities by using the following types:

- *Must Have* - critical requirements for the project success also considered an acronym for the minimum usable subset.
- *Should Have* - important requirements but not necessary for delivery of a successful project.
- *Could Have* - desirable but not necessary requirements that could improve the user experience and that are typically included if time and resources permit.
- *Won't Have this time (would like/wish)* - agreed as the least-critical or not appropriate at the time moment. They are either dropped or reconsidered for inclusion in a later timebox.

The use of MoSCoW works particularly well on projects. It also overcomes the problems associated with simpler prioritisation approaches which are based on relative priorities. engAGE design requirements are summarized in the below table and detailed for each service in Section 4.

Table 1: engAGE requirements mapping on user needs

Needs and challenges addressed	Requirement ID
Games and cognitive stimulation must be available in the institution and at the SMCIs home	CPIP_1, SRCCS_4, SRCCS_7
Maintain their cognitive state and try to improve it	CPIP_1, SRCCS_1
Inform on the progress or regression of their cognitive state	MLCDA_5, MLCDA_6
Have some motivational quotes to help the senior if he/she doesn't feel well, was wrong or needs help to go through the exercises	CPIP_2
Informal carers have to receive motivational tips and advice to better face their beloveds' cognitive deterioration	CPIP_2, CPIP_3
SMCIs must be motivated to do more physical exercises, depending on their score and mobility capacities the system should push them to go through physical exercises	MLCDA_4, MLCDA_6
System must provide some gamification to motivate SMCIs to achieve goals and don't give up	CPIP_ 1, SRCCS_4
Motivational settings must be customized or personalized to offer a better adherence	CPIP_ 3

[1] https://www.agilebusiness.org/page/ProjectFramework_10_MoSCoWPrioritisation

Motivation settings must not be offensive or infantilizing	CPIP_3
System must give some clear indications allowing to spot alarm signs, by taking the information of the recorded scores	MLCDA_1, MLCDA_6
System must also assess the well-being of the SMCI and provide some motivational quotes	MLCDA_2
System must be able to suggest SMCIs games and levels of difficulties depending on the results obtained	MLCDA_3
Carers must have access to the data gathered by the system at any time	CPIP_4, SRCCS_8
Data gathered by the system must be secured and only used for analysing SMCIs situation	CPIP_13
Bad results should come with recommendation and not be scaring	CPIP_4, CPIP_13
Indicators must be designed to help SMCI to complete a game	CPIP_1
Interfaces must be readable and funny to use to have a better adherence	CPIP_5, SRCCS_9
The design should be spaced, the font should be big enough, with quiet music in the background to help SMCI to remain calm and don't feel disoriented	CPIP_5
Interfaces and the information on don't have to be intrusive but must reassure and encourage SMCIs to use the system	CPIP_5
The system should be designed to offer SMCIs control on the information gathered (clickable options to share scores, share cognitive analyses or well-being evaluation)	CPIP_6, SRCCS_5
The design must provide enough satisfaction to help SMCI to accept the solution as a new tool and to be more confident to rely on technology	CPIP_5, SRCCS_10
Interactions should be designed in a way for SMCI to feel qualitatively supported as well by the machine as by a human	CPIP_5, CPIP_8, SRCCS_2, SRCCS_3, SRCCS_11
A history of SMCIs actions and scores should be added to the system, end-users must be able to read their score and be aware of the games already done and the levels completed	CPIP_4, SRCCS_6
Formal carers need a system simple to use and non-time-consuming	CPIP_5, CPIP_14
Carers using MEMAS application must be also trained to take it in charge and adapt their care	CPIP_7
The platform should monitor: sleeping, physical activity and movement habits; vital signs (heart rate, blood pressure, blood oxygen level, etc); state of IoT devices and their connectivity, and warn relevant personnel of persistent errors.	MSRBD_1, MSRBD_2, MSRBD_3, MSRBD_4, MSRBD_5
Self-reporting for primary end users, for cognitive function and perceived health and wellbeing should be provided.	CPIP_11, CPIP_12
All data collected must be securely stored, and accessible by authorized and authenticated users.	MSRBD_6, MSRBD_7, MSRBD_8, SRCCS_12, CPIP_16
Video meetings for video calls to friends and family.	CPIP_10, CPIP_15

4 engAGE conceptual architecture

Based on existing architectures in the literature, we designed the engAGE architecture by considering the end-users requirements and needs (see Figure 2).

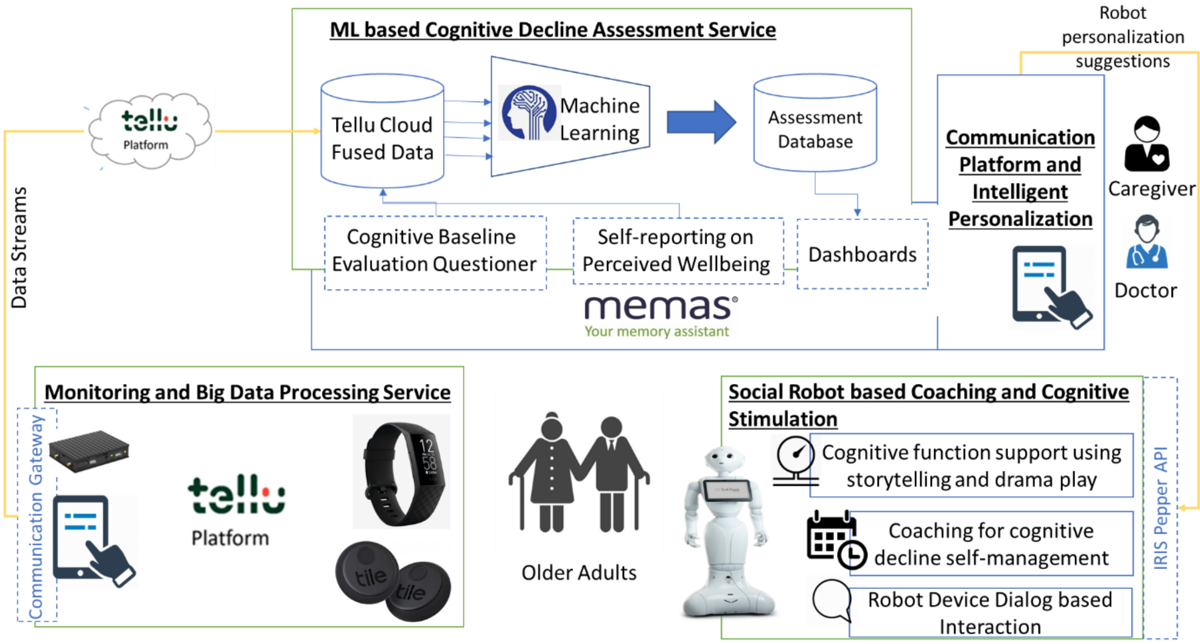

Figure 2: engAGE conceptual architecture.

From an architectural point of view, the system is based on a combination of 3 architectures: (i) streaming data architecture for sensor data acquisition, (ii) blackboard architecture used for data processing, machine learning component to analyse activities and data and (iii) event-driven architecture for action planner module developed for Human-Robot Interaction (HRI).

The streaming data architecture allows data read from the sensors to be processed and saved in real time in a non-relational database. In most cases, stream processing is associated with real-time processing. For this reason, stream processing is a reliable solution for IoT applications. The main reasons for choosing this type of architecture are:

- Reduced latency for data transmission
- Stream processing allows data to be manipulated as soon as it is received and saved
- Integration with different data sources
- Event detection (collection, filtering, prediction)
- Real-time data discovery and monitoring
- Real-time performance, scalability and response

This Blackboard architecture is also known as the Model Integration Module. It is an architectural style for sharing data between multiple components that contain sets of rules, algorithms that read the data, process it and then save the result back to the blackboard. Blackboard contains a central area where data is saved in the database and all components end up sharing the same database. Through this approach, data consistency is fulfilled and for the administration of a single database it brings a benefit. In the proposed system, we have a MySQL database where pre-processed data from sensors are stored. Also, patient information and details are found in this database along with robot knowledge base. Based on monitored data and machine learning algorithms, a set of actions can be sent to the Robot Design Thinking module and then inferred on the robot. This architecture was chosen for the following reasons:

- Deterministic solution is difficult to find
- The system can be divided into small components to delimit the workload and implicitly to provide a partial or approximate solution related to patient's activities and the action planner module able to transmit actions on the robot to interact with the user
- The architecture is iteratively updated by a diverse group of specialized knowledge sources starting with a specification of the problem and then ending with a solution
- Represents a way to deal with complex problems that can or should be delimited
- Error tolerance and robustness – the results are saved in the blackboard and are accessible to any component

Event-driven architecture represents a good solution for creating customized actions depending on the input received either from sensors (after analysing the data from them) or from the HRI where actions are sent by the social robot.

The conceptual architecture contains four core services that will be described in the next sections in terms of envisioned functionalities (functional / non-functional requirements) and internal design:

- Monitoring, Self-Reporting and Big Data Processing (MSRBD)
- ML-based Cognitive Decline Assessment (MLCDA)
- Social Robot Coaching and Cognitive Stimulation (SRCCS)
- Communication Platform and Intelligent Personalization (CPIP).

4.1 Monitoring, Self-Reporting and Big Data Processing

The stated goal of Monitoring, Self-Reporting and Big Data Processing (MSRBD) service is holistic and non-invasive monitoring of older adults with MCI using easy-to-collect variables on their ability to conduct ADL, perceived health, and wellbeing state. This is a data collection service, and data is to be collected in two main ways: using IoT sensor devices, and through self-reporting using questionnaires/user interfaces. The collected data will be transmitted to the ML-based Cognitive Decline Assessment Service, and in addition it should be possible for users to access the data collected about them. The service will be built upon the TelluCloud monitoring infrastructure which includes a cloud service with data storage and a personal Health Gateway for managing IoT level devices and performing some edge processing. Table 2 lists the requirements for this service, based on the service specification in the DoW.

Table 2: Requirements for Monitoring, Self-Reporting and Big Data Processing

ID	Type	Description	Source	MosCoW	Target end-users
MSRBD_1	Functional	The platform should monitor sleeping and sleep quality.	DoW	Should	Primary
MSRBD_2	Functional	The platform should monitor physical activity and movement habits.	DoW	Must	Primary
MSRBD_3	Functional	The platform should monitor eating/food intake.	DoW	Could	Primary

MSRBD_4	Functional	The platform should monitor vital signs (heart rate, blood pressure, blood oxygen level, etc).	DoW	Could	Primary
MSRBD_5	Functional	The platform should monitor the state of IoT devices and their connectivity and warn relevant personnel of persistent errors.		Must	ALL
MSRBD_6	Functional	All data collected must be stored and associated with the primary end user they relate to.	DoW	Must	ALL
MSRBD_7	Non-Functional	All data collected must only be accessible by authorized users.	DoW	Must	ALL
MSRBD_8	Non-Functional	All user interfaces in engAGE require authentication of the user, and a user should be able to use the same credentials in all user interfaces (single sign-on).		Should	ALL

The architecture of this service is based around the streaming of data from sensor devices into cloud storage, and this is based on Tellu's TelluCare service for remote patient monitoring. Figure 3 shows an overview of the relevant parts of the service. IoT sensor devices, on the left side of the figure, need to connect to a gateway device, and for this we will use a mobile application running on an Android or Apple phone or tablet. The gateway device collects data from sensor devices and sends the data to the TelluCare cloud application, where it is stored. The cloud application has connection points for integration with the other engAGE services. Two such integration points are indicated in the figure. The ID broker handles all authentication in the TelluCare service, and as a general authentication broker it can be integrated with other user IDs or be used for authentication in other services, which means that it can be used to implement common authentication throughout the engAGE system. The TelluCare API provides access to the stored data to the other services. The TelluCare cloud application also has its own web interface for administration and health personnel, which can be used to configure the service and access the collected data. The following sub-sections look at these components in more detail.

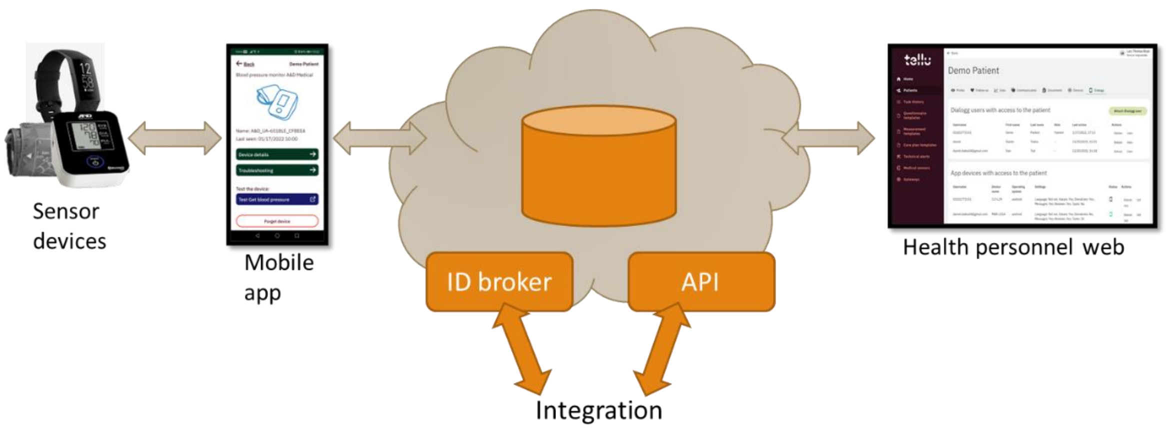

Figure 3: TelluCare monitoring infrastructure

4.1.1 Sensor devices

For data collection from sensor devices, we wish to use off-the-shelf commercial IoT sensors integrated with the Tellu infrastructure. From the requirements we have a list of things we would like to monitor, and then we have evaluated available sensors with regards to what they provide, how they can be integrated in the system and how non-intrusive and user-friendly they are. Table 3 lists the devices we have so far found to be potential candidates for use in engAGE, as they are both feasible to integrate in the system and measure something which could be of interest according to the requirements. The last two devices, Cosinuss and Somnofy, are new devices which Tellu has not worked which previously, but which have been tested and show great promise. Tellu has prior experience working with the rest of the devices in the list.

Table 3: Potential IoT sensor devices for engAGE

Device	Measures	Integration	Notes
A&D Blood pressure monitor	Blood pressure	Bluetooth	
A&D Scale	Weight (food intake)	Bluetooth	
Contour Next blood glucose meter	Glucose (food intake)	Bluetooth	Need to draw blood from a finger.
Nonin pulse oximeter	Heart rate, blood oxygen	Bluetooth	Insert finger to measure.
A&D Thermometer	Temperature	Bluetooth	
Fitbit activity tracker	Activity, heart rate, sleep/sleep quality, (food intake)	HTTP API	Worn on wrist.
GPS	Outdoor position (activity)	Bluetooth (if separate)	Can use GPS in the phone, or separate device.
iBeacons	Indoor position (activity)	Bluetooth	Phone detects proximity to beacons placed in the home.
Cosinuss ear sensor	Heart rate, blood oxygen, temperature	Bluetooth	Can be worn in ear.
Somnofy sleep monitor	Sleep/sleep quality	Mobile API	Stands next to the bed.

There are three different ways of integration found among these devices – ways of connecting the device to the mobile application gateway:

- Bluetooth: Bluetooth Low Energy is the primary form of integration between sensor device and gateway in our architecture. This allows a direct integration between the app and the device. Once a Bluetooth pairing has been established, our app can communicate with the device whenever its Bluetooth radio is on. This form of integration requires a device which implements a Bluetooth LE protocol, and for that protocol to either follow a known standard or be documented.
- HTTP API: The sensor device sends its data into its own cloud service, typically through its own proprietary app. If this third-party cloud service has a public API and an authorization mechanism, we can retrieve data from this API over an internet connection. The authorization is typically handled by making a request for access to the data in the third-party cloud, which the owner of the sensor device can grant, giving us an OAuth token needed for the API requests. The negative aspects to this form of integration are that the user needs an

additional account and application, and that data access is indirect and therefore typically has considerable delay. The data may also be processed and filtered by the third-party service and may not include all the data collected from the sensor.

- Mobile API: Sensor data is available from an API on the mobile device. Apple's iOS platform has a framework called Apple Health Kit, and Android has Google Fit. These frameworks are used to share health and activity data between applications on the device, with authorization from the owner. So far, we have a single device which requires this approach (the Somnofy sleep monitor), but it may be possible to get data from some of the other devices through this approach. The big strength of this approach is that these mobile frameworks constitute common APIs which are supported by an ecosystem of devices and services, so that if we implement support for them in the mobile application gateway, we should be able to integrate with a number of devices. The negative aspects are the same as for the HTTP API: data access is indirect and restricted, and the user needs to use other apps and services.

From the list of potential devices, we have selected the **Fitbit activity tracker** as the primary and first device to integrate in engAGE. The reason is that it provides a good deal of data from a single device, and this device is always worn without being invasive. It is the best device for providing activity data (MSRBD_2), and it monitors sleep and sleep quality (MSRBD_1), covering the two most important monitoring requirements. It also provides heart rate data, the most relevant vital sign (MSRBD_4). The drawback with the Fitbit is that it does not permit direct integration. It communicates with Fitbit's own mobile app and sends the data into Fitbit's cloud service. This means that the user must have a Fitbit account and install the Fitbit app on their phone, and our mobile application must request data access. We describe the architecture of the integration in the mobile application section below.

The Fitbit activity tracker will be integrated in the first prototype. We will return to the list of potential devices for later prototype iterations. From the requirements we have four types of data to monitor with IoT devices. We can consider the other devices in the context of these requirements:

MSRBD_1 – Sleeping/sleep quality: This is covered well by the Fitbit, which tracks sleep and distinguishes between heavy, light and REM sleep. If even better sleep tracking is wanted, a dedicated sleep tracking sensor is needed, which we have in the Somnofy sleep monitor. However, it so far seems unnecessary to integrate a dedicated sleep sensor when we have the Fitbit.

MSRBD_2 – Physical activity and moving habits: There are different ways of monitoring this. The Fitbit uses heart rate monitor and accelerometer to deduce activity level. It is also possible to track specific activities through the Fitbit system, but this typically requires manual input (the user specifies starting and stopping the activity through the device screen or phone app). Alternatives are the use of GPS to track outdoor movement or iBeacons to track indoor movement. GPS does not distinguish between different types of movement, but the speed can be used to deduce if the movement is motorized or not. iBeacons are a form of tags which can be placed around the home. They are not really sensors, they just send out a signal, and the phone or tablet with the mobile application gateway senses these signals, using them to deduce relative location. It can be used to monitor which room of the house the user is in, but it only works if the user always brings the phone with them.

MSRBD_3 – Eating/food intake: There are no sensors which can directly monitor food intake. The options are to either monitor something which is affected by food intake, or to use self-reporting. Potential sensors are scale to monitor variation in weight and blood glucose monitor. The weight tells us if the user is eating too much or too little over time. The blood glucose monitor is not a good device in our use case, as it is a manual process which requires drawing blood each time and it would need to be done often to get an accurate picture of when the user eats. As such, the only viable use case seems to be if the primary user is diabetic and needs to measure blood glucose in any case. We should also note that the Fitbit system can track food intake, mainly to count calories. This is done with self-reporting in the Fitbit app. If food intake is reported in this way, the calories are available through the Fitbit API.

MSRBD_4 – Vital signs: We have a requirement for vital signs, but this is of low priority (should) as it is not so relevant in our use case (MCI). We get heart rate through the Fitbit, although we don't necessarily get direct access to the individual samples. Tellu already have integrations for several medical Bluetooth devices, so it would be easy to add them to the prototype, but their value in engAGE is low. Relative changes in heart rate and blood pressure can be used in the deduction of mood, but that would require frequent and accurate measurements to be useful. We have included the Cosinuss ear sensor in our list, as it is a new device with offers continuous measurement of multiple vital signs. It sits on and in an ear, like a hearing aid. It can be inserted to make a measurement and then taken off, or it can be worn continuously so that it can make regular measurements throughout the day. It has sensors for heart rate, temperature and blood oxygen saturation, and the manufacturer is working on algorithms to deduce blood pressure and respiratory frequency. It is comfortable enough to wear for long periods of time, but since it plugs into an ear it affects the hearing on that ear and the way your own voice sound when you speak, which means you may not want to keep it on in a social setting.

4.1.2 Mobile application gateway

Based on the architecture and sensor devices, we need a mobile application gateway to transfer sensor data into the TelluCare cloud. The first integration needed is for the Fitbit service. As discussed in the previous section, the Fitbit device does not allow direct integration. Instead, the mobile application gateway must request data through the HTTP API of the Fitbit cloud service. The architecture of the Fitbit integration is shown in Figure 4. The primary user needs a Fitbit device and a mobile device (phone or tablet). The Fitbit is a bracelet worn on the wrist. The Fitbit app must be installed on the mobile device, and the primary user needs a Fitbit account which is entered in this app. Data is transferred from the Fitbit device to the Fitbit app, and the Fitbit app sends the data to the Fitbit cloud, where it is stored. This is all part of the Fitbit service, and outside our control.

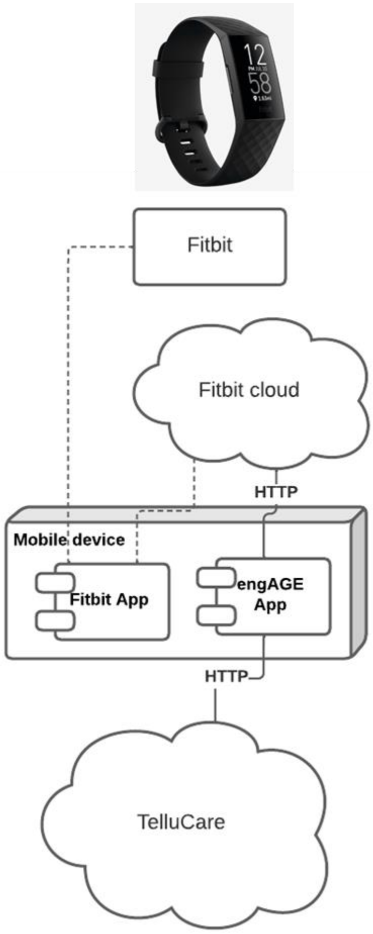

Figure 4: Fitbit integration architecture

The engAGE mobile gateway app must also be installed on the mobile device (technically it does not need to be installed on the same device, since the integration between the two systems happen over an internet connection). It needs the following functionality:

- Launch the Fitbit authorization web view to request access to the Fitbit account. If the user grants access, the engAGE app gets an OAuth token it stores. This token needs to be refreshed regularly to stay valid.

- Poll the Fitbit API regularly, using the OAuth token to access data from the Fitbit account. The first thing to request from the Fitbit API is the device status, to know if the Fitbit device is operational and when it was last synced with the Fitbit cloud. If it has been synced lately, we can request data.
- Send the data retrieved from the Fitbit API into an engAGE service (either TelluCare or directly to the ML-based Cognitive Decline Assessment service).
- Notify the primary user if the device status is in error or unsynced for a significant amount of time. We need to indicate how to troubleshoot and rectify the issue, such as opening the Fitbit app or charging the Fitbit device.

We would like the engAGE app to run in the background, automatically attempting to transfer data at a regular interval. If this works, the primary user should not need to do anything. Only if there is a persistent error or a new authorization is required do we need to notify the user, who will then open the app's user interface. Tellu has previous experience with Fitbit integration and the Fitbit API, but not with transferring data automatically or in the background (data transfer has been controlled by the user in the UI).

Tellu has a framework and code base for cross-platform mobile applications connected to Tellu services such as TelluCare. Cross-platform means that instances can be made for both Android and Apple devices, and they can run on different screen sizes (phones and tablets). Specifically, for TelluCare, Tellu has a patient app called Dialogg, which has several functions:

- Mobile gateway with Bluetooth integrations
- Scheduled tasks, with notifications
- Questionnaire engine for self-reporting
- Video meetings
- Text chat
- Show care plan, documents, and history

Per the current requirements and architecture, most of these functions are not needed in the engAGE mobile app. Also, Dialogg is a front-end application, only active when its UI is on screen. We therefore want to develop a new engAGE mobile application, with Fitbit integration running in the background. It will be based on the common Tellu application framework, so that it will be possible to include Bluetooth gateway functionality and other Dialogg modules in the future, if the need arises.

4.1.3 Identity and access management

TelluCloud includes an identity and access management service. All users of the TelluCare service, including mobile apps, are registered here, with roles to control what they have access to. Any service which wants to use the TelluCare APIs need an authentication token issued here, with the correct authorization. The process of authenticating a user is implemented using the OpenID Connect v1.0 protocol[2]. OpenID Connect is an authentication layer on top of the authorization framework OAuth 2.0. The protocol defines a set of different authentication flows, where the choice of the used flow typically depends on the type of client application and type of user that will be authenticated.

[2] https://openid.net/connect/

Authorization code flow, implicit flow and hybrid flow are supported. This means that client applications must follow state-of-the-art security patterns. A client application can't implement its own login UI, it must redirect the user to the identity and access management service and get back a token if the user was able to authenticate themselves.

The identity and access management service can implement its own authentication of registered users, such as with username and password, but it can also federate identities provided by other federation services and identity providers, participating in a network of trust. Therefore, we refer to this service as the ID broker in our architecture, and it is a key feature for the engAGE system. An ID broker makes it possible to implement single sign-on and let the user use the same ID to authenticate with many different services, without any explicit connections between these services. New ID providers can be added as requested by partners and customers, with the various forms of authentication supported by these providers, without changes to the engAGE applications. Importantly, it provides support for two-factor authentication and use of national identity federation services, which are important in the health domain. Identities supported by the TelluCloud authentication broker include:

- ID-porten: the national identity federation service in Norway that provides identities verified by five different identity providers: MinID, BankID, BankID on mobile, Buypass or Commfides. Identities provided by ID-porten must only be used by public services, or service providers operating on behalf of a public service. If commercialisation targets municipal service providers or public health providers in Norway, ID-porten authentication must be used by primary users and informal carers.
- HelseID: an identity federation service provided by Norsk Helsenett for authenticating health personnel in Norwegian e-health solutions. HelseID federates identities from regional health organizations, local identity providers and ID-porten. In addition, HelseID will enrich the identity with information about the user from Helsepersonellregisteret and Personregisteret.
- Social Identity Providers: TelluCloud's ID broker can also be configured to federate identity from social identity providers. Currently a number of social identity providers are supported, such as Facebook, Google, LinkedIn, Microsoft, Twitter and PayPal.

Tellu also have sub-contractors to federate identities from ID-providers outside of Norway, including providers in Nordic countries and a set of countries in the EU.

4.1.4 TelluCare cloud

The heart of the TelluCare backend is the cloud storage of data. The data model is based on FHIR[3]. FHIR is a standard for health care data exchange, published by HL7. TelluCare use the FHIR standard to ease interoperability with other services. The person monitored is in this context known as a *patient* and represented with a FHIR Patient object. The primary user needs to be registered as a patient in TelluCare, and all data will refer to this patient object.

For the engAGE use-case there are two main forms of data in the TelluCare backend. Firstly, there is the patient profile, which contains information about the primary user and the care plan. As a minimum, the plan must contain information about what to monitor, as a configuration of what data to collect and how. A schedule can be made to specify when and how often to make a measurement,

[3] https://www.hl7.org/fhir/

and notifications can be sent to both the primary user and different types of caregivers. It is also possible to store more information related to the primary user here. The other type of data is the observations from sensor devices and other forms of monitoring. The FHIR Observation object is used for representing sensor measurements. In addition to sensor observations, the system has support for FHIR Questionnaire objects, which defines forms for self-reporting, with the corresponding QuestionnaireResponse objects for storing the input. All data is stored in an encrypted database.

Data flows in and out of the FHIR database through APIs. All API transactions require authorization, which is handled by the ID broker in TelluCloud, described above. The authorization is role-based, and access is logged, with an audit log also available through the APIs. The APIs are used by other components in the infrastructure, including mobile apps. The APIs are built with GraphQL[4], a query language. The client sends a GraphQL query to the API, specifying exactly which objects and fields it wants, from those available in the FHIR standard. FHIR objects are returned in JSON format. The APIs provide an integration point for other engAGE services, through which measurements can be retrieved and patient information can be updated.

A web application is built and maintained on the GraphQL FHIR API, to allow access to the data for administrators and formal carers. It allows creating and updating patient profiles and view patient medical measurements, in tables and graphs over time. The web application is role-based, with different functionality available for different roles. Based on the identity of the authenticated user, one or more roles can be available.

4.2 ML-based Cognitive Decline Assessment

The goal of ML-based Cognitive Decline Assessment (MLCDA) service is to analyse and corelate by means of machine learning algorithms the information acquired by different engAGE services on the older adult with the goal of determining insights onto the cognitive state and potential decline. The insights can then be used by the formal care givers in day care centres to fine tune and personalize the robot-based intervention.

During the cocreation phase several needs, challenges, and expectations of the end users in relation to the engAGE system were identified and prioritized. Then we have used them to derive functional requirements that may be implemented by the present service. They are listed in table below.

Table 4: Requirements for MLCDA

ID	Type	Description	Source	MosCoW	Target end-users
MLCDA_1	Functional	Spot alarming insights on cognitive state from the analysed data	D2.1	Must	Primary, Secondary
MLCDA_2	Functional	Assess the wellbeing of the SMCI	D2.1	Must	Primary, Secondary
MLCDA_3	Functional	Corelated games and levels of difficulties considering the insights determined	D2.1	Should	Primary, Secondary

[4] https://graphql.org/

MLCDA_4	Functional	Run analytics on the monitored data to detect trends and deviations	D2.1	Should	Primary, Secondary
MLCDA_5	Functional	Assess the cognitive state based on data to determine progress or regression	D2.1	Must	Primary, Secondary
MLCDA_6	Functional	Asses the functional state based on the ability to carry out activities of daily living	DoW	Should	Primary, Secondary
MLCDA_7	Non-functional	The service must consider heterogenous information sources	DoW	Must	-
MLCDA_8	Non-functional	The service should use machine learning algorithms	DoW	Must	-

Machine learning techniques will be developed to analyse the sensors-based data acquired by the monitored infrastructure, self-reporting data provided by the older adult by means of questioners and the scores obtained when playing different games.

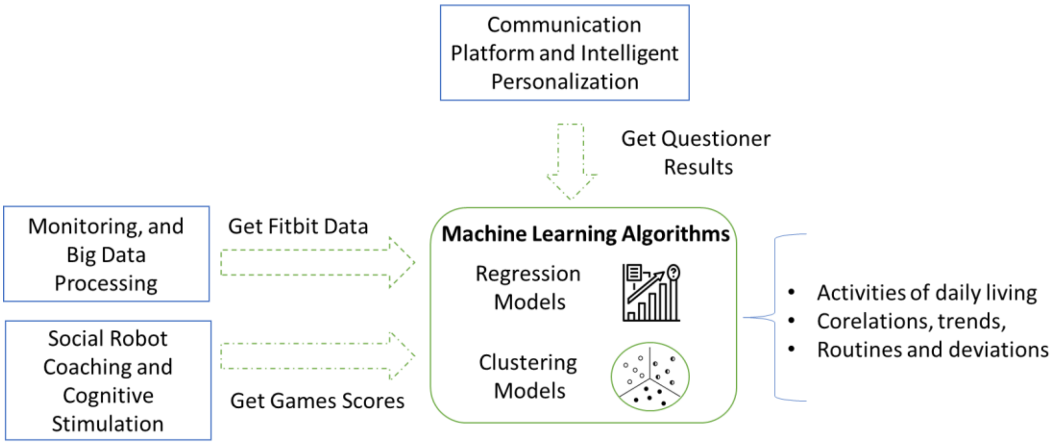

Figure 5: Machine Learning algorithms integration in engAGE

The Monitoring and Big Data Service, historical data as well as real-time access can be obtained to data describing the daily living activities performed by a person as well as to some health data. Such data is useful to identify a possible deterioration in the person's cognitive states which can be reflected in the daily activities. Data can be fused, and machine learning techniques and technologies can be used to extract patterns, detect anomalies or situations that require intervention. The daily living activities data of a person could be used to detect regular daily activities patterns (i.e., daily routine) as well as deviations from them. The daily routine describes information on activity type, frequency, and sequence and are key elements in transforming the information collected from sensors into useful observations through which the medical staff can draw conclusions regarding the change of the adult's health conditions.

Similarly, the Social Robot can register and provide information related to the older adult performance in playing cognitive games. The machine learning algorithms may be corelated with the information of the daily live functional ability of the person to get insights in potential cognitive deterioration allowing the tuning of the intervention. For example, the suggestion of games or levels to which the older adult should play.

Finally, the Communication Platform and Intelligent Personalization will provide the scores obtained by the older adults to the questioners used to acquire the baseline cognitive and functional state (more rarely taken) as well as the wellbeing and emotional state which can be captured on daily basis. This information can be used by the machine learning algorithms in two ways: the baseline information can be used to detect potential deterioration trends while the wellbeing or emotional information can be used for labelling and fine tuning the learning process.

The service will innovatively consider two types of features in the learning process: features extracted from the monitored data on daily life activities and contextual features related to the baseline cognitive function, age, and subjective reports on heath state and well-being.

When using machine learning algorithms on sensor data challenges such as the missing or out of scale data, the noise, the large number of features, etc. need to be addressed. Figure 6 presents the pipeline of activities used to apply the machine learning algorithms.

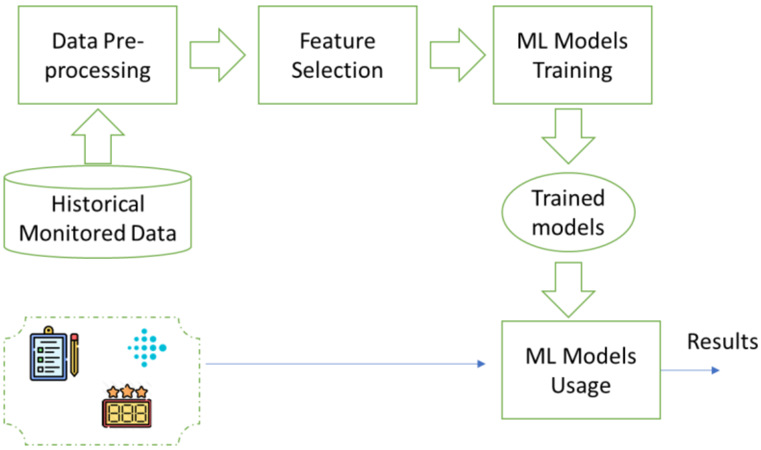

Figure 6: Machine Learning pipeline of activities

Data pre-processing and cleaning – aims to prepare the data to be programmatically processed conforming to a well-defined data model scheme. Data transformations can be done depending on the type and quality of data. The most likely candidates are missing values imputation, filtering undefined or out of scale values and data normalization or discretization, etc. The problems are usually generated by sensors heterogeneity and lack of standardization, different rate of data sampling, and errors in data transmission (i.e., lost messages).

Feature selection – aims at collapsing the characteristics considered in the learning algorithms by eliminating the ones which have no influence on the results. Thus, the search space is reduced, and the performance of the machine learning algorithm improved. Algorithms such as Principal Component Analysis can be used in this step to determine features influence scores.

Cross Validation – aims at splitting the historical monitored data in two subsets, one for training the machine learning algorithms and one for estimating the performance of the algorithms. For Cross Validation a 5-fold approach can be used. The data set is split randomly in 5 subsets that have an equal number of samples. The machine learning algorithms are repeatedly applied on 4 folds of the data set while the remaining fold will represent the testing data set.

Learning step – aims at applying machine learning algorithms on the training data with the goal of learning a model which will be then used on the monitored data received from sensors on a daily basis.

Model Evaluation – the model results are evaluated based on the test data to determine its performance prior to its actual usage on monitored data of the elderly.

The learning process will consider various of features in the learning process:

- Features extracted from the monitored data on daily life activities: morning, afternoon, evening and night routines, daily activities type, their sequence and duration, etc.
- Baseline cognitive function
- Subjective reports on wellbeing and emotional states

4.3 Social Robot Coaching and Cognitive Stimulation

This Social Robot Coaching and Cognitive Stimulation (SRCCS) service aims to provide personalized brain training in day care centres by employing the Pepper social robot as a tool to address important areas for a healthy brain, such as socialization, drama, and storytelling, etc. The robot will provide a wide spectrum of cognitive stimulation activities (e.g. drama storytelling, cognitive games, etc.).

SRCCS will be based on the interactive social robot Pepper which can speak, engage in dialogs, move around the room, and receive and send notifications. It will be programmed to engage with the older adult, recognize him/her, and will suggest a drama dialog to exercise and will act as the older adult partner in that dialog. We will add to the robot the option of motivating the older adult to tell stories and describe memories from his/her past. The level of engagement in cognitive training will be personalized and correlated with the output of the ML cognitive assessment targeting to maintain or improve the older adult cognitive state. In case of loss of ability in conducting ADL is detected the social robot will be able to provide guidance care allowing the older adult to repeat information back to confirm understanding.

According to the target group interviewed, the requirements of the Pepper robot must correspond to end users' needs. All the insights discovered during the co-creation phase should be correlated to specific features included in the robot application.

These actions will be done in UI/UX of the main tablet application, but we will also involve a complex hardware engagement with the Pepper SDK to control actuators, touch sensors, main camera, microphones, LEDs and speakers.

Table 5: Requirements for SRCCS

ID	Type	Description	Source	MosCoW	Target end-users
SRCCS_1	Functional	Give a strong cognitive stimulation (the added value regarding cognitive state has to be clear)	D2.1	Must	Primary
SRCCS_2	Functional	Use different means to create an interaction: speaking, making sounds, movement (increase interest)	D2.1 / DoW	Must	Primary
SRCCS_3	Functional	Use simple ways to interact simple but complete (no technological background needed)	D2.1	Must	Primary

SRCCS_4	Functional	Offer various games to entertain the senior while he/she works his/her memory skills (increase interest)	D2.1 / DoW	Must	Primary
SRCCS_5	Functional	Allow a simple identification and connection, with tips to remember the seniors' nicknames (ease-of-use)	D2.1	Must	Primary
SRCCS_6	Functional	Save previous scores of the senior to give information on progression or regression of the SCMI's state	D2.1	Must	Secondary
SRCCS_7	Functional	Be completed with a strong coaching support, adapted to the levels of difficulty (increase adherence)	D2.1 / DoW	Must	ALL
SRCCS_8	Functional	Have to be installed in an institution and not at the seniors' home	D2.1	Must	ALL
SRCCS_9	Functional	Be delivered with a pen as seniors often have issues on using tablets (problem to click)	D2.1	Should	Primary
SRCCS_10	Functional	Have a low power consumption and stay autonomous almost for 4 hours straight	D2.1	Should	ALL
SRCCS_11	Functional	Be able to offer SMCI an easy way to ask the robot to repeat itself	D2.1 / DoW	Must	Primary
SRCCS_12	Non-Functional	The social robot must follow GDPR constraints in terms of personal data.	DoW	Must	ALL

4.3.1 Voice interaction software architecture

It will be used and enhanced a speech engine based on NLP for TTS and custom-made STT which is a reproduced version of robot voice. Based on the triggering event speech listener immediately receives a signal to start listening (i.e. the older adult voice that is interacting with the robot). The speech is translated into specific languages to be sent to knowledge-based AI to provide the corresponding response to the user's query. The translated text will be sent to the TTS engine which is designed specifically for the robot's voice for it to speak out to the user.

This solution will help us interact with people in their own language because it is modular and can be easily swapped between different languages. For the engAGE project, Pepper will be able to be used the same way in partners mother languages, which will offer a better communication understanding to the primary end users.

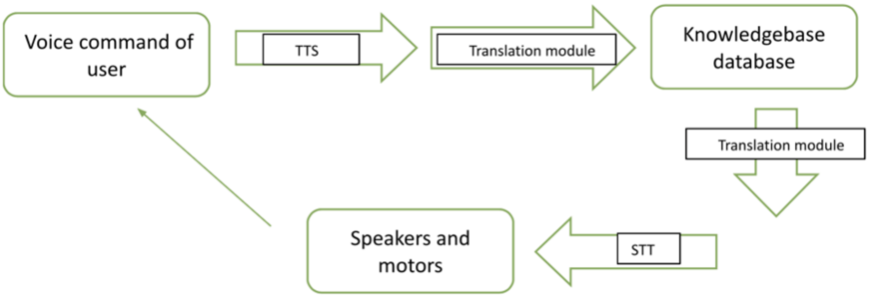

Figure 7: Voice interaction architecture

4.3.2 Pepper robot interactions

Robot interaction with the end users will be completed through the tablet of the robot, but also by movements, sounds and LEDs. The hardware elements of the robot will cover besides the familiar experience with tablets, a new emotional and interactive communication held by robot's responsive sensors. During the development of the project we will use camera, microphone, speaker and touch sensor.

- Camera will be used for tracking the head position of the subject and also to recognize the user with facial recognition software.
- Microphone will be used to hear the voice command said by user and will be converted in text using STT software.
- Speakers and robot's motors will be used for voice commands spoken by the robot and actuators will be used to animate the speech of the robot with it is natural movements.
- Touch sensors will be used to detect the hand presence of the user and they are present in head, hands and on top of the wheels base of the robot. Those sensors will be used during games and also to trigger voice command interactions before a voice command.

4.3.3 Cognitive games

On Peppers' tablet, 4 distinct game types (discussed in deliverable D2.1) will be developed and integrated for SMCIs:

- *familiar games* which seniors are used to play (e.g. crosswords);
- *quizzes* to train their memory while having fun (e.g. picture quiz);
- *physical games* to sustain health issues related to MCI (e.g. miming);
- *story / plays telling* to go deeper in memory trainings (story listening).

The familiar activities, tests, physical games, and storytelling are all beneficial for maintaining their memory skills. Since most seniors are already skilled, it won't take them much effort to learn how the games function, so the system will be user-friendly enough for them to understand how to play.

1. **Game selection** – available by voice or by touching the tablet
2. **Level selection** – according to the stage of the MCI, patients will train their memory

3. **Game progress** – robot will ask the user different information by voice to complete the level

4. **Finishing game** – at the end of the game, user will see the personal leader board and his progress during the current and previous sessions

5. **General leader board –** where each user can compete with other patients to improve his personal results, but also to offer a relevant insight for caregivers to check how many exercises are needed for each patient

4.4 Communication Platform and Intelligent Personalization

The Communication Platform and Intelligent Personalization (CPIP) consists of several dashboards that will be developed and integrated with the defined services to show care status information concerning the cognitive baseline, ADL monitoring, self-reporting, and cognitive decline assessment and to enable interaction and communication of all types of interested actors with the system. CPIP will be able to remind or step by step instruction on conducting ADL (e. taking medication, drinking water, etc.), and will allow configuration of personal services are by the carer (secondary user - family or professional) connected to the primary user.

The platform will be based on the Karde product MEMAS which is a Life Mastering Assistant especially targeted towards people with MCI. More specifically the older adults and caregivers will have dashboards allowing them to check up the information about the cognitive state evolution, ADL, etc., and will be able to respond to questioners and provide self-reporting on the health and wellbeing state. Caregivers will be empowered to check up on the older adult data, progress and will be able to provide configuration of the overall interaction. For older adults, MEMAS will provide simple-to-use user interfaces with an additional possibility to configure personalized pieces of advice. The appearance, accessibility features, security, and privacy need to be considered for CPIP.

MEMAS is a web app, built in Drupal. It consists of two parts:

- an app with services for the primary user and
- an app for the secondary user to administer data and services for the primary user.

It is envisioned to deploy MEMAS on the Pepper robot to allow interactions directly with the robot tablet. Additionally MEMAS can also act as the older adult communication “tablet” or the “travel robot” and can follow the user anywhere, whilst the robot stays in day care centres.

At present MEMAS is built around a calendar for keeping track of events and appointments for the primary user during the day. The calendar is maintained and updated by secondary users with tight relations to the primary user, informal (most often family) or formal carers.

MEMAS also contains services for albums which may contain photos with spoken stories connected to the photo and private videos.

In engAGE, MEMAS will be adapted to the requirements from the DOW and user requirements described in D2.1 and section 3 in this document. Table below addresses requirements which will be provided by CPIP.

Table 6: Requirements for CPIP

ID	Type	Description	Source	MosCoW	Target end-users
CPIP_1	Functional	Allow to play the games for cognitive support.	DoW	Must	Primary
CPIP_2	Functional	Offer motivation mechanisms	DoW	Should	Primary
CPIP_3	Functional	Allow configuration of the platform for the caregiver.	D2.1	Must	Secondary
CPIP_4	Functional	Display the ML service results in an intuitive dashboard.	DoW	Must	Secondary
CPIP_5	Functional	Offer personalization for the HCI interface	D2.1	Should	Secondary
CPIP_6	Functional	Primary end-user must have control over the dashboards.	D2.1	Must	Primary
CPIP_7	Functional	Offer training mechanisms.	DoW	Should	All
CPIP_8	Functional	Instructions for Activities of Daily Living. Defined by secondary user and used by primary user.	DoW	Should	All
CPIP_9	Functional	Calendar for reminders.	DoW	Must	All
CPIP_10	Functional	Video meetings for video calls to friends and family.	DoW	Should	All
CPIP_11	Functional	Self-reporting for primary end users, for cognitive function and perceived health and wellbeing.	DoW	Must	Primary
CPIP_12	Functional	Caregivers can report the primary end user's moods, sentiments, (changes in) behaviour, and contact with the physical environment (home).	DoW	Must	Secondary
CPIP_13	Functional	Make a way to see progression/regression in memory skills and cognitive state	D2.1	Must	Primary
CPIP_14	Functional	Allow carers through an application to adapt treatments / configure /personalize the services	D2.1	Must	Secondary

CPIP_15	Functional	Put seniors in contact with other people like them (e.g. video calls)	D2.1	Must	Primary
CPIP_16	Non-Functional	MEMAS should be GDPR proof	Dow	Must	All

CPIP_1: The present MEMAS does not contain games. In engAGE, the games to be embedded in the web app must be decided. Suitable games that are available as free software will be investigated and integration cost estimated. MEMAS has services for photo albums which may contain images with spoken comments and videos. Favourite music and therapeutic music will be available from commercial streaming services like Spotify at a monthly cost. The Secondary user may configure the system without music.

CPIP_2: Motivation mechanisms must be developed. If this functionality is built around motivational quotes, the context (i.e. the data that is used to identify a particular context for presenting a motivational quote) must be specified. This can be done by writing brief use cases in the format of a goal-oriented script for each context.

CPIP_3: The admin part of MEMAS must contain mechanisms which enable the secondary user to configure motivational step. A similar specification for how to identify the context for these motivational actions must be developed.

CPIP_4: Dashboard must be developed. MEMAS get input from Machine Learning (sensor, reporting, activity) in REST API and present the result to secondary users in a simple and appealing way. REST endpoints for delivery of data from Machine learning must be specified. The reports to present to the secondary user based upon this data must be designed.

CPIP_5: These requirements are concerned with the HCI of MEMAS. The present MEMAS has undergone lot of user testing in Norway, Germany and UK in previous AAL-projects. Experiences from the present system in addition to user testing in engAGE will seek to satisfy the user requirements in Table 1. The HCI may be personalised for the primary user in the admin part of MEMAS. An organizational structure diagram of the system must be designed, supplemented by storyboards that shows high or low fidelity mock-ups of the main individual pages that is seen by the primary and secondary users.

CPIP_6: To give the primary user some control over the distribution of the dashboard must be developed. Requirements for this service must be sought in user activities in the engAGE-project. Information is distributed to secondary users and carers based on valid consent (as defined in GDPR) has been given. We need to define a suitable consent mechanism that does not impose too high a cognitive load on the primary user.

CPIP_7: Training mechanisms must be developed. Training for carers is not currently part of the design. The information architecture of the training section needs to be designed, using the same approach as the one described for CPIP_5. A series of screen casts may be one route to explore.

CPIP_16: MEMAS will in all instances satisfy GDPR. We will create DPIA to make sure this requirement is satisfied.

5 Conclusions

This report defines and lists the main functionalities of engAGE services in terms of functional / non-functional requirements and define the initial system architecture. The system design considers the functionalities promised in the DoW together with deliverable D2.1 findings and further transforms the user needs and requirements, scenarios and use cases into more specific system level functional and non-functional requirements. The document will be used as input for the system development activities in WP1.

References

[1] C. E. D. W. P. R. S. Autumn Edwards, "Initial expectations, interactions, and beyond with social robots," Computers in Human Behavior, vol. 90, no. https://doi.org/10.1016/j.chb.2018.08.042., pp. 308-314, 2019.

[2] D. M. G. O.-S. Martina Čaić, "Value of social robots in services: social cognition perspective," Journal of Services Marketing, vol. Vol. 33 No. 4, no. https://doi.org/10.1108/JSM-02-2018-0080, pp. 463-478, 2019.

[3] H. R. a. W. A. Cross Emily S., "From social brains to social robots: applying neurocognitive insights to human–robot interaction," Phil. Trans. R. Soc, no. http://doi.org/10.1098/rstb.2018.0024, 2019.

[4] G.-V. D. C. N. M. M. R. F. B. P. R. S. B. M. C. R. C. C. A. Sierra Marín Sergio D., "Expectations and Perceptions of Healthcare Professionals for Robot Deployment in Hospital Environments During the COVID-19 Pandemic," Frontiers in Robotics and AI , vol. 8, no. https://www.frontiersin.org/article/10.3389/frobt.2021.612746 , 2021.

[5] Z. H. S. A. a. L. C. W. Khan, "Robotics utilization for healthcare digitization in global covid-19 management," Int. J. Environ. Res. Public Health, vol. 17:3819, no. 10.3390/ijerph17113819, 2020.

[6] L. C. C. S. M. K. V. Wazir Hassam Khan, "A COVID-19 Emergency Response for Remote Control of a Dialysis Machine with Mobile HRI," Frontiers in Robotics and AI, vol. 8, no. https://www.frontiersin.org/article/10.3389/frobt.2021.612855 , 2021.

[7] Chita-Tegmark, M., Scheutz, M. Assistive Robots for the Social Management of Health: A Framework for Robot Design and Human–Robot Interaction Research. Int J of Soc Robotics 13, 197–217 (2021). https://doi.org/10.1007/s12369-020-00634-z

[8] Mois, G., Beer, J.M. The Role of Healthcare Robotics in Providing Support to Older Adults: a Socio-ecological Perspective. Curr Geri Rep 9, 82–89 (2020). https://doi.org/10.1007/s13670-020-00314-w

[9] F. C. R. A. Wu YH, "Designing robots for the elderly: appearance issue and beyond," Arch Gerontol Geriat, no. 10.1016/j.archger.2011.02.003, 2012.

[10] R. G. Amit Kumar Pandey, "A Mass-Produced Sociable Humanoid Robot: Pepper: The First Machine of Its Kind," IEEE/SICE International Symposium on System Integration, vol. 25, no. 3, 2018.

[11] D. Brugali and P. Scandurra, "Component-based robotic engineering (Part I) [Tutorial]," in IEEE Robotics & Automation Magazine, vol. 16, no. 4, pp. 84-96, December 2009, doi: 10.1109/MRA.2009.934837.

[12] F. M. B. I. Enrique Coronado, "Visual Programming Environments for End-User Development of Intelligent and Social Robots, a Systematic Review," Journal of Computer Languages, no. https://doi.org/10.1016/j.cola.2020.100970, 2020.

[13] O. &. F. L. &. A. G. &. S. A. &. M. G. &. C. F. Nocentini, "A Survey of Behavioral Models for Social Robots," Robotics, vol. 8, no. 10.3390/robotics8030054 , p. 54, 2019.

[14] H. -L. C. e. al., "A Personalized and Platform-Independent Behavior Control System for Social Robots in Therapy: Development and Applications," IEEE Transactions on Cognitive and Developmental Systems, vol. 11, no. 10.1109/TCDS.2018.2795343, pp. 334-346, 2019.

[15] G. L. C. a. A. C. A. Ortony, "The cognitive structure of emotions," Cambridge university press, 1990.

[16] A. L. &. C. P. &. N. A. &. P. V. &. R. Alessandro, "A Reference Software Architecture for Social Robots," 2020.

[17]P. C. A. G. N. V. P. A. R. Luigi Asprino, "A reference architecture for social robots," Journal of Web Semantics, vol. 72, no. https://doi.org/10.1016/j.websem.2021.100683., 2022.
[18][Online]. Available: http://www.mario-project.eu/portal/.
[19]F. Martín, F. Rodríguez Lera, J. Ginés and V. Matellán, Evolution of a Cognitive Architecture for Social Robots: Integrating Behaviors and Symbolic Knowledge., vol. 6067, no. https://doi.org/10.3390/app10176067 , p. 16, 2020.
[20][Online]. Available: https://github.com/IntelligentRoboticsLabs/BICA.
[21]Y. Huo, J. Tang, Y. Pan, Y. Zeng and L. Cao, "Learning a Planning Domain Model From Natural Language Process Manuals," in IEEE Access, vol. 8, pp. 143219-143232, 2020, doi: 10.1109/ACCESS.2020.3013237.
[22]D. &. S. S. &. K. T. &. H. N. Glas, "An Interaction Design Framework for Social Robots," no. 10.15607/RSS.2011.VII.014. , 2011.
[23]F. Barroso, C. Santos and J. C. Moreno, "Influence of the robotic exoskeleton Lokomat on the control of human gait: An electromyographic and kinematic analysis," 2013 IEEE 3rd Portuguese Meeting in Bioengineering (ENBENG), 2013, pp. 1-6, doi: 10.1109/ENBENG.2013.6518442.
[24]H.-L. G. E. P. D. B. A. S. V. R. V. D. P. G. L. D. &. V. B. Cao, "A survey on behavior control architectures for social robots in healthcare interventions," International Journal of Humanoid Robotics, pp. 1-24, 2017.
[25]A. A. U. M. G. P. a. F. V. I. Infantino, "A Cognitive Architecture for Social Robots," IEEE 4th International Forum on Research and Technology for Society and Industry (RTSI), no. doi: 10.1109/RTSI.2018.8548520, 2018.
[26]F. Hegel, M. Lohse, A. Swadzba, S. Wachsmuth, K. Rohlfing and B. Wrede, "Classes of Applications for Social Robots: A User Study," RO-MAN 2007 - The 16th IEEE International Symposium on Robot and Human Interactive Communication, 2007, pp. 938-943, doi: 10.1109/ROMAN.2007.4415218.
[27]M. Podpora, A. Gardecki, R. Beniak, B. Klin, J. Vicario and Kawala-Sterniuk, "Human Interaction Smart Subsystem—Extending Speech-Based Human-Robot Interaction Systems with an Implementation of External Smart Sensors," Sensors, no. https://doi.org/10.3390/s20082376 , 2020.
[28]J. Casas, N. Céspedes, C. Cifuentes, L. Gutierrez, M. Rincón-Roncancio and M. Múnera, "Expectation vs. Reality: Attitudes Towards a Socially Assistive Robot in Cardiac Rehabilitation," Applied Sciences, no. https://doi.org/10.3390/app9214651, 2019.
[29]M. M. G. C. C. C. Cespedes N, "Social Human-Robot Interaction for Gait Rehabilitation," IEEE Trans Neural Syst Rehabil , no. 10.1109/TNSRE.2020.2987428, pp. 1299-1307, 2020.
[30]D. R. M. M. a. C. A. C. Nathalia Céspedes, "Long-Term Social Human-Robot Interaction for Neurorehabilitation: Robots as a Tool to Support Gait Therapy in the Pandemic," Frontiers in Neurorobotics, vol. 15, no. 10.3389/fnbot.2021.612034 , 2021.
[31]C. B. M. S. G. S. J. B. O. D. S.-F. J. H. P. W. Deirdre E. Logan, "Social Robots for Hospitalized Children," Pediatrics, no. 144 (1): e20181511. 10.1542/peds.2018-1511, 2019.
[32]C. P. M. C. N. e. a. Cifuentes, "Social Robots in Therapy and Care," Curr Robot Rep, no. https://doi.org/10.1007/s43154-020-00009-2, 2020.