Ageing@Work

Smart, Personalized and Adaptive ICT Solutions for Active, Healthy and Productive Ageing with enhanced Workability

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Ageing@Work System Architecture

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Executive Summary

This document reports the first version of the Ageing@Work overall system architecture. This system includes the digital platform, the dashboards, the mobile app and the databases used to deliver services to factory managers and end-users (blue collar workers & office workers).

In order to describe the Ageing@Work system architecture we have followed the ITIL framework best practices[1] (formerly an acronym for Information Technology Infrastructure Library). ITIL facilitates the Ageing@Work designers and developers to establish a baseline for the planning, implementation, and measurement of technology improvement. On this basis, we describe procedures, processes and tasks.

In the technical description of the architecture, a first level overview of the Ageing@Work main system architecture component is provided in the present deliverable, along a more detailed description of sub-components, the services on offer and the main interactions among the architectural sub-components. According to our methodology, having as a starting point the user requirements in D2.1 we have made a mapping to the technical specifications of the system following the Volere[2] methodology and then we proceeded with the elaboration of original conceptual architecture on this basis (leads to high-level architecture). The high-level design was then broken down into low-level groups of functional components (subcomponents). A detailed technical description of those subcomponents is provided along with the required service design packages (for each individual component), to ensure that the proposed solution is consistent with the overall service strategy, i.e. with the aims of the Ageing@Work system, as defined in the user-centric requirements. Finally, an integration plan is proposed to explain how all those components will be merged together to construct a compact toolset.

The contents of the D2.3 will be used as a reference for the next technical WPs which refer to the development of the solutions.

[1] https://www.axelos.com/Corporate/media/Files/Misc%20Qualification%20Docs/ITIL_Value_Proposition-(1).pdf
[2] https://www.volere.org

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List of Terms and definitions

Abbreviation	Definition
API	Application Programing Interface
AVM	Architectural View Model
CIDEM	Common Information Data Exchange Model
COA	Cloud-Oriented Architecture
CSS	A language that describes the style of an HTML document
CSS3	The latest standard for CSS
DoA	Description of Action
DSS	Decision Support System
FoF	Factories of the Future
GIT	Git is a version control system that is used for software development and other version control tasks.
GFC	Groups of Functional Components
HTML	Hypertext Mark-up Language
HTML5	Hypertext Mark-up Language, version 5
ICT	Information and Communication Technology
ITIL	Information Technology Infrastructure Library
ITSM	IT service management
JSON	JavaScript Object Notation
PAAS	Platform as a Service
POMDP	Partially Observable Markov Decision Process
RDBMS	Relational Database Management System
WMF	World Manufacturing Forum
WP	Work Package
XML	Extensible Mark-up Language

Table 1 Definitions

1. Introduction

1.1 Scope of the deliverable

The technical description of the overall Ageing@Work system and the related system specifications were built upon the user requirements derived from the focus groups of the D2.1 and the related project use cases definition. This document serves in turn as input for writing detailed descriptions of the individual architectural components of the Ageing@Work system, including the functional and non-functional requirements of each and – if applicable –the Application Programing Interface (API) specifications for integrating the components into the overall system.

Taking the system architecture contained in the Description of Action (DoA) as a starting point, this document will further elaborate the required software and hardware components, involving many carefully arranged parts or details.

1.2 Relation to other activities and deliverables

The progress reported in this deliverable is based on the user requirements and the use cases description specified in WP2. More specifically, starting from the use cases description in D2.1, the user requirements are mapped herein to the system functionalities and technical specifications. The final outcome (the overall system architecture and the break-down into sub-components) and the details on their data exchange and interactions will lead the development tasks in the work packages from WP3 to WP6, and also the integration activities in WP7.

1.3 Structure of the deliverable

The D2.3 document is structured as follows:

- Chapter 1 is the introduction of this document and contains a State-Of-The-Art analysis on similar systems and some relevant design paradigms.
- Chapter 2 presents the technical specifications for the Ageing@Work system as they resulted after studying the user requirements and the use cases.
- Chapter 3 describes the main architecture principles followed by the design of the Ageing@Work architecture and the requirements elicitation methodology.
- Chapter 4 presents the overall architecture, both from a conceptual and a technical perspective.
- Chapter 5 contains a detailed description of the architectural subcomponents.
- Chapter 6 presents the approach to be followed during integration and technical validation (Integration Roadmap)
- Chapter 7 is the conclusion to this deliverable and summarizes its main findings

1.4 Related Projects and architectures

The main aim of this section is to briefly present a state of art in terms of a series of related projects and their corresponding architectures, focusing on areas and components that demonstrate relevance with Ageing@Work, so as to formulate a starting reference for each of the major components of the Ageing@Work architecture.

The Veritas project[3] aimed at the development of simulation-based and virtual reality tools to test the accessibility of assistive technologies and product design, in order to ensure that future products and services are being systematically designed for all. The main component of the Veritas project is the Core Simulation Platform (CSP), a platform that enables the evaluation of designs with respect to usability by individuals with disabilities. The main component of the CSP is a static and dynamic simulation component that accepts task scenarios and estimates their feasibility with respect to them being carried out by an individual with disability, their profile being input into the system as well. The Veritas CSP is in direct relation to the Ergonomics Optimization Support Tool (EOST) component of the Ageing@Work project, and as such the latter can build upon the general architecture of the CSP, being modified as deemed necessary for the goals of the project. It is noteworthy that the Ageing@Work EOST includes features that extend the scope of CSP, namely evaluation of ergonomics bottlenecks that may hinder a person's productivity and workability, and as such, appropriate extensions are necessary.

The City4Age project[4] (*Figure 1*) aimed at the development of an ICT framework to enhance early detection of risk related to Mild Cognitive Impairment (MCI) and to provide personalized intervention, through collecting data about elderly behavior by using unobtrusive and low-cost sensing devices (smartphones, wearables, Bluetooth beacons etc.) that do not interfere with their normal activities.

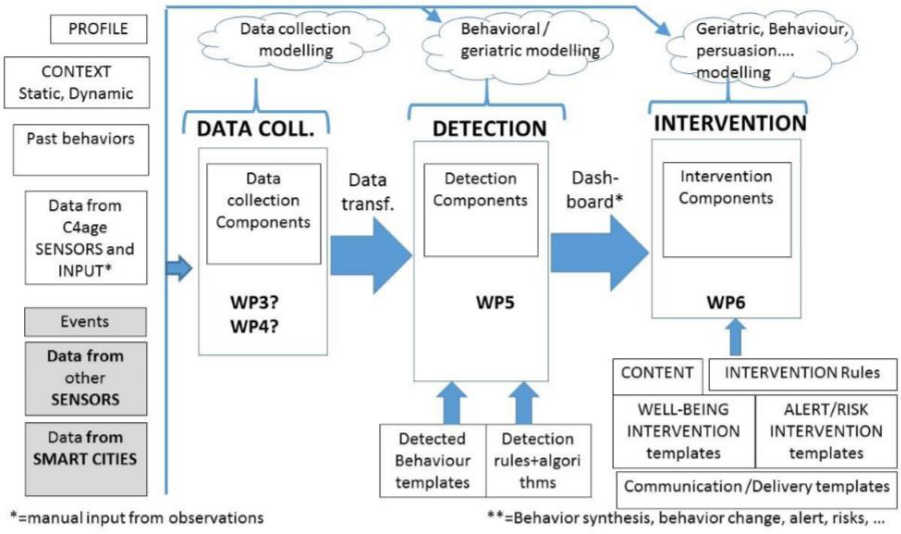

Figure 1. General scheme of the City4Age project

[3] https://www.age-platform.eu/project/veritas
[4] http://www.city4ageproject.eu/

With respect to collecting and processing data the City4Age project defines an architecture that distinguishes between involuntary (e.g. sensors, activity monitoring etc.) and voluntary (e.g. questionnaires, ratings etc.) data streams. Data from these streams are collected, interpreted and made available via an API, while as a second step analytics dashboards and risk detection algorithms operate on the data deriving behaviors of elderly individuals and propose interventions if necessary.

While the City4Age middleware bears similarities to the proposed one for Ageing@Work, an important distinction is the fact that Ageing@Work requires a much more specialized solution that is able to effectively collect and analyse data at an industrial environment, and, in addition, needs to derive work-oriented activity information from the individuals. Thus, while it is possible to build upon the middleware architecture of City4Age in an abstract scale, the particularities of the middleware and relevant analysis methods are expected to differ.

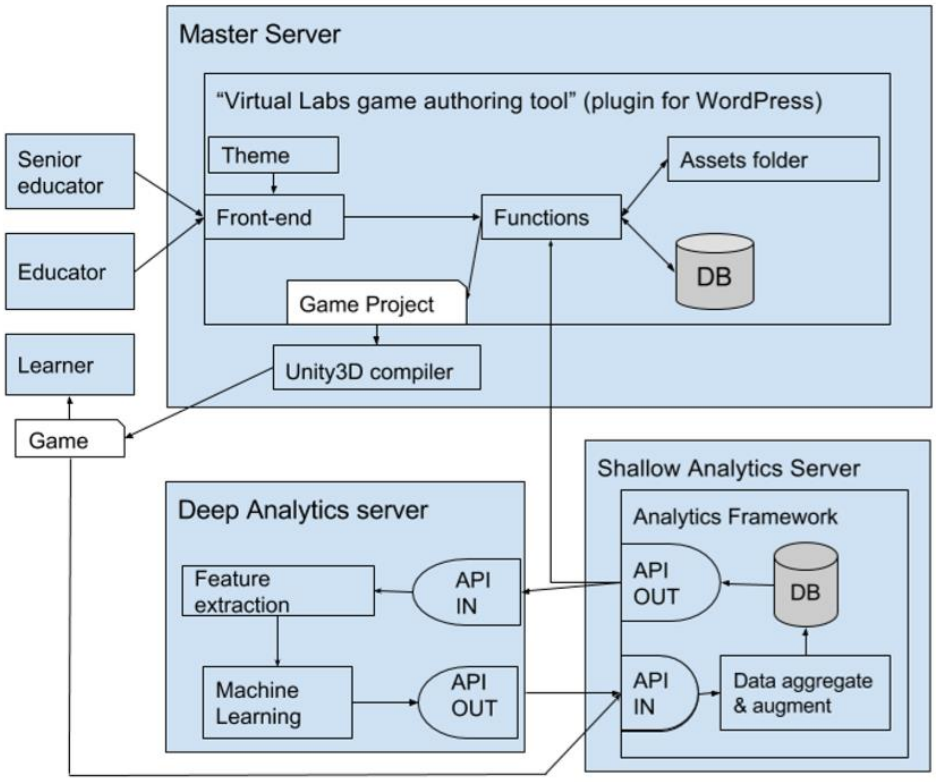

Figure 2. Envisage project conceptual architecture

The Envisage project[5] aims to improve the learning process proposing virtual labs for education, and the migration of knowledge from the domain of digital games in order to further optimize learning and education. The relation to Ageing@Work is found in the gamification component of the Envisage project. Indicatively, the sub-architecture of that part of the project is briefly outlined. Envisage includes a game authoring tool that is used by educators to define educational games, which are in turn compiled as Unity3D games and shared with learners. Learners only have access to the compiled version of the game,

[5] http://www.envisage-h2020.eu/

in effect playing with a ruleset that is composed by the educators and senior educators. The game transmits usage analytics to an analytics server that aggregates and augments the data before storing them for further analysis. Gamification is a core concept behind Ageing@Work, however there is a major difference in that in the Ageing@Work case the games are meant to promote well-being of the ageing workforce and as such have different constraints and objectives. Therefore, the considered gamification aspects need to be defined by a different functional architecture, which may borrow elements from, but will eventually expand the one found in Envisage.

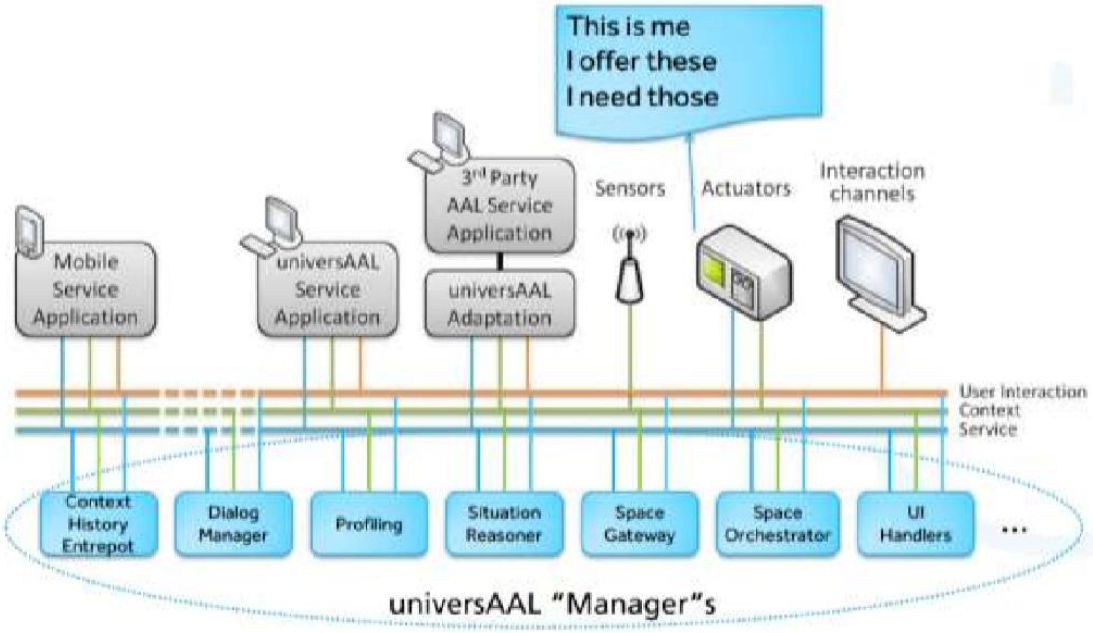

Figure 3. Conceptual architecture of the UniversAAL middleware

UniversAAL[6] is an open platform for IoT that has been developed as part of the FP7 UniversAAL project. UniversAAL provides a platform for connecting hardware sensor and actuator devices termed "exporters", which exposes the device interface to the UniversAAL environment. The relevance with Ageing@Work is found in this platform for connecting sensor and actuator hardware using a unified middleware. The difference with Ageing@Work is that in the case of Ageing@Work, the middleware focuses on the interconnection of sensors and tasks of normalizing, aligning and unifying sensed data are partially also the responsibility of the middleware, a feature not covered by the UniversAAL middleware.

The Factory2Fit project[7] develops adaptation solutions for smart factories of the future (FoF), to engage and motivate manufacturing workers with different skills, capabilities and preferences. A central component of Factory2Fit is the Dynamic Worker Model (DWM), which quantifies in detail key aspects of the worker related to performance, well-being, work satisfaction and preferences, knowledge and skills etc. The Factory2Fit DWM is a hierarchical model that includes increasingly time-varying components, starting from a static abstract model that describes time-invariant aspects of the workforce, an adaptive

[6] https://www.universaal.info/
[7] https://factory2fit.eu/

model that includes worker relations with contextual characteristics of the workspace, and finally a highly dynamic worker profile that describes each individual in the workforce at a specific time. Ageing@Work will base the architecture of the Virtual Worker User Model (vWUM) upon developments presented in the Factory2Fit DWM, and will adapt it to address the specific issues related to accurate modeling of ageing workforce.

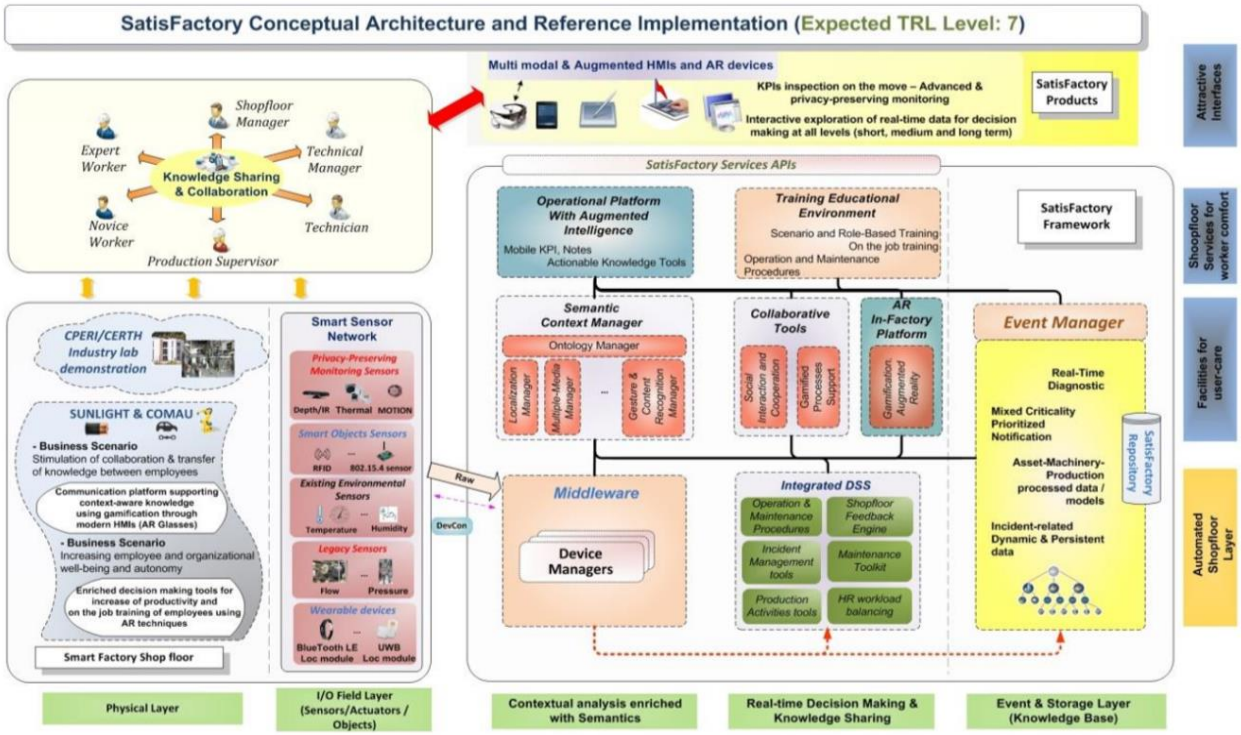

Figure 4. The conceptual architecture of the Satisfactory Project

The Satisfactory project[8] aimed to spearhead the factory of the future (FoF) and industry 4.0 revolution by providing a platform for increasing worker productivity and production efficiency. The architecture of Satisfactory comprises five layers of components in addition to an integrating middleware that facilitates inter-component communication. Satisfactory defines a common repository termed the Common Information Data Exchange Model (CIDEM), which is responsible for storing information acquired from various heterogeneous sources in the shop floor in a normalized uniform manner. Data exchange operations between CIDEM and other components are through the Middleware, including both model updates through the shopfloor sensor grid, as well as read/write operations from other components such as Decision Support System or user and manager HMIs.

The aforementioned related projects have a diverse focus range and the proposed architectures are related to Ageing@Work in different aspects. The following table provides a concise benchmarking of different projects in relation to the goals of the Ageing@Work project, which the developed Ageing@Work architecture is needed to support.

[8] http://www.satisfactory-project.eu/satisfactory/

Table 2. Related Project's benchmarking

Project Solution	User-driven solution	Focus on satisfaction and workability	Elderly-specific solution	Productivity enhancement	Focus on privacy and security	Distributed system
Veritas	√	√				
City4Age	√		√			
Envisage	√				√	
UniversAAL					√	√
Factory2Fit				√		
Satisfactory		√		√		

2. Technical Specifications

In order to end up with a comprehensive description of the technical specifications, we decomposed them into three categories. The technical specifications comprise the hardware and software prerequisites, as well as the quantitative needs for the Ageing@Work system to accomplish supportive tasks to aged workers. Therefore, the technical specifications are further decomposed into the performance requirements, the hardware requirements (i.e. explicit description of the identified IoT devices, the end-devices like tablets and PCs) and finally the software requirements (i.e. the core software components needed to integrate the functional requirements with the system's hardware).

The analysis followed herein has adopted some basic attributes / naming conventions from the Volere Requirements Resources template[9]. The following picture (Figure 5) provides an illustrative connection among the identified components of the technical specifications.

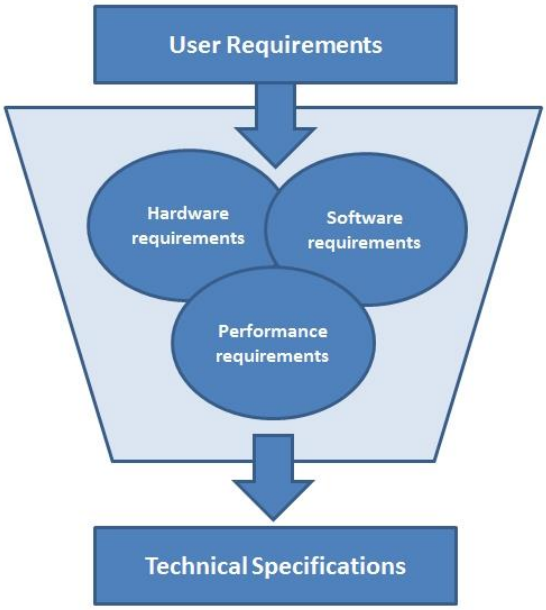

Figure 5. Illustrative representation for the decomposition of the Technical Specifications

2.1 General Ageing@Work System Requirements

The potential of exploitation of the Ageing@Work platform relies also on the possibility of the toolset to complete, integrate and add value to the potential of information of user models, covering different types of workers and job positions (as defined by the use cases in D2.1), especially those designed for a shared access in telepresence and interventions in an integrated system of work safety, quality of life, mental health and workability care.

[9] www.volere.co.uk

Therefore, based on the outcomes of the T2.1 (as reported in D2.1), the following overall functional and non-functional requirements of the Ageing@Work toolset (the platform as well as the peripheral components) are outlined. A more detailed list of technical specifications is presented in the following sub-sections 2.3 and 2.4; the detailed technical specifications are then mapped to the Ageing@Work system components in Section 5.

Table 3. General Functional and Non-Functional requirements of the overall Ageing@Work system

Functional Requirements	Non-functional Requirements
The workers must be unequivocally and uniquely identified in a trustworthy way to allow themselves and the HR managers to consult the available information.	The service must be accessible and usable when needed and requested, so technical unavailability must be detected and solved.
The Health and Safety Professionals, HR and floor managers must be unequivocally identified and authenticated in the Ageing@Work platform, according to their role and profile.	The communication (passage/exchange of information via the platform) must be secure and protected, and the integrity of information must be guaranteed.
The workers must provide informed, specific and independent (freely) consent and consent lifecycle must prove the evidence of its legitimacy.	The information must be meaningful to the information needs of the Health and Safety Professionals and the HR managers or floor supervisors and must be appropriately interpreted, treated and processed for further job optimization steps.
The information in the Ageing@Work backend must be structured through modular data groups to facilitate the understanding and optimise the interventions and job optimization.	The information must be meaningful to the customisation process of the Ageing@Work platform and tools, allowing the various types of professionals to adopt more consistent decisions and follow up.
All other user categories -apart from the workers themselves- must have access only to statistically processed and anonymized data.	The interventions generated by the professionals must be able to be executed through the Ageing@Work platform and delivered by distance using computer-mediated communication means.
All personal data must be stored and transmitted securely and protected from unauthorized access.	The Ageing@Work toolset must process personal data with lawfulness, fairness and transparency. The consent to the storage and processing of the workers personal data must be voluntary, specific, unambiguous and based on information. Personal data must be processed fairly and in a manner understandable to the workers.
Stored data must be protected (e.g. by backups) against unintentional data loss.	Personal data of workers must be collected for specified, explicit and legitimate purposes and must not be further processed in a way incompatible with those purposes. It must be clear to the worker which data is stored and processed.
The consent to the collection and processing of personal data must be revocable at any time. A revocation must lead to the	Personal data of workers, especially health data, must be adequate, relevant and limited to what is necessary for the purposes of the processing tools.

immediate deletion of all personal data if desired by the user.	
The tools must provide reliable and scientific based information on health and safety aspects to the user so that health problems can be solved effectively and not remain unnoticed or worsened.	Personal data of workers must be accurate and kept up to date. In particular, as health and safety aspects are involved, it is important that incorrect information is quickly erased or corrected.
	Personal data must be stored in a form which allows the workers to be identified for no longer than is necessary for the purposes for which they are processed. It must be possible to withdraw consent subsequently.
	Safety devices and appropriate technical measures must ensure adequate security of personal data including protection against unauthorised access or damage.
	The tools developed must be compatible with different hardware and software in order to guarantee general usability that is not limited to specific products of certain manufacturers.
	The usability of the tools must be ensured so that older workers or other employees who are not so familiar with new technologies can also learn how to use them.

Regarding the evaluation of the services delivered through the platform and the Ageing@Work toolset itself, there is the need to define what will be evaluated and by which method in order to ensure the monitoring of the overall functionality by workers and managers. In the evaluation process, it is necessary to review progresses achieved through the Ageing@Work toolset on both Quality of Life, and workability aspects.

Table 4. Dimensions for evaluation of the Ageing@Work toolset and interventions

Dimension	Description
Service	General usefulness of the services on offer
Acceptance	Degree of acceptance of the service by workers
Acceptance	Degree of acceptance of the service by managers
Usability	Usability of the designed process (maturity of system)
Infrastructure	Coverage of the infrastructure (mental health sensing and user monitoring infrastructure) for the service at the actors site (interoperability design evaluation)
Content	Completeness and usefulness of the available data (usefulness of specific and tailored views on the whole data set compared to specific datasets, within the multi-disciplinary approach of researchers, workers and managers).
Interventions	Recommendations and plans for a better QoL, workability and work-life balance (content evaluation)
Security and Privacy	Perceived security of the service and privacy of data

Consent and participation	Willingness of end users (workers and managers) to give consent and participate in the pilot studies
Quality of Life	System services aspects related to standardized Quality of Life questionnaire for measuring Health Related QoL (like EQ5D)
Work Ability Index	System services aspects related to a standardized measure of workability
Worker's Health	System services aspects related to physical and mental health scales

2.2 Technical Specifications for Software Components

In this section the outcomes of the more detailed analysis of the technical specifications is given, structured around cores aspects of the use cases (type) defined in D2.1. In particular, the following table takes into account the user-centric requirements of the D2.1 and provides the mapping to the system specifications. Each architectural element is then connected to its relevant technical specifications in Section 5, following the Volere requirements specification template.

Table 5. Detailed system functional specifications

Type	*Req. No*	*Requirement Description*	*Technical Specification*	*Spec No*
Emergency button	*FR1*	*An emergency button should be placed in the workplace/cabin or at the smartwatch, to be pressed in case of accident or another emergency, so that an emergency notification is sent to the management side and the worker is instantly geolocated if possible.*	The application, in case of emergency, should allow the user to be instantly geolocated.	TechSpec001
			In case of emergency, the app will send to the manager (or other authorized users) an alert providing the worker's geolocation if possible.	TechSpec002
Check-list platform / Security elements	*FR2*	*The platform would help the worker to do a check-list of all the security items. The results of the check-list should be uploaded and communicated to the manager or person responsible.*	The worker using the mobile app must complete the safety elements checklist before starting his/her shift.	TechSpec003
			The manager's UI should be accordingly updated when a safety element checklist is completed.	TechSpec004

			The system will notify the manager and the security responsible in case of failure (or non-completion) in any of the security elements.	TechSpec005
	FR3	*The worker should be able to complete the safety element checklist before starting his/her shift using the mobile app.*	The UI of the mobile app will allow users to complete the safety element checklist.	TechSpec006
			The system should be able to know of which machines are operated/observed by which workers.	TechSpec007
			The system should be aware of each job tasks and in addition the safety elements associated with them.	TechSpec008
	FR4	*The app/platform should send an instant alert to the person responsible of the security if there is a failure in any of the security elements, according to a previous list of security elements, both individual and collective, or in the machinery (for example failure in the break system). An instant dialog would be established between the user and the person in charge. The contents of the platform should be updated.*	The system should keep track of failures and provide to the worker interface to report a failure if not possible to be automatically detected.	TechSpec009
			In case of failure, the system should allow establishing immediate communication with the security manager.	TechSpec010
			If needed (e.g. inability to solve the problem through contacting the safety manager), mechanics will be contacted.	TechSpec011
	FR5	*In the event of a failure in the machinery the manager or security personnel will be able to initiate an immediate*	In the event of a failure in the machinery or safety equipment from the checklist the system should notify the manager or the security responsible.	TechSpec012

		communication via a mobile device to provide support.	In case of failure, the system should allow establishing immediate communication with the security manager.	TechSpec013
			If needed (e.g. inability to solve the problem through contacting the safety manager), mechanics will be contacted.	TechSpec014
	FR6	*The application should allow workers to virtually perform security checklists for training purposes (without a real machine involved) before taking the responsibility of a shift.*	The system should be able to reproduce hypothetical but realistic security issues.	TechSpec015
			The system should be able to virtually present the expected outcomes of hypothetical security scenarios on the AR/VR environment.	TechSpec016
Participatory work orchestration	*FR7*	*An age-friendly flexible work management should be provided to the users by the system (work from home/ request day-off)*	Workers should be able to prioritize their requests and explain the reasons.	TechSpec017
			Workers should be provided with an interface that allows them to request days-off or work-from-home, or be on-hold, through the Ageing@Work app.	TechSpec018
			Workers should be informed about the current status of their requests and the remaining days for work from home, distant support and days-off (personal history as a timeline/calendar).	TechSpec019
	FR8	*The platform would help the worker to ask the manager for free days or to work from home*	Each worker's request will be prioritized depending on the reason (emergencies, unexpected incidents, important health issues, etc.). Requests can	TechSpec020

		and to keep control for the free days that s/he has not enjoy yet.	be days off, work from home and be in-charge (stand-by).	
			Workers should be able to set the priority level of her/his request.	TechSpec021
			Workers should be informed about the current status of their requests and the remaining days for work from home, distant support and days-off (personal history as a timeline).	TechSpec022
	FR9	*The manager will be able to approve the worker's requests according to their priority and the needs of each shift work-plan.*	The application should enable the manager to insert the parameters related to the activity and the requirements of each job position, workers skills, machinery and shifts.	TechSpec023
			The manager should be able to set the work plan for the work shifts.	TechSpec024
			The manager should be able to organize the task allocation for the shifts based on available staff and machines.	TechSpec025
			The system should be able to perform allocation exercises for employees based on their skills and availability status, to the tasks available.	TechSpec026
	FR10	*Older and experienced users should be able to report their time availability to support younger workers from distance.*	The system should be able to provide a digital calendar with available date and time slots to collect the users feedback.	TechSpec027
			The system should visualize to younger workers, the current	TechSpec028

			availability of older/experienced workers.	
Support for musculoskeletal problems and healthy habits – Virtual Coach	*FR11*	*The worker should be able to perform evaluation of alternative ergonomics designs (ergonomics simulator) and receive the simulation results as a proof.*	The worker should be able to perform evaluation of alternative ergonomics designs (ergonomics simulator) and receive the simulation results as a proof.	TechSpec029
	FR12	*The app would provide the user with advice on physical exercise –related activities that s/he can perform during the working day, and also while s/he is at home.*	The user should receive advice from the Virtual Coach while performing the prescribed exercises according to his/her performance and to have the chance to make corrections whenever it is necessary.	TechSpec030
			The user should be able to control the notification settings (level of intrusiveness) like the time to receive reports, the frequency of notifications, disturbance-free time zones.	TechSpec031
			The application should be able to guide the user about the program of exercises to be performed both in the workplace, in home and on the move.	TechSpec032
	FR13	*The user would be supported by the system in the form of recommendations in the smartphone/smartwatch- to develop habits that will improve his/her physical health.*	The user should receive advice from the Virtual Coach relevant to behaviours that could positively affect her/his health and wellbeing.	TechSpec033
			The recommendations should be personalized should be personalized taking into account the user's personality.	TechSpec034

			The user should be able to control the notification settings (level of intrusiveness) like the time to receive reports, the frequency of notifications, disturbance-free time zones.	TechSpec031
	FR14	*The user should be able to provide information to the app on the type and level of pain.*	The complexity and level of difficulty of the proposed exercises proposed by the Virtual Coach should be relevant to the health conditions and the ability of the worker to perform them during work, home or on the move.	TechSpec035
	FR15	*The app would give the worker advice on healthy habits to improve her/his sleep quality.*	The user should receive advice from the Virtual Coach while performing the prescribed exercises according to his/her performance and to have the chance to make corrections whenever it is necessary.	TechSpec030
			The system should be able to monitor parameters related to user's sleep quality.	TechSpec036
			The application for sleep control will include information on the total number of sleeping hours, sleep quality, night-time interruptions, heart rate and evolution since the beginning of the measurement.	TechSpec037
	FR16	*Worker measurements would be available through the app, so the worker would be able to get an overview of parameters relevant to her/his health status,*	The performance of the worker would be checked up by the virtual agent, whenever possible (step counts, activity recognition, etc.).	TechSpec038

		the number of hours s/he has slept, the time dedicated to perform exercises, her/his cardiac rhythm or her/his improvement since starting to implement the advices in healthy habits.	The system should provide the user with appropriate interfaces that summarize worker measurements.	TechSpec039
	FR17	*Behavior aspects of the worker, in respect of the proposed interventions (e.g. adherence to exercise), should be monitored by the virtual agent.*	The system should be able to process data coming from mobile devices and IoT sensors if applicable in order to evaluate the intervention adherence.	TechSpec040
			The system should be able to identify abnormal parameter values of the user and push notifications to the user dashboard.	TechSpec041
	FR18	*The virtual Coach controls the worker while doing the prescribed exercises through a web camera and advices on changing them whenever it is necessary.*	The performance of the worker would be checked up by the virtual agent, whenever possible (step counts, activity recognition, etc.).	TechSpec038
			The user should receive at least once per day a short report on the achieved goals (% of exercises performed).	TechSpec042
	FR19	*The tool should monitor the cardiac rhythm of the user and vibrate in case that abnormal HR is detected. The vibration should be identifiable by the subject.*	The system should monitor the user's heart rate.	TechSpec043
			In case of abnormal heart rate detection, e.g. tachycardia/bradycardia, a vibration-based notification should be provided to the user.	TechSpec044

Knowledge exchange Platform, collaboration and productivity enhancement	*FR20*	*The platform would help the older workers to share their knowledge with the younger, uploading HD videos, images or documents or addressing the problem directly with an online chat.*	The worker who works on-site with a machine (on-site operator) will be informed by detailed instructions and virtual visual elements -on the AR glasses device- where to take the necessary action.	TechSpec045
			The system should hold a knowledge exchange base where videos, images or documents relevant to workplace operations tasks can be uploaded.	TechSpec046
			The system should allow the worker to create an entry for some workplace operational process as the knowledge base, as well as with the possibility to edit an existing entry.	TechSpec047
			The platform should allow the worker to record some operational process of the workplace and upload the corresponding video in the knowledge base.	TechSpec048
			The system should allow the worker to add images or documents to an entry of the knowledge base.	TechSpec049
			The system should allow the workers to perform online chat -like discussions over some process that is registered at the knowledge base.	TechSpec050
			Users will be able to regularly update the contents of the knowledge base, to create new entries, delete existing ones and	TechSpec051

			filter content according to user criteria (top rated, most seen, recent files, etc.).	
	FR21	*The worker should receive symbolic awards (or any other awards provided by the company policy) according to their personal or team performance.*	The system should be able to evaluate user achievements in relation to the goals and provide symbolic or company-provided awards.	TechSpec052
			The system should be able to provide to the user a personalized report of collected awards (points, badges etc.) in the form of a timeline.	TechSpec053
			The system should be able to provide an awards sharing feature to enhance the reputation of the user among colleagues.	TechSpec054
			The system should have the necessary infrastructure to centrally store awards-related information of the workers, relevant to the rewards-based motivation system.	TechSpec055
	FR22	*Less experienced workers should be able to search for solutions to specific problems using search criteria (e.g. key-words).*	Users will be able to regularly update the contents of the knowledge base, to create new entries, delete existing ones and filter content according to user criteria (top rated, most seen, recent files, etc.).	TechSpec051
			The system should provide browse and key-words based search functionalities to the users, so as to help them locate	TechSpec056

			information of interest within the knowledge base.	
			Elderly and more experienced users –who work from home- should be able to support younger ones on how to operate or repair the machinery using smart glasses.	TechSpec057
			The system should provide internet-based remote connection between workers who are on-site and at a remote location.	TechSpec058
			The system should allow the on-site and remote worker to initiate and perform a remote collaboration session.	TechSpec059
	FR23	*The experienced worker through the touch screen of his/her tablet will be able to provide remote guidance to a less experienced, e.g. younger worker who is on-site, to e.g. repair a machinery.*	During the remote collaboration session, the system should be able to transmit to the remote worker, video coming from the on-site worker's workplace.	TechSpec060
			The system should be able to take input from the remote worker, while s/he is using e.g. a tablet that shows aspects of the on-site workplace and provide relevant guidance instructions to the on-site worker, following the remote worker's interaction with the tablet.	TechSpec061
			In case that AR display is used for the collaboration at the on-site worker's side, graphic annotations will also be used at the AR display so as to help guiding the on-site worker.	TechSpec062

			The worker should be able to provide evaluation feedback on the assistance received from the AR telepresence tool (whether the telepresence tool helped solve the problem or not).	TechSpec063
			The system should keep track of problem solving AR-based telepresence session logs and keep relevant statistics at the DB.	TechSpec064
	FR24	*From the analysis of the AR Telepresence log files the manager will be aware of the areas/fields/sectors where the most problems occur, the level of support provided to the worker and the level of satisfaction. In addition, further information on failures or better handling of machinery may be added.*	The system should offer managers with the capability to view statistics relevant to problem solving sessions, including information covering the subject of the session, as well as aspects of workers' satisfaction from the session and session effectiveness.	TechSpec065
			The system should allow the manager to identify, within the knowledge base system, of domains where additional helping material may be needed to be added, so as to help guiding corresponding efforts for the elaboration of the knowledge base.	TechSpec066
	FR25	*The app allows the workers to remotely observe several machines and to receive notification of upcoming events from each machine.*	The system should be able to report the state of the machines to the workers through the user dashboard.	TechSpec067
			The system should be able to know of which machines are operated/observed by which workers.	TechSpec007
			The system should be able to provide notifications alerting the	TechSpec068

			worker to machines that need attention through smartphone/smartwatch.	
			The system should be able to track the state of machines and inform the user for upcoming machine events.	TechSpec069

Table 6. Detailed system design specifications

Type	*Req. No*	*Requirement Description*	*Technical Specification*	*Spec. No*
Emergency button	*DR1*	*The emergency button should be placed in the cabin or in the smart watch and activated by touch or with a voice command if possible, if the worker cannot use hands.*	The system should be able to monitor multiple sources of emergency signal and report if any one is activated.	TechSpec070
			The system should be able to identify voice commands used by the workers that signal an emergency situation.	TechSpec071
Check-list platform	*DR2*	*The check list for the security elements should be periodically updated. It should be sent to the manager or person responsible immediately after it is completed. The results of the security list should be uploaded to the manager´s platform profile.*	The manager's interface should present a concise overview of security checklists for each machine type, including updates pending approval.	TechSpec072
			The manager should be able to register and periodically update the security check-list elements at each job position and according to the machine operated.	TechSpec073

			The worker's UI should provide information to the worker, relevant to the security elements of the job position and offer also a walk-through guide that allows confirming the necessary security elements of the check-list.	TechSpec074
Participatory work orchestration	*DR3*	*The platform must be designed so that the user can check the days left to enjoy, the weeks or days of vacations available that have not yet been requested by colleague, and the ones that he can no longer request.*	The worker's UI should be designed so as to allow the worker's request to be prioritized depending on the reason (emergencies, unexpected incidents, important health issues, etc.).	TechSpec075
			The worker UI should allow the worker to express their daily preference on the work schedule and load, which can be days off, work from home and be in-charge (stand-by).	TechSpec076
			Workers should be informed about the current status of their requests and the remaining days for work from home, distant support and days-off (personal history as a timeline).	TechSpec022
Participatory work orchestration	*DR4*	*The user can mark her/his request for days with ranges from 1 to 3, one being unchangeable and three changeable.*	The worker app should include intuitive controls to allow the worker to prioritize their requests at the time of submission.	TechSpec077
			The worker app should be able to inform workers about the current status of their requests and the remaining days for work from home, distant support and days-off (personal history as a timeline).	TechSpec078

			The worker app should present to the worker a concise overview of their available requests for each request priority.	TechSpec079
Participatory work orchestration	*DR5*	*Employees will be provided the tools to manage requests based on a digital calendar visible in the mobile app.*	The worker app should provide a calendar-based view to the workers, as a primary interface to allow managing requests.	TechSpec080
			Workers should be able to receive an overview of the status of their requests overlaid on the calendar view.	TechSpec081
			The Work Orchestration tool available to managers should provide a corresponding calendar view with a concise summary of worker availability per day.	TechSpec082
			The Work Orchestration tool should offer intuitive controls to allow managers to provide feedback and manage worker requests.	TechSpec083
Knowledge exchange Platform, collaboration and productivity enhancement	*DR6*	*The platform must be designed so that high-quality videos, images, documents and other content about safety requirements or advices or tips from older workers can be shared with younger workers.*	The system should provide an easy to browse catalog of available videos and further material and allow basic categorization relevant to the content.	TechSpec084
			The system should produce a personalized notification when new, content has been posted that is relevant to the worker's professional niche.	TechSpec085
			The system should have basic rating features of posted content by peers.	TechSpec086

Knowledge exchange Platform, collaboration and productivity enhancement	*DR7*	*The content must be updated, and the platform should divide the contents into more recent files, more visualized and better valued.*	The content of the knowledge exchange platform should be presented in a structured manner, following categories relevant to the content and professional niche of the workers.	TechSpec087
			The platform should allow workers to update content (e.g. post new guides, videos etc.) in an easy and intuitive way.	TechSpec088
Knowledge exchange Platform, collaboration and productivity enhancement	*DR8*	*The platform will include a chat session to establish instantaneous communications between the workers.*	The system should allow workers to start a chat session with available expert workers at work or on standby at home.	TechSpec089
			Expert workers on standby at home or at work should receive a discreet char request notification in a way that does not disturb the currently performed task.	TechSpec090
			Expert workers should be able to respond to the request through different modalities (touch, gesture, voice), and a chat session should automatically start on positive response.	TechSpec091
Knowledge exchange Platform, collaboration and productivity enhancement	*DR9*	*Users should be guided into the necessary actions to be implemented using virtual objects projected on top of the real world scene (sensed through the mobile device camera).*	The system should be able to identify the current step of the performed process.	TechSpec092
			The system should be able to recognize relevant machine features (controls, meters etc.) and identify their state.	TechSpec093
			The system should be able to overlay recognized controls with overlays that demonstrate	TechSpec094

			intended use or desired end result.	
Knowledge exchange Platform, collaboration and productivity enhancement	*DR10*	*The AR-based telepresence tool should provide aids that will help the user into easy overview of the overall process, previous steps etc.*	The system should allow the remote user to easily specify relevant annotations on screen.	TechSpec095
			The system should overlay annotations to the device (phone, HMD) of the worker on-site.	TechSpec096
			The system should provide controls that allow the worker on-site to review previous steps and preview upcoming actions in the specified process.	TechSpec097
Knowledge exchange Platform, collaboration and productivity enhancement	*DR11*	*The younger users will be able to identify the authors of the uploaded materials, so to proceed with asking relevant questions through the platform if needed.*	The system should maintain records of knowledge base content contributors.	TechSpec098
			The system should present users with suitable interface to allow Q&A or chat between workers e.g. using mobile devices.	TechSpec099
Knowledge exchange Platform, collaboration and productivity enhancement	*DR12*	*The worker involved in a learning session will be informed by the virtual coach on the learning plan and the remaining exercises to be performed.*	The system should maintain record of the progress of workers on each learning task.	TechSpec100
			The system should generate notifications of upcoming learning tasks and encourage workers to continue their learning path.	TechSpec101
			The system should provide a concise summary of one's own learning achievements, as well as comparative figures if authorized.	TechSpec102
Knowledge exchange Platform,	*DR13*	*The application for remote machines surveillance should be incorporated into the user´s*	The system should be able to collect status of all monitored machines and present a concise	TechSpec103

collaboration and productivity enhancement		*smartwatch. It will include information from the user's machines (e.g. status, time2finish, …)*	overview fit for small displays (e.g. status matrix) if requested.	
			The system should allow the worker to filter out those machines needing attention and display them in a list.	TechSpec104
			The system should provide notifications (e.g. smartwatch vibration) if a machine needing attention is detected.	TechSpec105
Supporting health and wellbeing - Virtual Coach	*DR14*	*The tools to measure biosignals (e.g. the cardiac rhythm) should be light, easy to use, activated by touch and worn under the clothes.*	A lightweight and unobstrusive sensor should be provided in order to monitor biosignals (e.g. smartwatch sensors).	TechSpec106
	DR15	*The worker should be able to see information relevant to her/his health status (e.g. cardiac rhythm, quality of sleep, perceived stress level, etc.) through the mobile app.*	The mobile app should provide a dashboard for health-relevant information.	TechSpec107
			The mobile app should highlight health-relevant information that are deemed to be potentially detrimental.	TechSpec108
	DR16	*The user should have access to his/her own data recordings relevant to her/his health and behavior (e.g. number of hours s/he has slept, the time dedicated to perform exercises, cardiac rhythm or improvement traits by following relevant advice).*	The mobile app should provide a dashboard for reviewing captured data.	TechSpec109
	DR17	*The virtual coach must have a human-like appearance, a pleasant voice and respond to the voice of the user. The exercises proposed by the*	The mirroring avatar should visually express the estimated emotional state of the user both with body postures and facial expressions.	TechSpec110

		coach should be easy to perform and aimed at helping in the condition presented by the subject (e.g., back pain, shoulder pain, leg pain.	The advices of the virtual coach should be personalized according to the worker's conditions & personality and should targeted to adopting healthy habits.	TechSpec111
	DR18	*The system should provide vibration if the worker's heart-beat is abnormally high or low (e.g. brady-cardia, tachy-cardia), with a frequency of vibration identifiable for the user so that it does not confuse it with that of the machine.*	The application for sleep control will include information on the total number of sleeping hours, sleep quality, night-time interruptions, heart rate and evolution since the beginning of the measurement.	TechSpec037
	DR19	*The tools to monitor worker biosignals (e.g. cardiac rhythm) must not compromise the security of the worker or limit her/his movements.*	A lightweight and unobstrusive sensor should be provided in order to monitor biosignals (e.g. smartwatch sensors).	TechSpec106
	DR20	*Sleep control measurements should be taken by the user's smartwatch. It will include information on the total number of sleeping hours, sleep quality, night-time interruptions, heart rate and evolution since the beginning of the measurement.*	The application for sleep control will include information on the total number of sleeping hours, sleep quality, night-time interruptions, heart rate and evolution since the beginning of the measurement.	TechSpec037

Table 7. Detailed system interface specifications

Type	*Req.No*	*Requirement Description*	*Technical Specification*	*Spec.No*
Emergency button	*IR1*	*The emergency button will be activated by pressing or by voice command in case it is*	A suitable IoT device should be available that is able to trigger an emergency notification in the AGEING@WORK system.	TechSpec112

		not possible to touch it, if ambient noise allows this.	Worker smartwatch app should feature a panic button feature that is designed to be especially easy to reach (e.g. continuously visible or activated through combination of smartwatch switches or active when idle).	TechSpec113
			The voice recognition module of the worker app should be able to recognize specific words that trigger the emergency notification.	TechSpec114
	IR2	*If available to the system, the geolocation of the subject will be sent instantaneously to the responsible of security who will communicate with her/him to know the nature of the emergency.*	The worker app should be able to geolocate in an emergency situation.	TechSpec115
			The geolocation data should be transmitted automatically upon triggering of emergency by the worker.	TechSpec116
			The worker and manager apps should be able to provide notifications upon reception of an emergency signal. Such notifications should be conspicuous and particularly noticeable to incite reaction.	TechSpec117
Check-list platform	*IR3*	*In the event of a failure in the machinery or safety equipment from the checklist, an immediate communication will be established via the tablet or mobile phone webcam with the security manager to try to repair the problem. If this is not possible, mechanics will be contacted.*	The system should identify failure of a checklist step, or accept feedback from the worker performing the checklist notifying of failure of step.	TechSpec118
			The manager app should provide notifications as to the failure of machinery and provide a control to initiate a video session.	TechSpec119
			The worker app used by mechanics should provide notifications as to the failure,	TechSpec120

			provide a control to initiate a video session and provide guidance to the mechanic to arrive at the site.	
	IR4	*The results of the security checks will be sent to the profile of the manager on the platform.*	The manager app should provide an overview of security check results and highlight the cases where security checks have failed.	TechSpec121
			In the event of a failure in the machinery the manager or security personnel, through the appropriate interface, will be able to initiate an immediate communication via a mobile device to provide support.	TechSpec122
Supporting health and wellbeing - Virtual Coach	*IR5*	*The app will give health-related advice to the user preferably once a day, preferably in the morning when the subject goes to work. The advice should always be positive, encouraging the subject to continue with good habits taking into account the personal conditions of the use.*	The system will allow users to set the frequency of the advice they receive.	TechSpec123
			The app should support smooth exchange from negative to positive in the emotional state of the avatar.	TechSpec124
			The app should give personalized recommendations according to the personality of the user.	TechSpec125
	IR6	*The system notifications and recommendations should be provided to the user in an intuitive way, that will try to avoid attention theft.*	The system should be able to appraise the current state and action of the user.	TechSpec126
			The system should be able to derive a notification action that is compatible with the recognized user state.	TechSpec127
	IR7	*The user should be able to control the notification settings (level of*	The worker app should allow the user to input notification	TechSpec128

		intrusiveness) like the time to receive reports, the frequency of notifications, disturbance-free time zones.	preferences that are respected when generating notifications.	
			The worker app should allow the worker to specify what types of reports they would like to be notified about.	TechSpec129
	IR8	*Workers should be able to provide their feedback about health status using online questionnaires on their own time availability.*	The worker app should provide notifications as to the availability of online questionnaires in an unobstrusive manner not disturbing the carried out task.	TechSpec130
			The worker app should provide a direct interface to allow workers to complete online questionnaires.	TechSpec131
	IR9	*The worker will be able to see her/his the measurements and will be able to receive daily summaries of the results obtained.*	The mirroring avatar should visually express the estimated emotional state of the user both with body postures and facial expressions.	TechSpec110
			The worker app should provide notifications, respecting user settings and carried out task, when a new summary is available.	TechSpec132
			The worker app should provide intuitive and rich visual charts that summarize the worker related measurements in an easy to comprehend manner.	TechSpec133
	IR10	*The mirroring avatar should support both facial and body emotional expressions when communicating with the user.*	A suitable face and body (skeleton) model should be established, including expressive motions and smooth transitions.	TechSpec134
	IR11	*The user's emotional states should be reflected to the behavior of the virtual coach*	The system should be able to evaluate the current emotional state of the user.	TechSpec135

		and thus turn its appearance into that of an 'empathic mirroring avatar'.	The worker app should be able to correlate emotional state to emphatic avatar facial and posture parameters that accurately reflect the emotional state of the user.	TechSpec136
Participatory work orchestration	*IR12*	*The platform to request free days or vacations will be accessible both to the manager and to those responsible for human resources, so that they can organize work in advance according to the workers available that day*	The application should provide each employee a simple, easy-to-use interface to register their personal information in the system.	TechSpec137
			The participatory work orchestration tool should enable managers to specify the work plan for each shift.	TechSpec138
			The participatory work orchestration tool should provide information as to whether the workforce requirements for each shift are satisfied and the constraints in assigning workforce.	TechSpec139
	IR13	*The application will send a notification to the person in charge in case more worker requests a day of absence to optimize the workplace schedule.*	The system should be able to identify shortage of workforce according to each shift requirements.	TechSpec140
			The system should be able to propose to the managers shift plans according to employee's availability and skills and production needs.	TechSpec141
	IR14	*The managers will be supported by the system with automatically produced shifts work-plans suggestions, taking into account worker requests for day-off or work from home.*	The system should be able to propose to the managers shift plans according to employee's availability and skills and production needs.	TechSpec141

	IR15	*The system will provide managers the ability to access the ergonomics assessment results (performed by the users, upon workers' request) and to perform their own simulation testing.*	The worker app should allow workers to share their ergonomics assessment results with the managers.	TechSpec142
			The manager app should enable managers to receive notifications of new ergonomics results.	TechSpec143
			The manager app should enable managers to act on ergonomics results, performing additional simulations or evaluating results.	TechSpec144
Knowledge exchange platform, collaboration and productivity enhancement	*IR16*	*The knowledge exchange platform will be accessible to both older workers and young people through private profiles with a password.*	The worker app should provide a simple screen to allow workers to log into the knowledge exchange platform using their credentials.	TechSpec145
	IR17	*Users should be able to upload videos, images, documents or advice relevant addressing a specific problem in the work process (repairing of a machine, calibration session etc.).*	Older/Experienced users should be able, through the appropriate interface, to manage (insert/Modify/Delete) the content they upload on the knowledge exchange platform.	TechSpec146
	IR18	*The videos and other files uploaded by the worker can be deleted at any time by the user who uploaded it. The contents of the platform should not be distributed outside of it.*	Older/Experienced users should be able, through the appropriate interface, to manage (insert/Modify/Delete) the content they upload on the knowledge exchange platform.	TechSpec146
			The system should ensure authorized access to the uploaded content.	TechSpec147
	IR19	*The chat that will be included in the platform will allow the young user to address the*	The system should provide a context-specific private messaging feature among workers.	TechSpec148

		user who uploaded the content privately or do a general question on the wall and wait for another user to answer it.	The system should allow users to post on a public "message wall" directly linked to the relevant media (e.g. video), with notifications of new posts (questions/answers/comments).	TechSpec149
	IR20	*The videos and other content may be punctuated by users, with the best rated ones appearing in the first place*	The system should sort content by rating and relevance to the user query.	TechSpec150
			The worker app should feature a simple control to enable content rating.	TechSpec151
	IR21	*Distant users should be able to perform telepresence sessions in real-time with audio and share (camera) screen.*	The worker app will allow distant users to search for available workers and initiate telepresence sessions using their smartphone or tablet.	TechSpec152
	IR22	*Users will be able to evaluate the quality of the knowledge base contents and search results received using a metric system (e.g. using smiling faces evaluation).*	An appropriate, intuitive metric system should be available.	TechSpec153
			The worker app should provide simple and intuitive controls to enable content rating.	TechSpec154
	IR23	*Experienced users will be able to provide help by participating in a Question & Answer (Q&A) platform.*	The system should visualize to younger workers, the current availability of older/experienced workers.	TechSpec028
			The system should provide a simple interface for younger workers to compose questions with rich content.	TechSpec155
			The system should allow experienced workers to see unanswered questions and provide a simple interface to provide answers.	TechSpec156

	IR24	*Older and more experienced users should receive symbolic awards for their contribution to the Knowledge base and the Telepresence Tool, towards supporting their motivation to contribute.*	The user dashboard should have a separate interface for the Reward-based motivation system providing information about user's current status (how many rewards he/she have gained) and the rewards to be gained if he/she takes specific actions (beneficial activity/collaboration).	TechSpec157
	IR25	*The subject will wear the smartwatch which will notify by means of vibration when an interaction is required.*	The smartwatch should have the required vibration actuator and be able to receive and filter notifications.	TechSpec158
General	*IR26*	*The users should have access to the system's services on offer through personal smart phones, tablets, smart watches and PC devices.*	All AGEING@WORK tools (knowledge exchange platform, user dashboard, telepresence tool, etc.) should have UI designed for mobile devices (smart phone/tablet).	TechSpec159
	IR27	*The subject will not have to enter more data than the physical ones referring to their gender, age, weight and height at the beginning of the use of the application.*	The AGEING@WORK worker app should present a simple registration form allowing workers to input their gender, age, weight and height.	TechSpec160

2.3 Hardware Specifications

The present section summarizes the results of the initial analysis made, towards defining the specifications of the devices that can be used in the Ageing@Work system, for monitoring data that are of interest for relevant user activities monitoring. This will be further extended along with the WP3 and WP4 project efforts, where the complete list of user activities and parameters of interest for the Ageing@Work system are defined. The final H/W specifications will be reported in the updated version of the present deliverable, scheduled for M24 of the Ageing@Work project.

2.3.1 Smartwatch

The Smartwatch that will be used to collect information from the user (e.g. biosignals, GPS location, etc.) can be a device similar to the SAMSUNG Galaxy Watch 46mm with Bluetooth wireless connection capabilities. The following list presents the hardware specifications of this specific, indicative smartwatch.

- *Infra* Bluetooth Only
- *Network/Bearer (S/W Enabled)*
- *Network/Bearer (International Roaming)*
- *Network/Bearer (4G Band for China)*
- *Connectivity*
  - *ANT+*No
  - *Location Technology*GPS,Glonass
  - *Wi-Fi*802.11 b/g/n 2.4GHz
  - *NFC*Yes
  - *Bluetooth Version* Bluetooth v4.2
  - *Bluetooth Profiles*A2DP,AVRCP,HFP,HSP
  - Tizen
- *Display*
  - *Technology (Main Display)*Super AMOLED
  - *Size (Main Display)*1.3" (32.9mm)
  - *Resolution (Main Display)*360 x 360
  - *Color Depth (Main Display)*16M
- *Processor*
  - *CPU Speed*1.15GHz
  - *CPU Type* Dual-Core
- *General Information*
- *Memory*
  - *RAM Size (GB)*0.75
  - *ROM Size (GB)*4
  - *Available Memory (GB)**1.5
  - *External Memory Support* N/A
- *Camera*
- *Sensors*
  - *Accelerometer*
  - *Barometer*
  - *Gyro Sensor*
  - *HR Sensor*
  - *Light Sensor*
- *Physical specification*
  - *Dimension (HxWxD)* 49.0mm x 46.0mm x 13.0mm
  - *Weight (g)*63
- *Battery*
  - *Standard Battery Capacity*472mAh
  - *Removable* No
  - *Typical Usage Time (Hours)*Over 80 Hours
  - *Low Usage Time (Hours)*Up to 168 Hours
  - *Local Storage Music Playback Time*Up to 16 Hours
  - *Indoor Workout Time*Up to 77 Hours
  - *Outdoor Workout Time with GPS*Up to 23 Hours
- *Audio and Video*
  - *Audio Playing Format* MP3,M4A,3GA,AAC,OGG,OGA,WAV,WMA,AMR,AWB
- *Services and Applications*
  - *Notification Type* TTS, Vibrate

Listing 1.Hardware specifications of the Smartwatch

The smartwatch is intended to connect with a smartphone in order to operate in a paired mode. According to the physical setting, smartwatch sensors will transmit through a Bluetooth wireless connection data to the mobile app. The following list presents the hardware specifications of two mobile devices that can be taken into account in this respect, a Samsung Galaxy J6 Plus and a Samsung S9.

- *Network Technology*
  - *GSM / HSPA / LTE*
- *Body*
  - *dimentions 161.4 x 76.9 x 7.9 mm*
  - *weight 178 g*
- *SIM*
  - *Single SIM (Nano-SIM), or*
  - *Dual SIM (Nano-SIM, dual stand-by)*
- *Display*
  - *IPS LCD capacitive touchscreen, 16M colors*
  - *6.0 inches, 91.4 cm2*
  - *720 x 1480 pixels,*
  - *ratio 18.5:9*
- *Operating System*
  - *Android 8.1 (Oreo), upgradable to Android 9.0 (Pie) ; One UI*
  - *Qualcomm MSM8917 Snapdragon 425 (28 nm)*
  - *CPU Quad-core 1.4 GHz Cortex-A53*
  - *GPU Adreno 308*
- *Memory*
  - *microSD, up to 1 TB (dedicated slot)*
  - *32GB 3GB RAM, 64GB 4GB RAM (internal memory)*
- *Camera (Dual)*
  - *13 MP, f/1.9, 28mm (wide), AF*
  - *5 MP, f/2.2, (wide), 1/5.0", 1.12µm, depth sensor*
  - *Video 1080p, 30fps*
  - *8 MP Led Flash, f/1.9 selfie camera*
- *Sound*
  - *Loudspeaker*
  - *3.5mm jack*
  - *Dolby Atmos sound*
- *COMMS*
  - *Wi-Fi 802.11 b/g/n, Wi-Fi Direct, hotspot*
  - *Bluetooth 4.2*
  - *GPS with A-GPS, GLONASS, BDS*
  - *NFC*
  - *Stereo FM radio*
  - *microUSB 2.0*
  - *USB On-The-Go*
- *Sensors*
  - *Fingerprint (side-mounted)*
  - *Accelerometer*
  - *Gyro*
  - *Proximity*
  - *Compass*
- *Battery*

- Non-removable Li-Ion 3300 mAh

Listing 2.Hardware specifications of the Samsung Galaxy J6 Plus smartphone (low specs device)

- Network Technology
  - GSM / CDMA / HSPA / EVDO / LTE
- Body
  - dimentions 147.7 x 68.7 x 8.5 mm
  - weight 163 g
- SIM
  - Single SIM (Nano-SIM), or
  - Hybrid Dual SIM (Nano-SIM, dual stand-by)
- Display
  - Super AMOLED capacitive touchscreen, 16M colors
  - 5.8 inches, 84.8 cm2
  - 1440 x 2960 pixels
  - ratio 18.5:9
- Operating System
  - Android 8.0 (Oreo), upgradable to Android 9.0 (Pie)
  - Exynos 9810 (10 nm) - EMEA
  - Octa-core (4x2.7 GHz Mongoose M3 & 4x1.8 GHz Cortex-A55) - EMEA
  - Mali-G72 MP18 - EMEA
- Memory
  - microSD, up to 1 TB
  - 64GB 4GB RAM, 128GB 4GB RAM, 256GB 4GB RAM (internal memory)
- Camera
  - 12 MP, f/1.5-2.4, 26mm (wide), 1/2.55", 1.4µm, dual pixel PDAF, OIS
  - 8 MP, f/1.7, 25mm (wide), 1/3.6", 1.22µm, AF
  - 2160p@30/60fps, 1080p@30/60/240fps, 720p@960fps, HDR, dual-video rec., stereo sound rec., gyro-EIS & OIS (30fps)
- Sound
  - Loudspeaker
  - 3.5mm jack
  - Dolby Atmos sound tuned by AKG
- COMMS
  - Wi-Fi 802.11 b/g/n, dual-band, Wi-Fi Direct, hotspot
  - Bluetooth 5.0, A2DP, LE, aptX
  - GPS with A-GPS, GLONASS, BDS, GALILEO
  - NFC
  - Stereo FM radio
  - 3.1, Type-C 1.0 reversible connecto
- Sensors
  - Iris scanner
  - fingerprint (rear-mounted)
  - accelerometer
  - gyro
  - proximity
  - compass
  - barometer

- *heart rate, SpO2*
- *Samsung DeX (desktop experience support)*
- *ANT+*
- *Bixby natural language commands and dictation*

- *Battery*
  - *Non-removable Li-Ion 3000 mAh*

Listing 3.Hardware specifications of the Samsung Galaxy S9 smartphone (high specs device)

3. Architecture Principles & Methodology

3.1 Design Principles and Guidelines

World Manufacturing Forum (WMF) has published a report (2018) with its recommendations for the future of manufacturing and outlines the current SOTA of manufacturing and societal megatrends. Moreover, it discusses actions needed to achieve future the future-oriented development. In a full compliance with the priorities of the Factories of the Future (FoF), six areas of manufacturing have been identified as the ones which will shape future development: cognitive, hyper-personalised, risk-resilient, circular, inclusive and rapidly-responsive. The objectives of the Ageing@Work system design are in line with those recommendations, and more specifically will support-by-design the cultivation of a positive image of manufacturing to attract elderly workers, will promote resource efficiency, and the development of skills in ageing workers.

Societal megatrends (WMF, 2018) like the demographic changes due to ageing population (one of the largest shifts in global demographics) and the mass personalization of products and services were seriously taken into account when designing the Ageing@Work architecture and services. Moreover, the technological approaches of the Ageing@Work proposed architecture are the same with the ones proposed by the European Factories of the Future Research Association (EFFRA, 2017), at least in relation to the Simulation and Modelling (ergonomics optimization tool), the Data analytics (Mobile app, job orchestration tool), artificial intelligence (cognition of the eCoaching Avatar), machine learning (User Activity Monitoring) and the deployment of digital platforms for data management and sharing (overall Ageing@Work platform).

The design of the Ageing@Work architecture is strongly influenced by the Design-for-All design philosophy, which is to proactively apply principles and methods to promote universal design and to avoid posteriori adaptations (Stephanidis et al., 2001). Human diversity social inclusion and equality are the three pillars of the Design-for-All and sequentially for Ageing@Work.

The development of the solution also follows the hierarchical approach of Rozanski & Woods (2005), by developing first a high-level architecture to explain the concept and the objectives and to define the Groups of Functional Components (GFCs) required to address the use cases. Later on we perform a detailed architecture analysis on the static structures, then we implement a development and physical view and finally we describe the dynamic structures (the functional components over the use cases using Activity and Sequence SysML diagrams).

Last, but not least, a hybrid software development approach will be followed which will combine the principles of ‘agile’ development as well as principles of the ‘smart design’ approach.

3.2 Architecture Definition Methodology

This subsection describes the methodological approach followed by Task 2.3 to define the Ageing@Work architecture. It worth to be mentioned that T2.3 methodology includes the breaking-down of the major architectural components into smaller functional parts and components, the description of the functional and operational requirements and the description of the data exchanges among them. The wished outcome of this methodology is to have in hand all required information to allow the independent development of the components.

The design of the Ageing@Work system architecture follows a two-step approach: a first iteration will be complete in M12 and will provide the description of the first version of the overall Ageing@Work toolset, and this will be later followed by a second version on M24 to report updates and progress made while project developments move towards the pilot testing the solutions in real-world settings.

In this first iteration of architecture definition, three main phases are involved: 1) technology exploration, 2) A bottom-up approach, and 3) a top-down approach. This methodological approach is illustrated in the following figure.

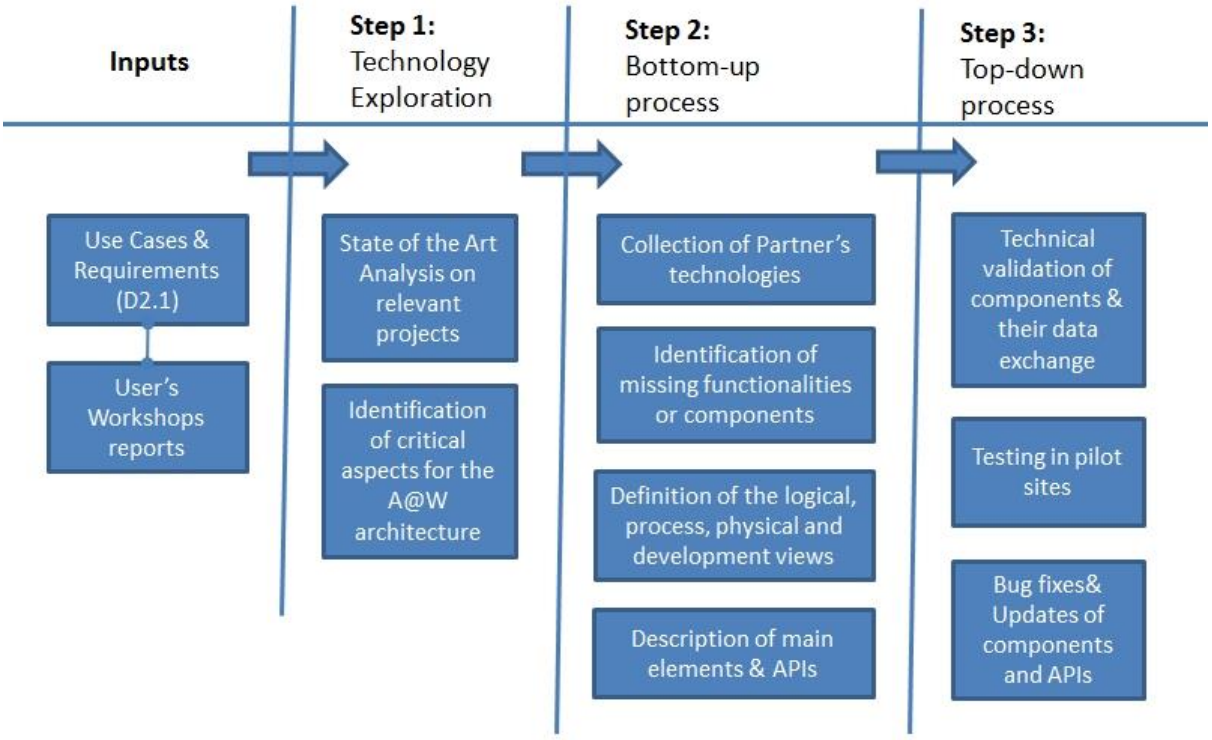

Figure 6. Design Methodology for the first iteration of the Architecture Design

The user requirements analysis and use cases definition is performed in the pre-design phase and is taken into account in here as input from other preparatory tasks. Thus, initially the input coming from the Requirements and Use Cases deliverable (D2.1) and some major findings from the user's workshops organized in pilot sites have been taken into account.

During the step 1 (technology exploration), a state-of-the-art analysis will identify architectures used in other relevant projects, their advantages and disadvantages. Based on that, good examples to follow, as well as critical aspects of the Ageing@Work architecture will be identified.

During step 2 (Bottom-up process) the technical specifications definition, the mapping to the user requirements (and with measurable KPIs where possible) and the system architecture definition (based on the technical specifications) will be performed. Moreover, the consortium will perform an analysis on the technologies they have already developed in other similar or relevant projects (e.g. the work of CERTH in VERITAS project on VUMs, UPAT on emotions recognition, SAMSUNG in Bixby, etc). Next, technology providers will identify the missing components and functionalities to be designed from scratch.

Finally, step 3 is about validation of the proposed architecture and includes all updates and fixes in the diagrams and the API descriptions used in integration.

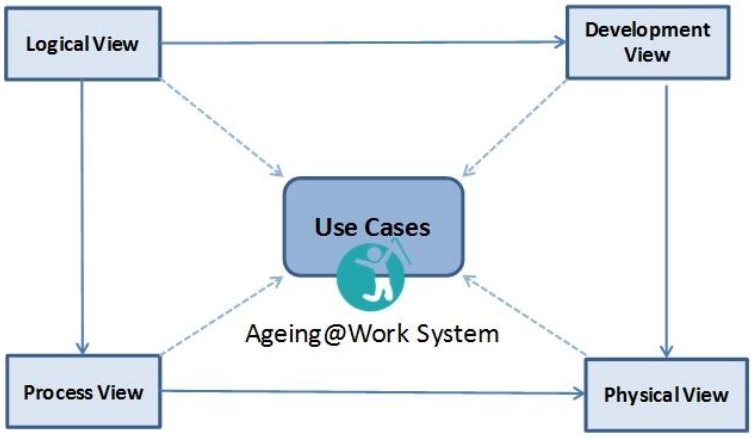

Figure 7. The architectural view model

According to the Architectural View Model (AVM) proposed by Kruchten (1995), we will use multiple, concurrent views to describe the architecture of software-intensive systems like the Ageing@Work (as presented in *Figure 7*). Using those multiple views, the concept will become clearer for a wide range of different stakeholders, such as end-users, health and safety experts, software developers, project managers, and system integrators. Those views can be briefly described as (Kruchten, 1995):

- **Logical view:** Describes the functionality that the system will provide to end-users. A block diagram can be used to represent main entities which implement the wished functionalities.
- **Process view:** This view deals with the dynamic aspects of the architecture, explains the processes and how they communicate with each other. In other words, the process view describes the run time behavior of the system. UML diagrams and/or activity diagrams (graphical representations of activities and actions) can be used to support the description of the process view.
- **Development view:** Illustrates a system from a programmer's and software management point of view (it is also called 'implementation view'). The development view may use UML diagrams to describe the system components, and those may include package diagrams as well.

- **Physical view:** The physical view represents the system engineer's point of view and describes the topology of the various software components and their physical connections.

The 4+1 architectural view model includes also the **scenarios**, which are descriptions of how the system will be used to solve real-world problems. According to the use case under study, the scenarios describe sequences of interactions between software and hardware components and also between processes. This additional element of the methodology can be seen as a way to validate the architecture design and as a starting point for tests of an architecture prototype. In Ageing@Work, the 4+1 architectural view model will be applied having in mind the use cases descriptions included in D2.1. References will be made to those use cases when needed.

To be noted that not all views are necessary to be used in all cases; it is up to the designers to decide which and how many views are necessary to clearly explain all sides of the their proposal.

4. Overall Architecture

The scope of this chapter is to define the overall Ageing@Work architecture after taking into consideration the use cases, the user requirements and the system specifications. Starting from the conceptual architecture described in the Description of Action (DoA), further development and more detailed and technical descriptions of software components are being described in the following sections.

4.1 Conceptual Architecture

As explained in the DoA, the Ageing@Work vision is to support workers both at work and home environments, as well as when they are on the move as visually explained by *Figure 8*. Important tools to achieve these goals are the knowledge sharing collaboration tools, the reward system, the productivity enhancement tools and a pool of interventions targeted to ergonomics, health & safety.

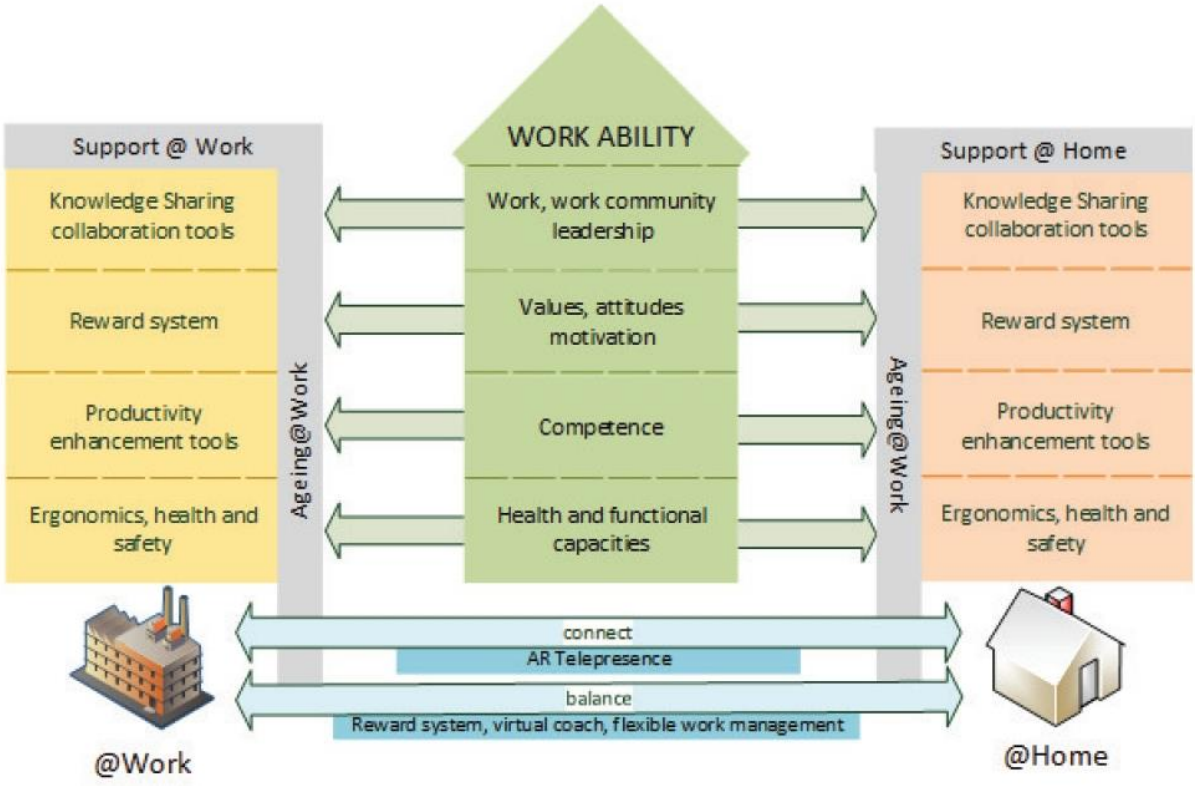

Figure 8. The Ageing@Work vision

The way to achieve this vision is taking advantage of disruptive technologies like the Augmented Reality for telepresence, the 3D simulation technologies for ergonomics assessment, the Virtual User models to represent workers in the system processes and a state-of-the-art Knowledgebase to support the Life Long Learning activities.

Figure 9 presents the concept of the project in which main software modules are featured: A. the wVUMs, B. the virtual workplace model (3D), C. the ergonomic assessment for workplace designs (including machinery), D. a flexible and age-friendly work management, E. Life Long Learning, F. AR/VR tools and finally G. the mirroring avatar.

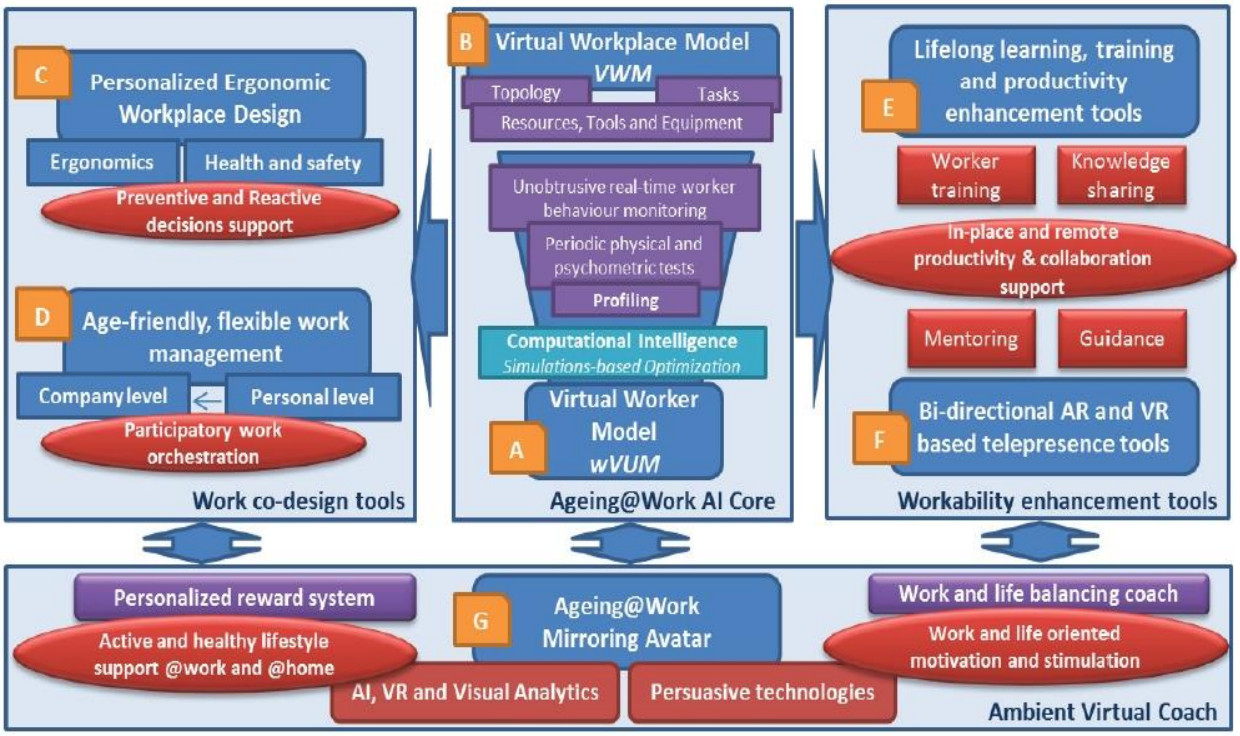

Figure 9. The Ageing@Work concept

The first attempt to have a picture of the conceptual architecture of the envisioned system is presented in Figure 10. Starting from the lower layers, the periodic measurements and the real-time user monitoring will provide large collections of data which will be processed by the virtual models and the Ageing@Work back services before making the Virtual Coach to communicate an intervention to the user.

The term 'intervention' is being used in here to describe various proposed actions to users, from simple recommendations (for health, safety and well-being), to more advanced solutions which include productivity enhancement and ergonomics optimization.

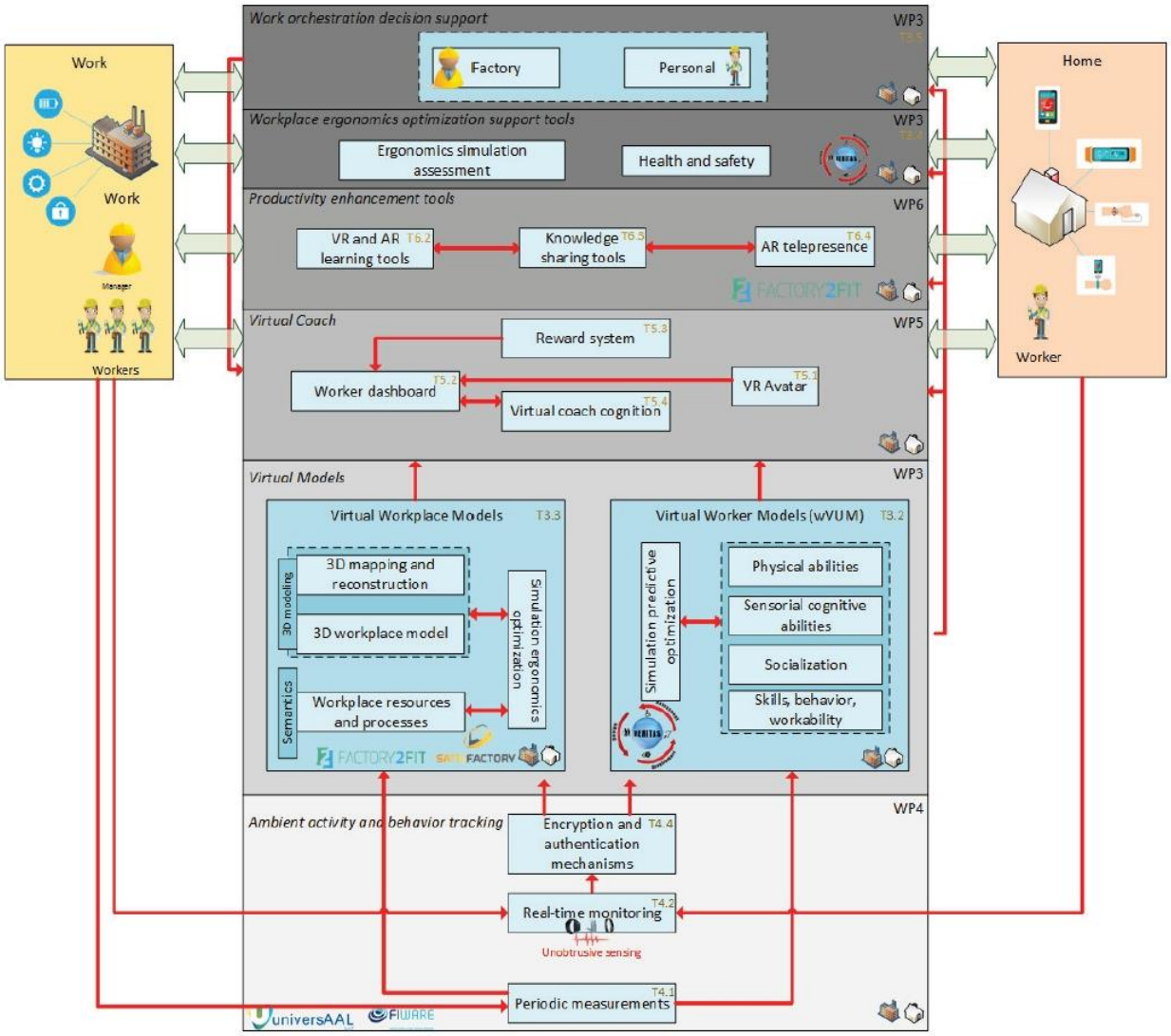

Figure 10. The Ageing@Work conceptual architecture

4.2 The technical Architecture

In order to deliver a coherent and consistent approach for the development and delivery of the Ageing@Work technical capabilities, a first design of the system architecture, as derived after elaborating the above, preliminary schema, is presented and explained in detail in what follows. The overall architecture consists of the software components, which will be developed by the technical partners of the consortium based on the system specifications defined earlier. Open technology standards and global technology interoperability techniques will be used when possible.

Figure 11 graphically presents the overall structure and clearly depicts the relations between major components. Starting from the **Ambient Activity & Behaviour Tracking Tools** to be implemented in WP4, a group of IoT sensors and mobile devices will be used as a physical equipment to collect data from users and their working environments. The activity and environmental sensing is mandatory before making the

next step. Since data protection is a critical issue in this project, the **Encryption, Authentication and Security** will be an in-between component to protect the collection and transmission of sensitive data to Ageing@Work cloud services.

Next, the **Centralized Repository** will be responsible for storing the collected datasets for long (before a recycling mechanism will be triggered to remove unused or very old data). This repository will store data from IoT sensors, user's responses to questionnaires, scenarios for AR, VR and **Life Long Learning** (LLL) and models (user, workplace & processes). The repository will be equipped with an internal search engine to allow users apply search criteria, filter the contents of the repository and finally explore the results.

The **Productivity Enhancement** is a set of software tools to be used for accessing the **knowledgebase**, and also for situation awareness and telepresence using AR technologies. Moreover, it will be possible to use the same tools for learning purposes (LLL).

The **mobile app** (bottom-left on the *Figure 11*) is the entry point for workers who want to access the Ageing@Work services and also hosts the **Virtual Avatar** that is the agent to companion the user in most platform activities. The Virtual Avatar lives on the UI of the mobile app and is the first responder to any change in the user model, current or future shifts and recent notifications send by the system. It is equipped with multimodal interaction characteristics and can communicate with the user with natural language. This requirement justifies the Text-to-Speech and Speech-to-Text subcomponents. More information of the functionalities of the Virtual Avatar is presented later in this document.

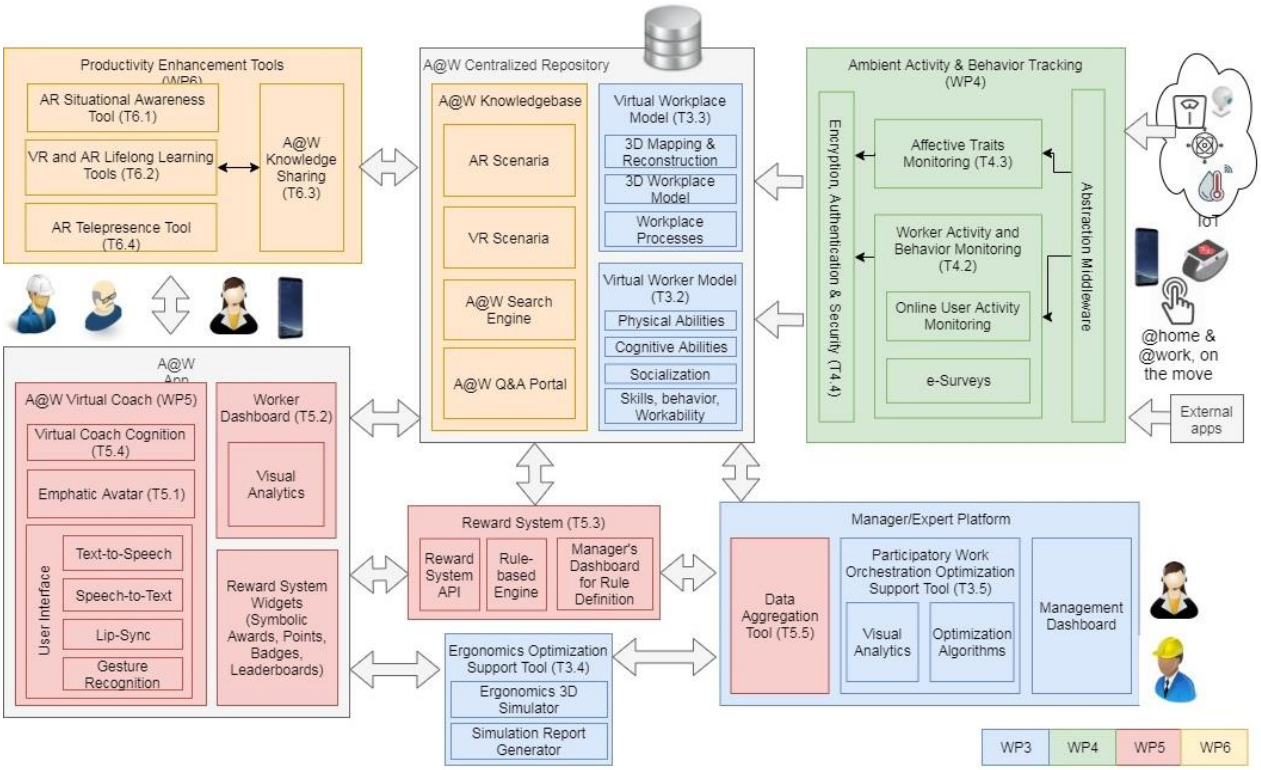

Figure 11. The Overall Technical architecture

The **Reward System** is actually a gamification engine used to share symbolic awards to users who adopt a wished behaviour like intervention adherence, active participation in in the user-generated content of the knowledgebase, and more. This engine will be integrated into the mobile app using an API to establish direct links between awards and user's actions.

The **Ergonomics Optimization Support Tool** consists of the Ergonomics 3D Simulator which will perform the assessment of workplace and machine ergonomic designs and the report generator to produce and share the results with interested parties. At principle the first concerned is the user him/herself, but later on results may be shared –after permission given by the user- with HR managers for decision making.

Finally the Ageing@Work architecture is completed by the **Management/Expert Platform** that is the collection of tools intended for the managers, plus the Data Aggregation Tool. This toolset includes the Participatory Work Orchestration Optimization Support Tool and its sibling module which contains the Optimization Algorithms, and the Manager Dashboard to be used for visualizing the available data (using Visual Analytics tools and principles) and interacting with each individual management tool.

The following paragraphs describe in more detail the main components of the Ageing@Work architecture and its sub-modules. In particular, section 4.3 below summarizes the groups of functional components defined after the overall technical architecture of Figure 11, while Chapter 5 provides the detailed description of the Ageing@Work system components.

4.3 Group of Functional Components

The basic Group of functional components per task has been identified as it can be seen in *Table 8*.

Table 8. List of basic Groups of Functional Components for the Ageing@Work architecture

Group	Title of functional component	Related Task	Responsible partner
GFC1	Ageing@Work Mobile app	WP5	
	Virtual Coach Cognition	T5.4	CERTH
	User's Emotions Mirroring	T5.1	UPAT, CERTH
	UI: Text-to-Speech	T5.1	CERTH
	UI: Speech-to-Text	T5.1	CERTH
	UI: Lip Sync	T5.1	CERTH
	UI: Gesture Recognition	T5.1 & T5.4	CERTH
	Worker Dashboard	T5.2	CERTH
	Reward System Widgets	T5.3	SAMSUNG
GFC2	Ambient Activity & Behaviour Tracking	WP4	
	Affective Traits Monitoring	T4.3	UPAT
	Worker Activity & Behaviour Monitoring	T4.2	CERTH
	Online User Activity Monitoring	T4.2	CERTH
	eSurveys	T4.2	CERTH
	Encryption, Authentication, Security	T4.4	CERTH
GFC3	Productivity enhancement tools	WP6	

	AR Telepresence Tools	T6.4	CERTH
	AR Situational Awareness Tools	T6.1	CERTH
	VR and AR Life Long Learning Tools	T6.2	UPAT
	Knowledge sharing tools	T6.3	UPAT
GFC4	Manager/Expert Platform	WP3	
	Participatory Work Orchestration Optimization Support Tool	T3.5	HIT
	Management Dashboard	T3.5	CERTH
	Visual Analytics	T3.5	CERTH
	Optimization Algorithms	T3.5	HIT
	Data Aggregation Tool	T5.5	CERTH
GFC5	Ergonomics Optimization Support Tool	T3.4	MYSPHERA
	3D Simulator	T3.4	MYSPHERA
	Simulation Testing Report Generator	T3.4	MYSPHERA
GFC6	Reward System (Gamification Engine)	T5.3	SAMSUNG
	Rule-Based Engine	T5.3	SAMSUNG
	Manager's Dashboard	T5.3	SAMSUNG
	Reward System API	T5.3	SAMSUNG
GFC7	Ageing@Work Centralized Repository	WP3, WP6	UPAT
	Knowledgebase: AR &VR Scenaria	T6.2	CERTH, Pilots
	Knowledgebase: Search Engine	T6.2	UPAT, SAMSUNG
	Virtual Worker Models	T3.2	CERTH
	Virtual Workplace Models	T3.3	UPAT

5. Detailed Descriptions of Subcomponents

5.1 Ageing@Work Mobile app

The Ageing@Work mobile app is the software application designed to run on the user's mobile device such as a smartphone or tablet. Originally, it was intended to host the Virtual Coach functionality, but the demand to have a single access point for all Ageing@Work services for the workers caused an expansion into other architectural sub-components like the gamification, Life Long Learning and knowledge sharing tool, the Virtual/Augmented Reality services and the GPS and location-based services. *Figure 12* presents the logical view of the overall mobile app (featured in the centre) and its peripheral components.

The mobile app consists of the user's dashboard, the virtual coach front-end (UI) and back-end (cognition). It is connected to other components like: 1. the reward based motivation system (gamification) to offer room for visualizing the achieved goals and won awards, 2. the ambient activity & behaviour tracking components in order to sense the status of the users and their environment, 3. the productivity enhancement tools to offer access to the WP6 components and 4. the Ageing@Work database (access to models, monitoring data, etc.).

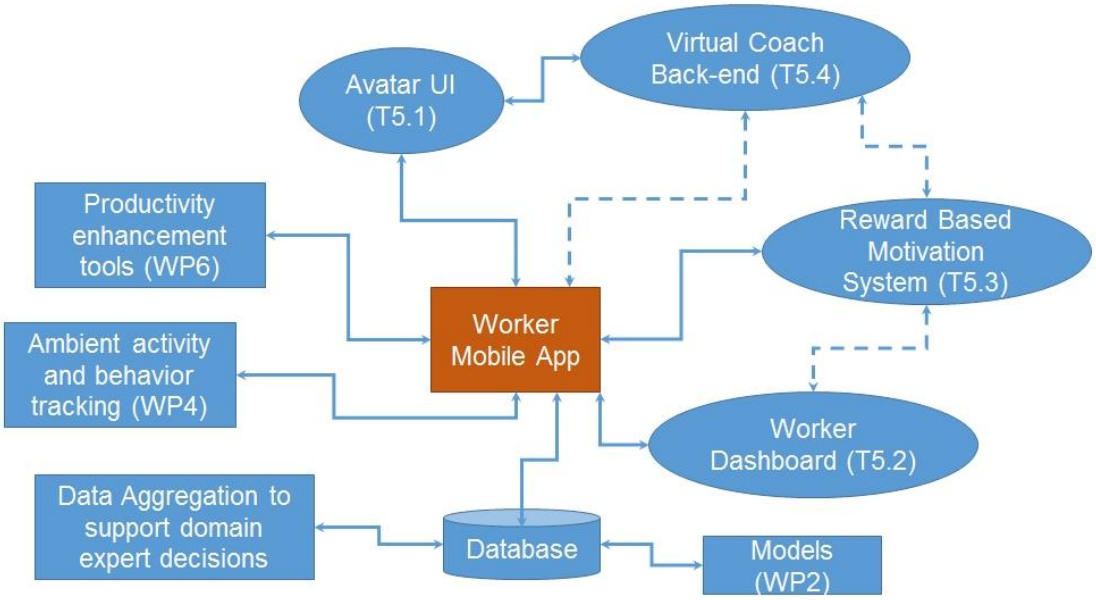

Figure 12. Logical view of the mobile app

5.1.1Virtual Coach Cognition

This component will be responsible for realizing the cognitive functions of the AGEING@WORK virtual coach, governing its behavior in terms of providing proactive and discreet assistance to the user. To this end, the virtual coach cognition component will fulfill a series of tasks, namely i. establishing an estimate

of the state of the user based on input from the worker monitoring components, ii. infer based on the state of the user and the workplace which information needs to be highlighted, and iii. decide based on research on persuasive technologies (T2.2) in order to convey the needed message in the most effective way possible, helping towards better reception, perception and, where required, reaction. The virtual coach cognition component will contribute to the achievement of Objective 4.

From a technical standpoint, the core of the virtual coach cognitive component will be a decision-making system that will be able to infer the time, content and manner by which to deliver notifications to the user so as to ensure proactive and discrete intervention. The input to the decision making system will be introduced through the worker dashboard — to which the cognition component will be tightly bound, and will comprise, on the one hand, pending notifications to be delivered to the user and, on the other hand, inputs from the vWUM, VWM, Affective Traits Monitoring, Worker Activity and Behavior Modeling and Online User Activity Monitoring components. The latter will be user to establish an estimate of the current user state and identify the most appropriate action through the application of a multi-parametric optimization module (e.g. using POMDPs).

The output of the decision making (e.g. using POMDP-based) module will be a decision on what to notify the user about at the particular point in time, taking into account also past notifications. The output will be input to the second component of the cognitive module, which will derive, based on findings of T2.2, the most effective means to deliver the notification, taking into account the current state and/or activity of the user (e.g. at home, at office, working on a machine, taking a break/ lunch, etc.). The cognition module will communicate the result to the worker dashboard so that the appropriate notification action may take place.

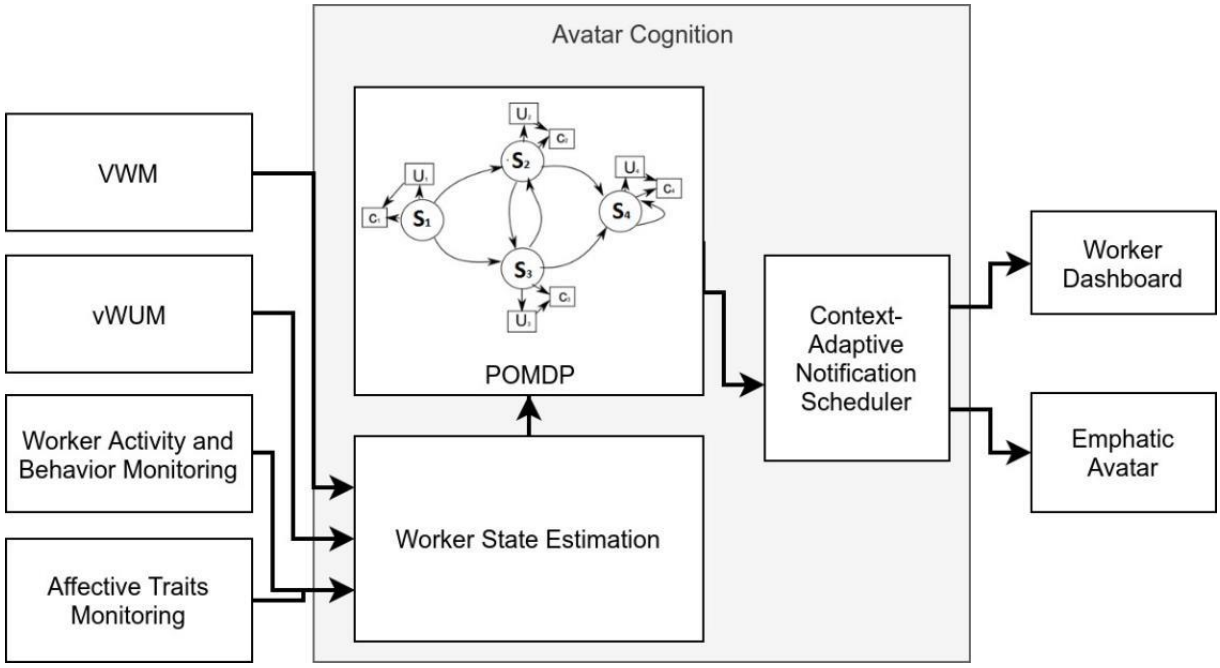

Figure 13. The subarchitecture of the Virtual Coach Cognition component (logical view)

Table 9. Summary of the Virtual Coach Cognition and related services

Name: VCG	Virtual Coach Cognition		
Description	The Virtual Coach Cognition component is responsible for realizing the decision making capabilities of the virtual coach pertaining to the time, means and content of notification delivery to the worker.		
Objective	Obj. 4: To research and develop a novel, joint productivity and life support virtual assistant		
Related Use Cases	USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH. The VCG will draw inference on suggestions of the virtual coach oriented around physical activity and healthy habits. USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT. The VCG component may infer the most appropriate way to remind the user to engage in the knowledge sharing platform according to current activity and location. USE CASE 2: PARTICIPATORY WORK ORCHESTRATION. The VCG may infer a non-intrusive way of reminding the user to schedule their leave days and vacations. USE CASE 6: EMERGENCY BUTTON. The VCG may infer the most appropriate way to alert the user that remote assistance is available.		
Related Technical Specifications	TS022, TS030, TS031, TS033, TS034, TS038, TS068, TS078, TS085, TS090, TS091, TS099, TS101, TS105, TS110, TS114, TS117, TS120, TS124, TS125, TS126, TS127, TS130, TS132, TS133, TS134, TS135		
Input	Ambient activity and behavior tracking, Affective Traits Monitoring, Online User Monitoring, vWUM	**Output**	Time, means and content of personalized notification, or scheduled notification delivery
Sub-components	Decision Making Engine: • User state estimation • Decision Making	**How they are connected**	Input: High-level user state descriptor, location descriptor Output: Best notification method assuming current state
	Persuasive Notifications Generator	**How they are connected**	Input: Notification method, content Output: Personalized notification, notification schedule
List of Services			

VCG1	Worker state estimation using activity and behavior data
VCG2	Optimal action determination considering user state and location
VCG3	Optimal time of delivery determination considering user state and location
VCG4	Personalized, affective message delivery
Hardware	HMD, Tablet

5.1.2 Avatar Empathic Expressions Controller

The Avatar Empathic Expressions Controller (AEEC) component is responsible for establishing the emotional state of the user through the Affective Traits Monitoring module (see Section 5.2.1). In this basis, the UEM component will form the input to the Affective Emotions Mirroring Avatar, in the sense that it will provide the input concerning the user affective and emotional state, which will be used to accurately express similar emotions on the avatar.

The avatar empathic expressions module will get input from the Affective traits monitoring module and specifically the accumulated result of the emotion recognition component. This will be achieved via the Android infrastructure that exists to support the communication between the Android Activities. The infrastructure is based on Intents, which act as messages/signals that the Android OS receives and distributes. An Intent is used to instruct the Android OS to start a new Activity or switch to an existing one, but it can also transfer payload data, such as the resulted user's emotion and the recognition score.

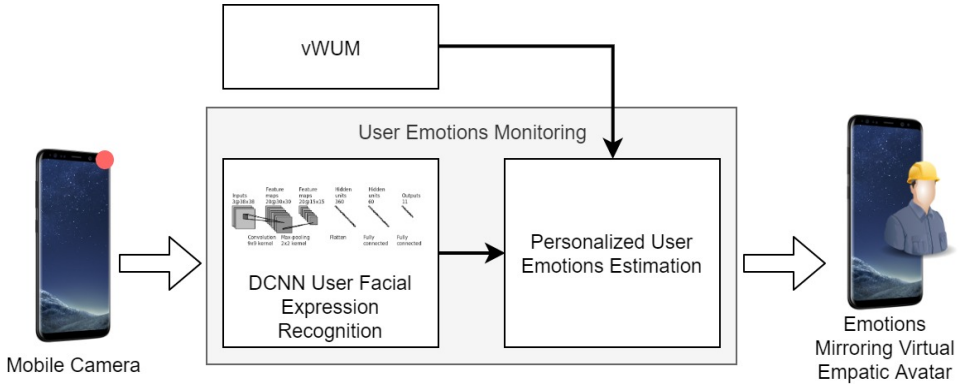

Figure 14. The subarchitecture of the User's Emotions Mirroring (logical view)

From a technical perspective, rich information from the expressions recognizer is combined with user-specific metrics from the Virtual Worker User Model (vWUM), in order to adapt recognized expressions and features to individual emotional states. The UEM module runs completely on the mobile device thus minimizing the risk of private data breach.

Table 10. Tab of the User's Emotions Monitoring and related services

Name: AEEC	Avatar Empathic Expressions Controller		
Description	The UEM module enables estimation of emotional state of the user through analysis of user facial expressions input through a mobile device camera.		
Objective	Obj. 4: To research and develop a novel, joint productivity and life support virtual assistant		
Related Use Cases	USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH: The UEM module will drive affect-oriented adaptations in the appearance of the virtual coach.		
Related Technical Specifications	TS075, TS076, TS106, TS125, TS126, TS127, TS110, TS136		
Input	Camera Input, vWUM	**Output**	User-Specific emotional state-describing vector
Sub-components	User Emotions Monitoring Buffer	**How they are connected**	Input: User emotions, relevant facial features and expression descriptions (from Affective Traits Monitoring) Output: User mood estimates
	Personalized Avatar Emotions Estimation	**How they are connected**	Input: Facial features and expressions, Worker Model Output: Avatar Emotional State Estimate
List of Services			
AEEC1	Avatar Facial Expression Estimation		
AEEC2	Facial Features Inference engine		
Hardware	Phone, Tablet		

5.1.3 Virtual Avatar

This component refers to the avatar appearance and its interaction modalities. From an operational point of view it is included in the Worker Dashboard and appears to users as one and single component, but its internal structure justifies the study of this component as a separate one. As it can be easily understood,

the Virtual Avatar front-end (appearance and interaction with the user) is an agent-based communication system between the end-users and the Ageing@Work platform.

The Ageing@Work intelligent personal assistant is a software agent able to perform tasks for individual users based on natural language and gestures. Due to its capability of exchanging messages with the user in online chat threads, it can be called "chatbot". The natural language processing capabilities include two kinds of functionalities: 1. the ability to interpret human speech, and 2. the ability to respond back via synthesized voices. In this fashion, workers can ask their virtual assistants questions about the contents of the knowledgebase, the current status of the machines they supervise, the working environment or even themselves (physical and mental health). Moreover, they can be able to perform some standard tasks in the User Dashboard like check their shift, make a day-off request, call an experienced worker to ask something and more.

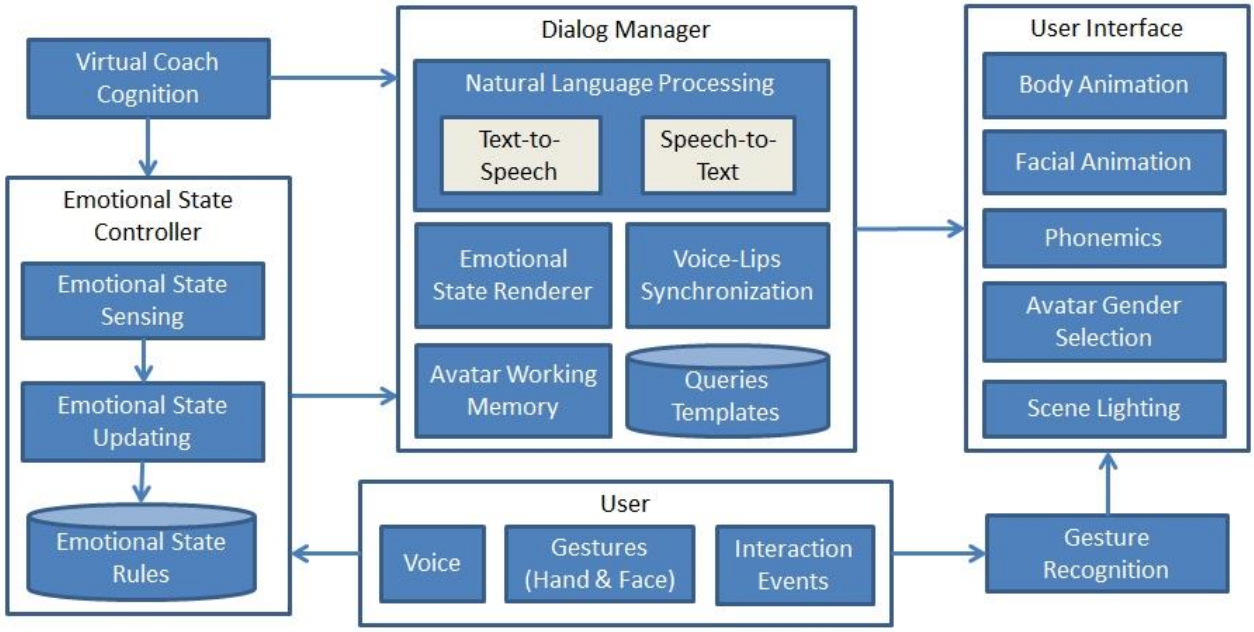

Figure 15. The subarchitecture of the Virtual Avatar (logical view)

An additional feature introduced in the Virtual Avatar to help users interact with the system with an easy and fast way is gesture recognition. More specifically, by using algorithms for hand gesture recognition users can be able to interact with the end-devices without physically touching them. Last but not least, the Emotional State Renderer is a subcomponent used to reproduce on-demand emotions on the avatar based on a classification of emotions (neutral, happy, sad, fear, surprised and disgust). This is strongly related to the User's emotions mirroring module described above. The Emotional State Renderer is based on a Facial Action Coding System (FACS) for the face animations and a custom-based body language renderer. Moreover, attention is paid on the need to synchronize those two means of emotional expression (body & face).

The physical view of the Virtual Avatar is very simple. It consists of the user providing voice commands and gestures on one hand and the mobile device (e.g. Tablet) on the other hand in which the Virtual Avatar operates.

Table 11. Tab of the Virtual Avatar (virtual coach appearance) and related services

Name: VA	**Virtual Avatar**		
Description	The Virtual Avatar refers to the visual outcome of the Virtual Coach and the human-machine interaction (everything except the cognition). Finally it will be integrated with the Worker Dashboard into a single piece of software working in parallel and will be operated: 1. By the user for actions to be performed in the User Dashboard, and 2. by the system as the 'first responder' to any change happened in the user model, machine state or shift.		
Objective	Obj. 4: To research and develop a novel, joint productivity and life support virtual assistant Moreover, this component is indirectly related to the project objectives which are related to personalization since the use of a Virtual Avatar can be considered as an optimal method to deliver highly personalized services. The project objectives which this component serves are: • Obj. 1: Enable extensive personalization capabilities to the Ageing@Work supportive approach • Obj. 3: Provide workers with personalized work ergonomics and process design services • Obj. 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics		
Related Use Cases	The Virtual Avatar is a main component in the user Dashboard and thus it is related with all Use Cases which actually use the mobile app. From UC1 (CHECK-LIST PLATFORM) to UC6 (PRODUCTIVITY ENHANCEMENT TOOLS) the Virtual Avatar is being used to communicate messages from system to user and to receive user's response or confirmation.		
Related Technical Specifications	TS031, TS033, TS034, TS035, TS038, TS053, TS068, TS070, TS071, TS022, TS078, TS085, TS090, TS101, TS105, TS110, TS111TS114, TS117, TS120, TS124, TS125, TS127, TS134, TS135, TS136		
Input	• User emotional states (API of User Emotions Mirroring) • Avatar appearance models	**Output**	• Skeletal animation • Synthetic speech

	• User gestures		• Mirrored emotional states • User voice/gesture commands (recognition)
Sub-components	• Emotional State Controller • Dialog Manager • User Interface	**How they are connected**	The Emotional State Controller receives the emotional states of the user and drives the mirroring functionality of the avatar. At the same time, the Virtual Coach Cognition (described as a separate item) leads the Dialog Manager and finally all interactions are taking part in the UI. Gesture recognition is a supplementary UI feature.
List of Services			
VA1	Mirror the emotional state of the user using body skeletal animation and facial animation (posture).		
VA2	Synchronize the lips motion according to the Text-to-Speech audio outcome		
VA3	Recognize dictated audio input in real-time (Speech-to-Text)		
VA4	Produce synthetic spoken text (Text-to-Speech) on demand		
VA5	Recognize hand user gestures		
VA6	Render and light the final virtual scene		
VA7	Maintain avatar memory (what has been said in the recent dialog history, next steps, pending user requests, etc.)		
VA8	Switch avatar appearance (e.g. gender) and voice type according to user settings		
Hardware	Mobile Device to host the avatar		

The next figure presents the process view of the Virtual Avatar for the basic processes described above. To be noted that the Virtual Coach Cognition appears at the right-most part of the sequence diagram as an external component that provides the responses of the system (text, audio) and UI element updates.

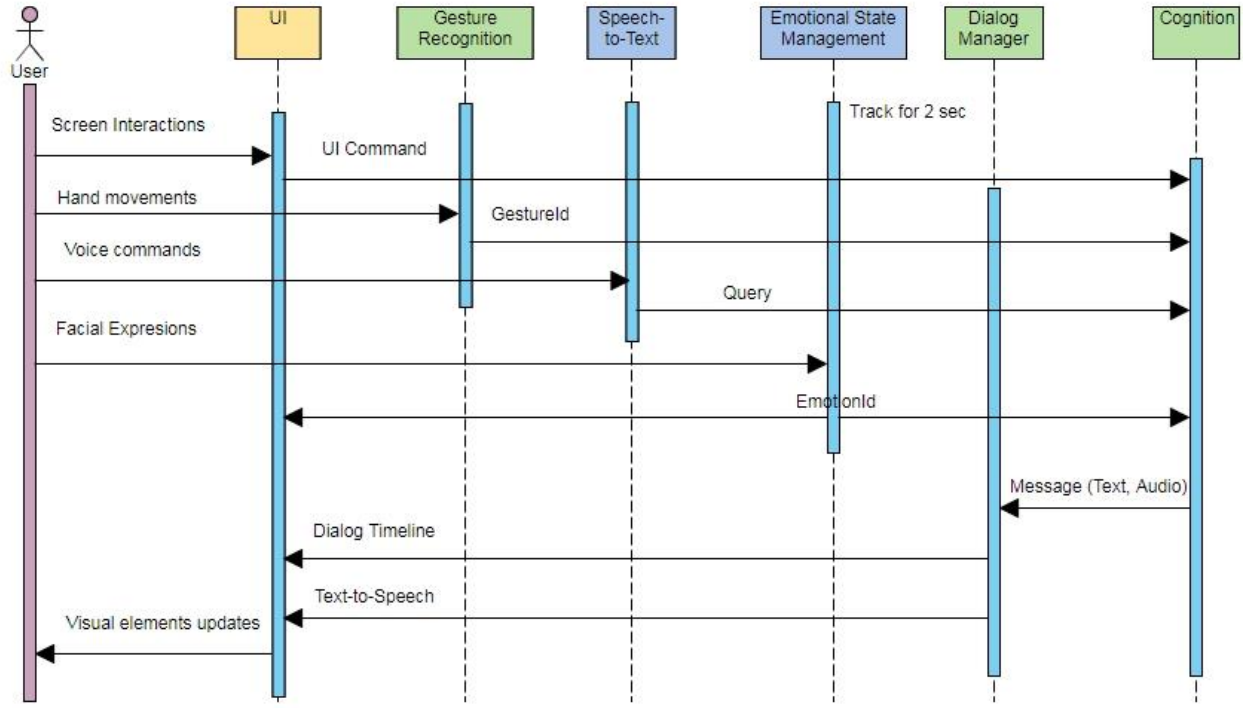

Figure 16. Process view of the Virtual Avatar

5.1.4Worker Dashboard

The purpose of the User Dashboard is to provide end-users (workers) with a simple to use view that presents all information relevant to their profile, personal information collected by the system, their recent health and QoL evaluation results (questionnaires), the reward collected for following wished behaviours and the results of the ergonomics assessment. Moreover, the Visual Analytics implementation for the Worker Dashboard will be able to show trends and risky areas, to update the user on what happened recently on Ageing@Work and guide him/her into a personal navigation route to various areas of the Ageing @Work platform that require users attention.

From the end-user's point of view there will be one mobile application to host all user-related tools like the User Dashboard. The functional way the Ageing@Work mobile app will host all other components, including the User Dashboard, is visually presented in *Figure 17*. According to this, the use of OpenAPI could be an optimal way to ensure a rapid and complete integration of data from the different Ageing@work services. OpenAPI Specification (formerly Swagger Specification) is an API description format for REST APIs. An OpenAPI file allows developers to describe their entire API, including: Available endpoints (/users) and operations on each endpoint (GET /users , POST /users), operation parameters Input and output for each operation.

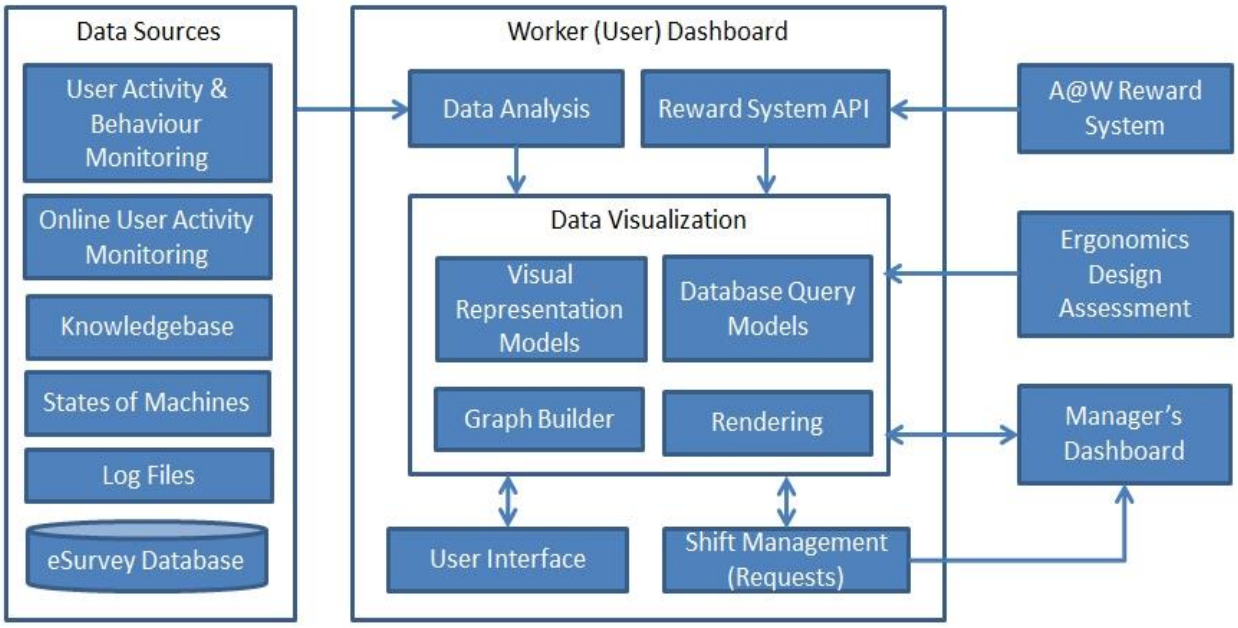

Figure 17. The logical view of the Worker Dashboard

It is worth to mention that -apart from an entry page in which users will give their credentials to access the mobile app- the User Interface component will include:

- **My Daily Habits:** to be directly connected with Abstraction Middleware restAPI (T4.1)
- **My Mood:** that is a view with the avatar's emotions
- **My Adaptations:** a collection of information from the Ergonomic Optimization Support Tool (T3.4) restAPI
- **My Records:** a historical summary of all activities of an individual user
- **My Alerts:** messages that require attention according to unexpected values of health and work safety parameters (standardized recommendations)
- **My Jobs**: information about the current work position and ongoing tasks (depends on the sensors that we can have in the job position using the Participatory Work orchestration tool rest API)

The User Dashboard is like a 'control room' for users to access the contents of the data sources (perceived behaviour & IoT sensors data, eSurvey results, log files, etc), the current status of the award system (personal achievements and award rules) and the results of the ergonomics assessment. It worth to mention that some information from the Visual Analytics component for users will be redirected –after permission- to the managers and Health & Safety Professionals.

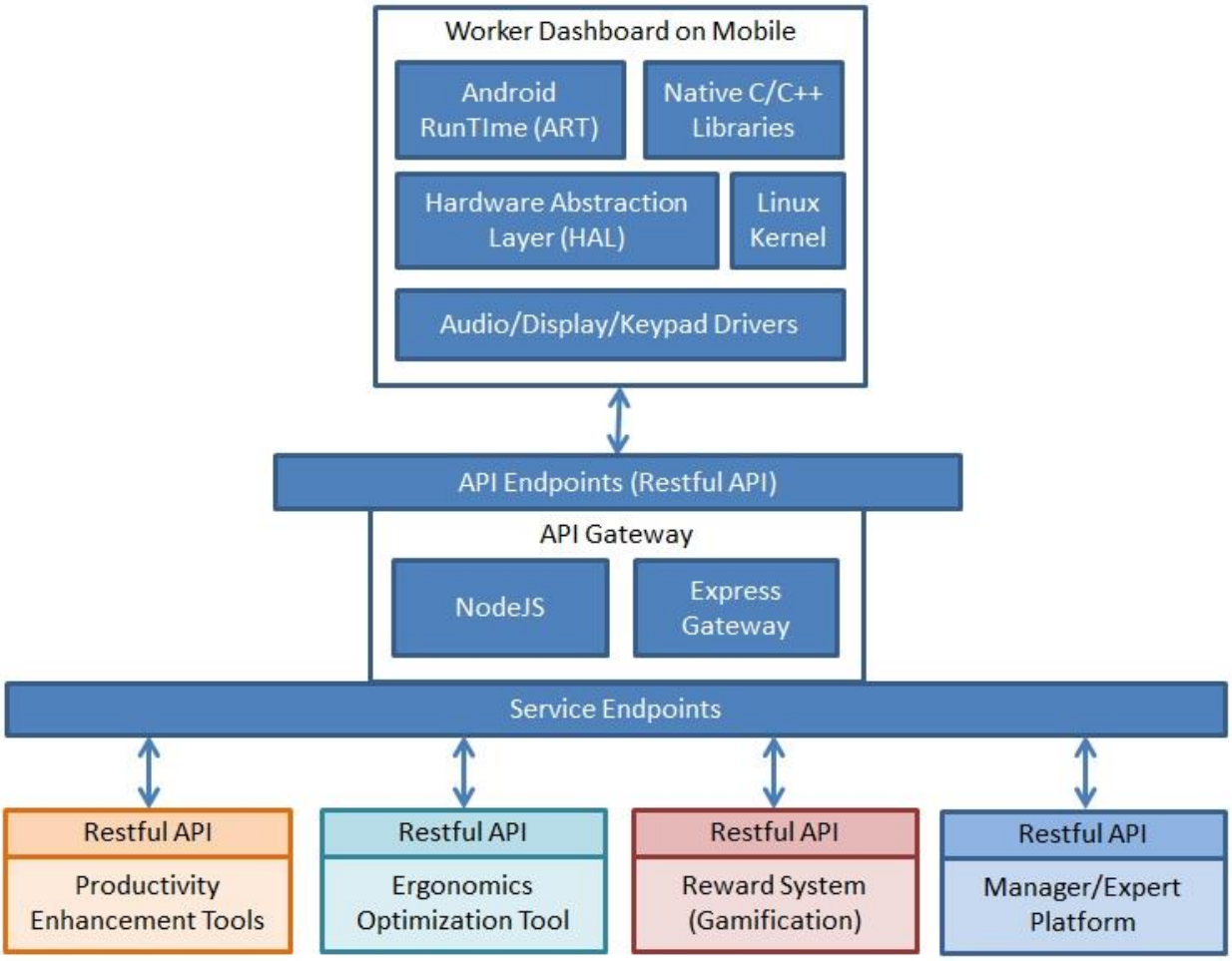

Figure 18. The development view of how the Worker Dashboard is operated from within the mobile app

Form a physical installation point of view, the Worker Dashboard operates from the mobile device of the end-users (e.g. Tablets and Smartphones) and is capable of sensing push notifications to the Smartwatch – if available. It receives data from:

1. IoT sensors (mobile devices, webcameras, and smartwatches) while users are in home, work or at the move,

2. APIs and 3. various databases (e.g. eSurvey, Knowledgebase) and visualize the available data collections thought its internal Visual Analytics subcomponent.

As presented in *Figure 19*, apart from visualizing data, the Worker Dashboard will be capable to exchange (send/receive) notifications with the Manager's Dashboard regarding the shift/days off and work from home requests.

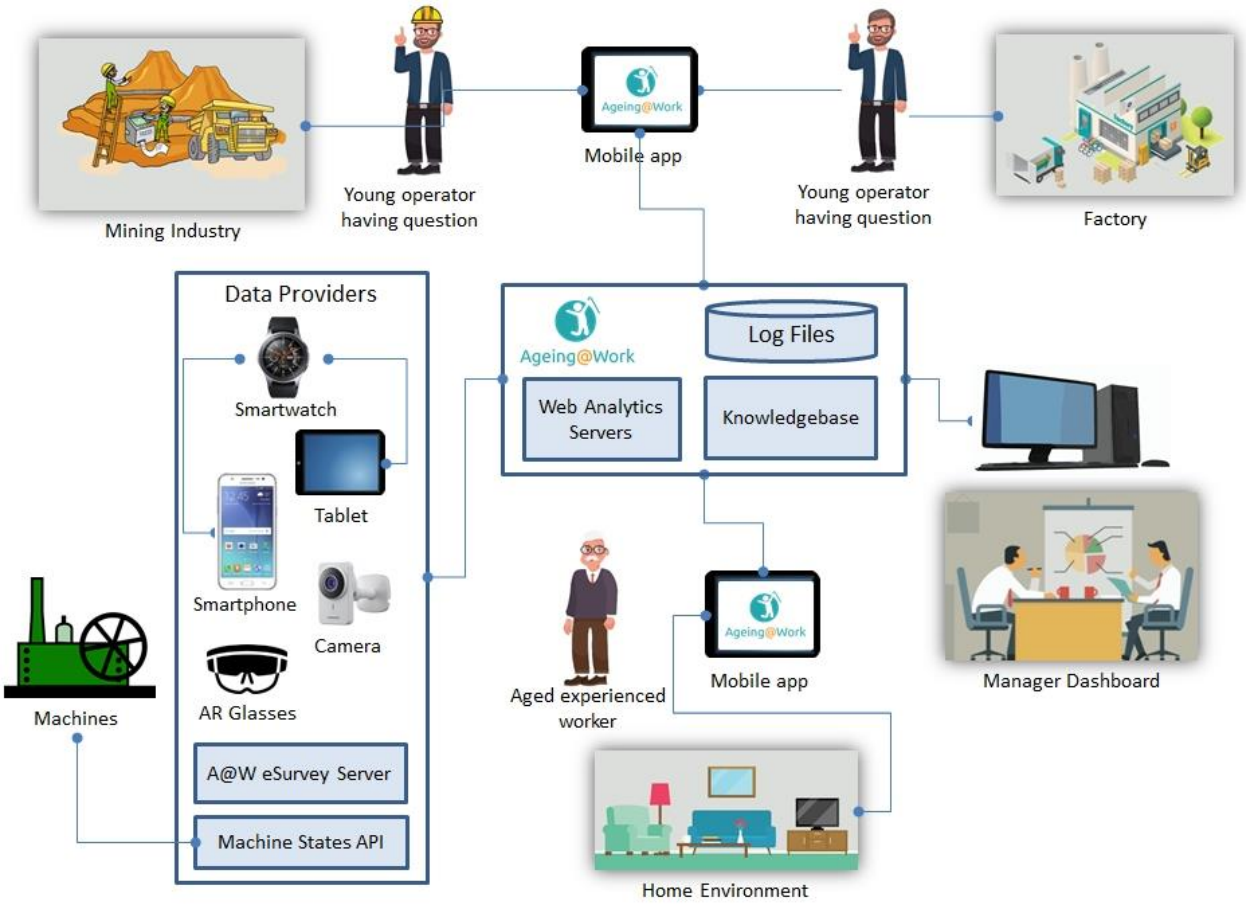

Figure 19. The physical view of the Worker Dashboard

Table 12. Summary of the Worker Dashboard and related services

Name: WD	Worker Dashboard
Description	The Worker Dashboard is integrated into the mobile app and works closely with the Virtual Avatar, but can also be accessed through a web interface. In its desktop version the Worker Dashboard includes the 3D Ergonomics Assessment Tool. The ergonomics design assessment results (valuation reports) will be presented in both web and mobile versions of the User Dashboard.
Objective	The Worker Dashboard meets the objectives of the project which include the ergonomics assessment and the evidence-based interventions sported by the visual analytics tools. More specifically, this tool can be referred in relation to: Obj. 3: Provide workers with personalized work ergonomics and process design services

	Obj. 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics		
Related Use Cases	USE CASE 2: PARTICIPATORY WORK ORCHESTRATION. Workers will access the User Dashboard to use the digital calendar feature and initiate a request for days off and work from home. USE CASE 3: SUPPORT FOR MUSCULOSKELETAL PROBLEMS. Workers will use the Visual Analytics of the User Dashboard to access their recent data related to their symptoms and make decisions based on that data. USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH. Same as UC3, users will access and manage their personal data related to their health and well-being. USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM, REMOTE COLLABORATION AND PRODUCTIVITY ENHANCEMENT. The User Dashboard will be used as the interface between the user and the contents of the knowledgebase. Practically the Ageing@Work search engine could present the search results through the User Dashboard. The contents of the knowledgebase would be delivered to the users through the User Dashboard.		
Related Technical Specifications	TS074, TS075, TS076, TS077, TS078, TS079, TS080, TS081, TS081, TS084, TS086, TS087, TS088, TS102, TS103, TS107, TS108, TS109		
Input	All data sources, namely: • AGEING@WORK Database (data from User Activity & Behaviour Monitoring, States of Machines, user profiles, Log files, etc.) • Online activity monitoring database • eSurvey Database • Knowledgebase • Award System Database	**Output**	The output consists of a number of views: • Interactive charts to present the data visualization results • Personal award collection view • Ergonomics assessment outcomes report • History (timeline) of user's requests (to the manager)

Sub-components	• Access to data sources • Data visualization • Personal profile management • User Interface • Message exchange with the Manager Dashboard	**How they are connected**	The various data sources provide data to be visualized in the interactive charts of the Worker Dashboard. Moreover, additional components like the shift management and the knowledgebase search engine are closely connected.
List of Services			
WD1	Initiation and management of requests for days-off, work from home and be in charge.		
WD2	Visualization of personal information related to health and QoL		
WD3	Access the Knowledgebase search engine so as to explore results		
WD4	Access recent events in a timeline (from log files)		
WD5	Access the current states of the machines under surveillance (during shift)		
WD5	Access the awards collected by following the wished behaviour		
Hardware	Tablet, Smartphone		

User's dashboard will provide services to be consumed by the users during working time, as well as during free time (from home or on the move). This is highlighted in the following UML diagrams in *Figure 20* and *Figure 21*.

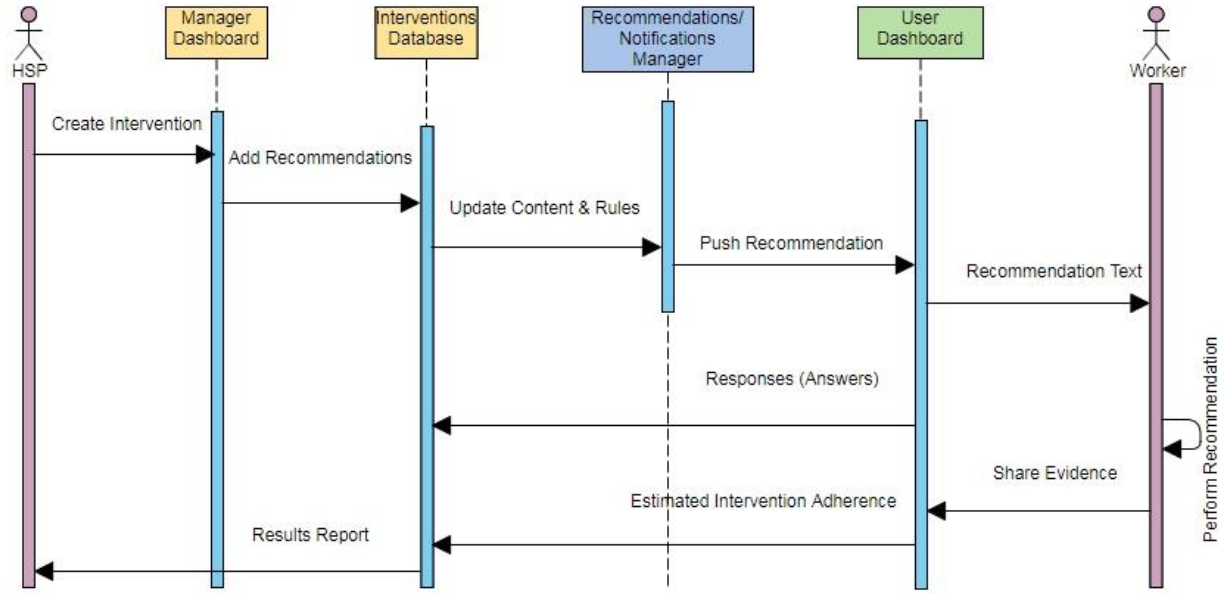

Figure 20. The process view of the User Dashboard for the interventions (UC3, UC4 and UC7)

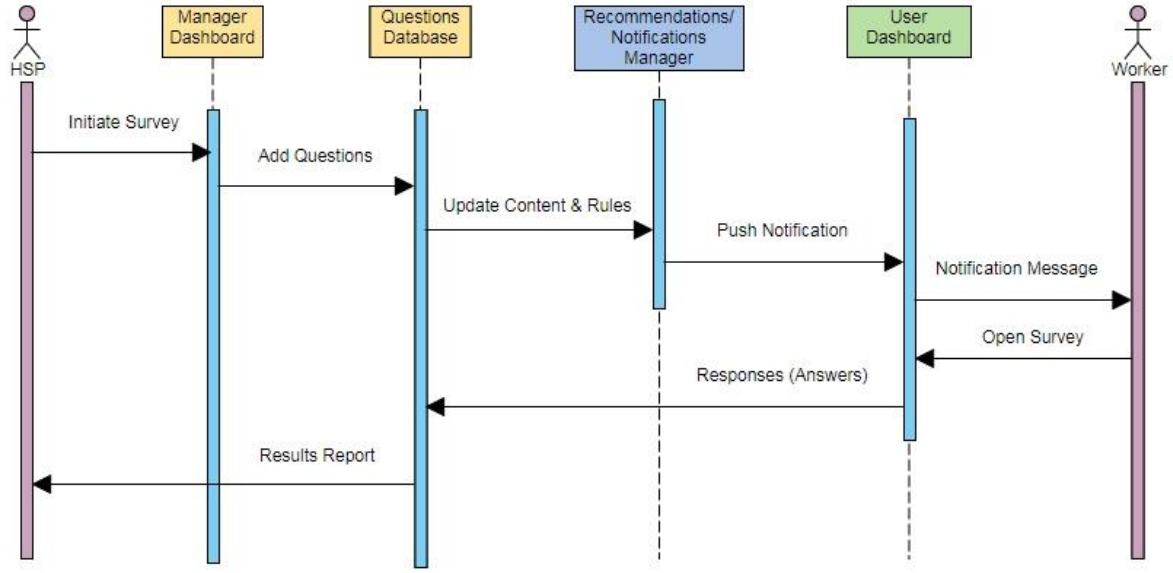

Figure 21. The process view of the User Dashboard for the eSurvey

From a programmer's point of view, the User's Dashboard will be developed as a typical mobile application (*Figure 22*) using Android libraries to access raw data, cloud-bases services and interact with the user using mobile device modalities. For web access, a typical web interface using HTML5, CSS3, JavaScript and Bootstrap framework.

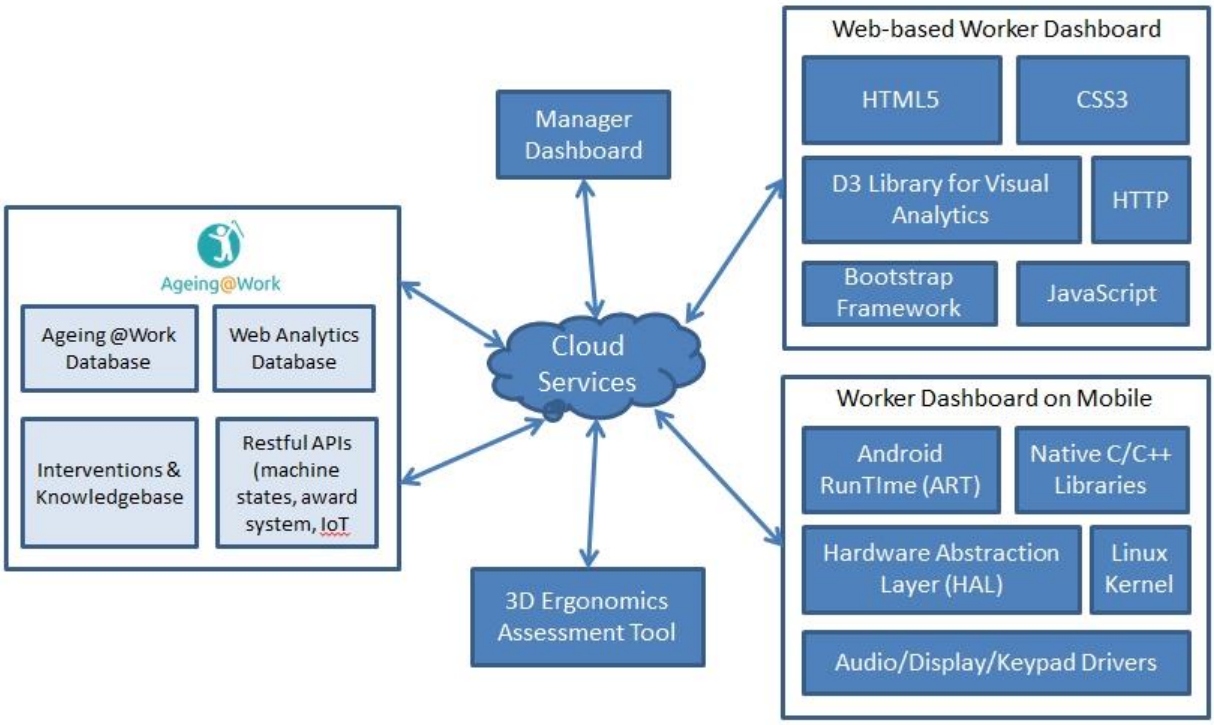

Figure 22. The development view of the User Dashboard

5.2 Ambient Activity & Behaviour Tracking

The components outlined in this section collectively are responsible for comprehensively and ubiquitously tracking the workforce activity and behavior, both in terms of physical activity as well as identification of affective traits and finally online activity pertaining to the use patterns of the AGEING@WORK online infrastructure. Additionally, this section describes the necessary components to enable the safeguarding of data storage and exchange of sensitive and personal data, as well as intrusion prevention and data breach aversion.

5.2.1 Affective Traits Monitoring

This component aims to detect stress and emotions of the user from input sources such as wearables, mobile devices and physical activity sensors. Fusion and correlation of the collected data will allow their analysis in order to derive affective traits estimators for short and long-term prediction revealing e.g. possible burn-out and extreme fatigue events.

The following figures provide the affective traits monitoring module architecture and physical layer interactions. Data from office cameras and Kinect sensors (if possible) are fused with mobile device captured images and smart band related biosignals to derive stress indicators. A sensor orchestration module collects and synchronizes all information that are subsequently employed as input for image analysis and biosignal analysis. The decision support module evaluates stress and emotions while submits data to long term prediction module.

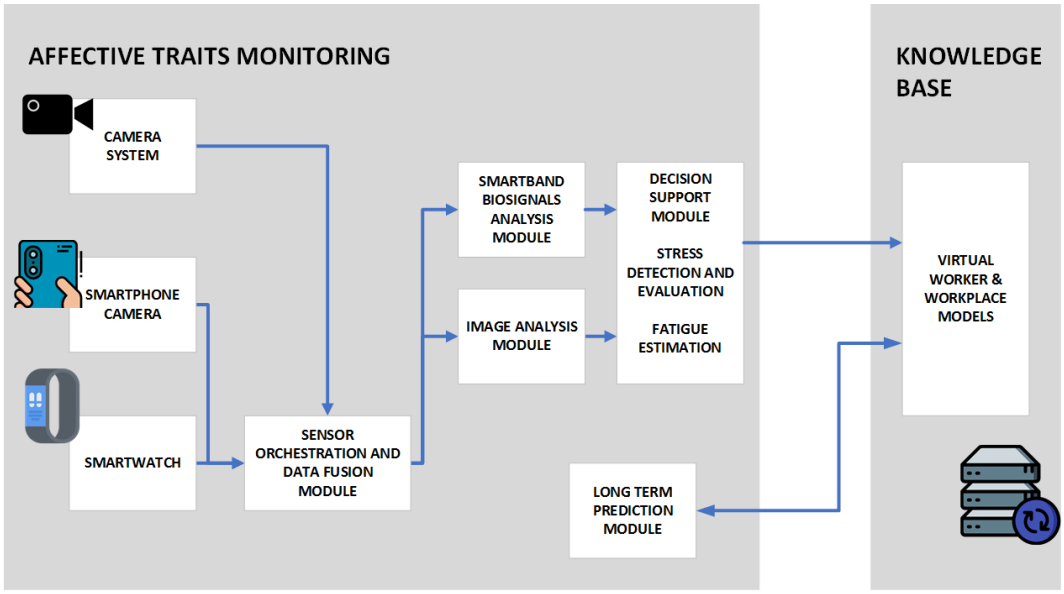

Figure 23: Architectural diagram of the affective traits monitoring module

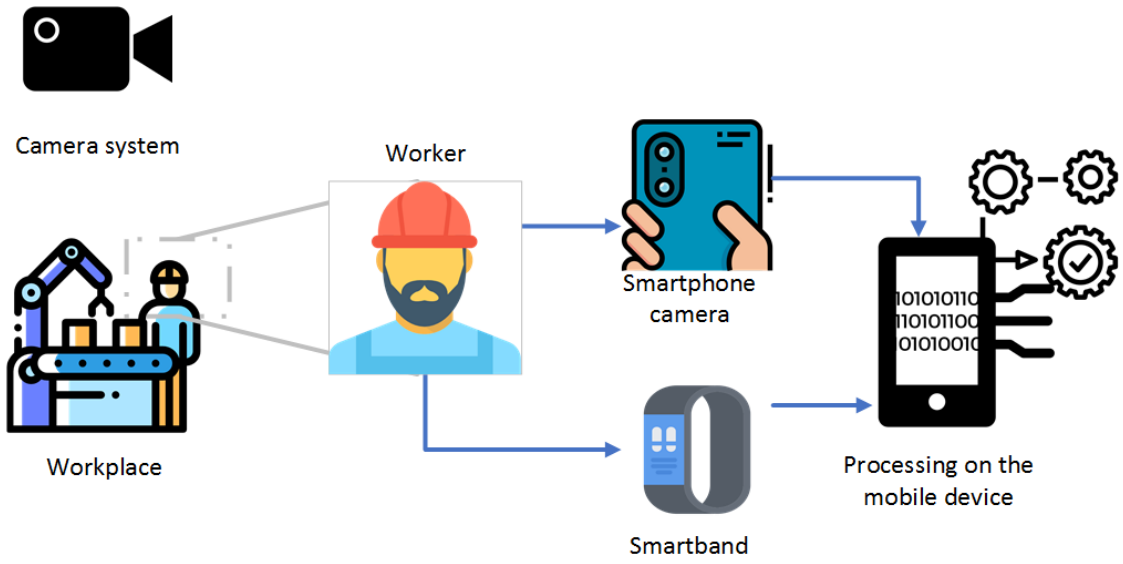

Figure 24 : Visual representation of physical layer of the affective traits monitoring module

Table 13. Summary of the Affective Traits Monitor and related services

Name: ATM	Affective Traits Monitor Component
Description	The affective traits monitor module

Objective	Objective 2: Design a novel unobtrusive worker activity and behaviour monitoring framework, coupling work, on the move and home -based tracking elements		
Related Use Cases	USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH: User emotion estimation provided as input to the virtual coach decisions on user support.		
Related Technical Specifications	TechSpec036, TechSpec037, TechSpec040, TechSpec041, TechSpec043, TechSpec044, TechSpec106, TechSpec107, TechSpec110, TechSpec111, TechSpec132, TechSpec133, TechSpec134, TechSpec135, TechSpec136, TechSpec069, TechSpec105, TechSpec158		
Input	Heart rate, Smart band data, Image from mobile device, Images from fixed camera	**Output**	Detection of stress and identification of emotions. Long term prediction of worker state. Estimation of probability to exhibit acute stress episodes or burn outs

Sub-components	• Analysis module
	  ○ Stress analysis from biosignals
	  ○ Emotion analysis from images
		How they are connected	Upon biosignal reception , the analysis module will generate stress estimators

	• Sensor orchestration and data fusion module	**How they are connected**	The sensor biosignals and captured images and features are extracted. Fusion will be performed in the feature or decision level
	• Prediction module	**How they are connected**	Periodically the prediction module is activated and then the relevant services for upcoming positive or negative situations are updated
List of Services			
ATM1	Collect and fuse data		
ATM2	Analyze smart band biosignals		
ATM3	Analyze mobile camera image inputs		

ATM4	Detect stress
ATM5	Perform long-term detection, estimate probability of acute stress and burn out events
ATM6	Communication with knowledge-base
Hardware	Smart band, Mobile device, Camera

A worth mentioned component of the affective traits monitoring module is the emotion recognition tool. This component is responsible for the tracking of worker's emotions during the day at regular and event-based basis. The emotion recognition can be based on a deep learning approach where e.g. a DNN is trained with a combination of FER2013 and project datasets.

Indicatively, *Figure 25* graphically describes the components of the emotion recognition component. From the left the first component is the DNN trainer component where the datasets are imported as inputs. The trainer trains the DNN model and is based on TensorFlow2.0 and Keras. When the model is trained, it is converted to TFLite model (TensorFlow Lite model) which introduces further size and calculation optimizations in order for the model to run on mobile devices such as smartphones. The TFLite model is uploaded to the server and the Ageing@Work mobile application receives the updated version of the TFLite model.

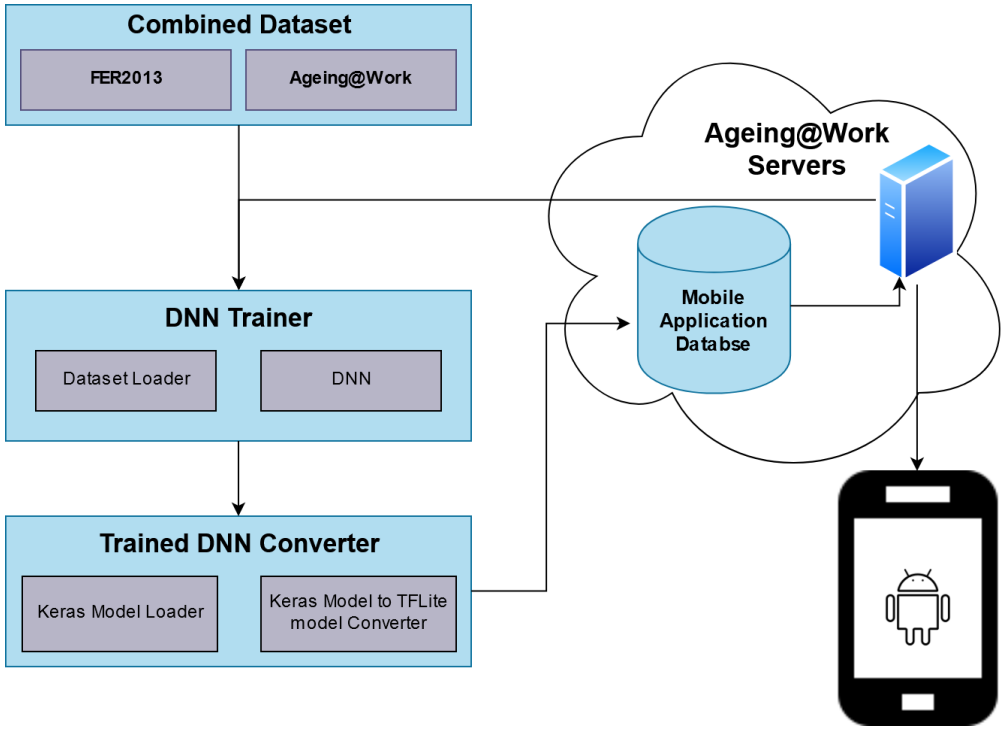

Figure 25 Emotion Recognition sub-module server-side architecture

Figure *26* presents the mobile application sub-component responsible for the user's emotion recognition. In the diagram both the individual components and their timeline of execution is presented. As shown the Ageing@Work mobile application requests from the emotion recognition sub-module a new emotion recognition and the sub-process begins by creating a new Android Activity with Camera Context. The new activity initializes the Face detection feature of Android Camera2API in order to detect in real time the face sub-region of the image. Then an image crop is followed by several conversion filters in order to convert the cropped face region to a suitable format following the DNN input specifications. Along with the Camera Context activity another threaded process runs at the same time, the ERIS (Emotion Recognition Inference Scheduler). ERIS receives the converted images while packing them at batches of 10, which have a good face detection score. ERIS then schedules the DNN model inference with the collected batches and extracts the accumulated result as a list of all available emotions associated with a score. After several batches pass the above procedure, the emotion recognition process finishes and transmits the emotion with the highest score as the final result back to the rest of the mobile application followed by a suitable cleanup execution.

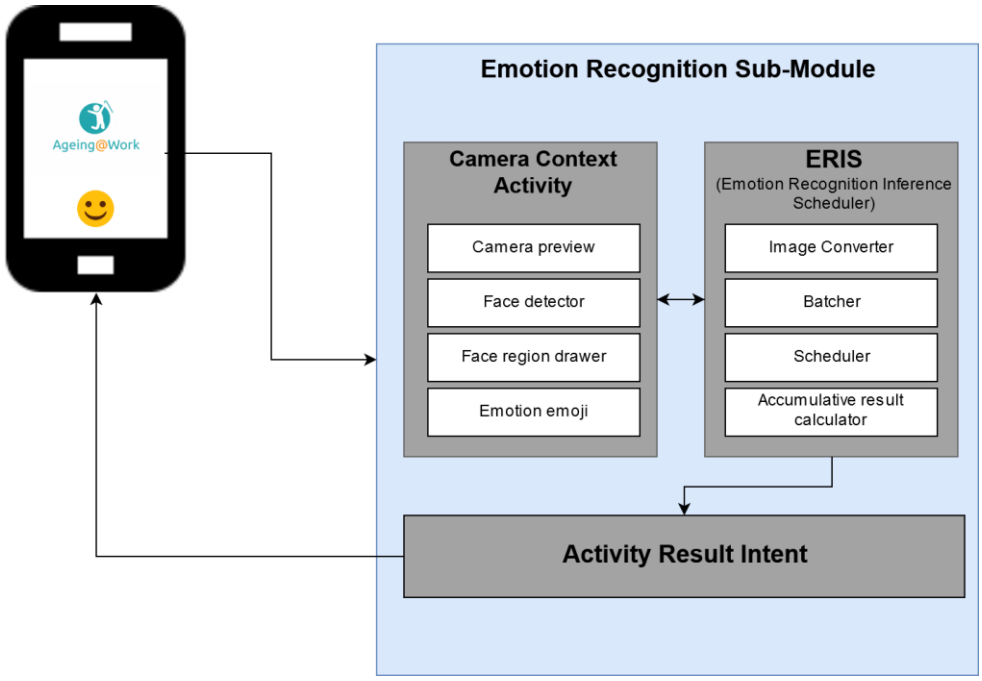

Figure 26 Architecture of Emotion Recognition sub-module of the mobile application

5.2.2 Worker Activity & Behaviour Monitoring

The Worker Activity and Behavior Monitoring (WABM) component is mainly responsible for ubiquitously monitoring important aspects of the worker's activity and behavior at work, at home or while on the move, utilizing the multi-modal data available from the diverse sensory modalities available through the data collection and monitoring middleware that is developed as part of T4.1.

From a technical standpoint, the WABM component comprises a module that is responsible for the classification of the multi-modal time series data coming from the middleware into meaningful representations of user behavior. At the core of this module are machine learning elements able to classify

the time series in real-time according to pre-determined activity labels corresponding to relevant activities. The time series comprise measurements coming from several different types and instances of sensors, such as IMUs (accelerometer, gyro, magnetometer), NFC tags, IoT devices etc. The values are initially filtered and feature augmentation with features of both time and frequency domain is used to improve classification performance and robustness. Subsequently, a convolutional deep neural network performs inference on the augmented time-series and outputs a classification probability.

In addition to activity recognition the WABM component includes a secondary module that contextualizes the recognized worker activities using a wide range of sensing modalities and especially location information.

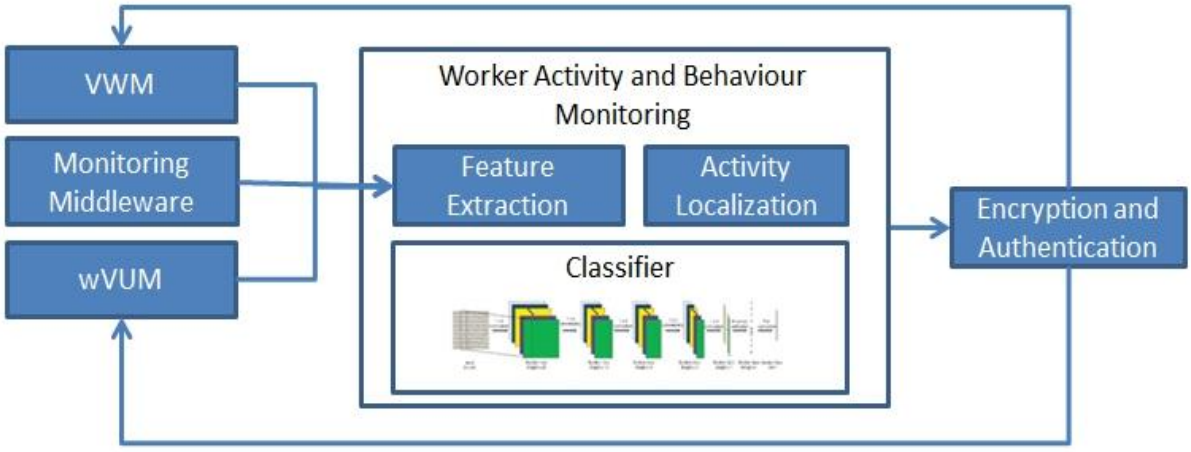

Figure 27. The subarchitecture of the Worker Activity and Behavior Monitoring component (logical view

Table 14. Summary of the Worker Activity and Behavior Monitoring and related services

Name: WABM	Worker Activity and Behavior Monitoring
Description	The Worker Activity and Behavior Monitoring module is responsible for extracting high level semantic data from the low level time-series input by diverse arrays of sensors, and contextualizing those using spatial information about the user.
Objective	Objective 2: Design a novel unobtrusive worker activity and behavior monitoring framework, coupling work, on the move and home -based tracking elements
Related Use Cases	USE CASE 3: SUPPORT FOR MUSCULOSKELETAL PROBLEMS: The WABM component will enable detecting whether the user is performing activities suggested by the system

	USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH: The WABM system will enable further contextualization of relevant analysis based on detected activities USE CASE 7: EMERGENCY/PANIC BUTTON: The WABM component could enable more detailed identification of the emergency through recognition of worker activity		
Related Technical Specifications	TechSpec001, TechSpec030, TechSpec033, TechSpec034, TechSpec035, TechSpec037, TechSpec038, TechSpec039, TechSpec040, TechSpec041, TechSpec044, TechSpec070, TechSpec071, TechSpec111, TechSpec124, TechSpec127, TechSpec135, TechSpec136		
Input	sensor time series from sensor middleware, location, vWUM	**Output**	semantic and spatially contextualized activity information
Sub-components	activity classifying deep convolutional neural network	**How they are connected**	input: sensor measurements from monitoring middleware output: classified activity
	activity contextualization based on spatial data	**How they are connected**	input: worker location, activity classification output: spatially contextualized activity
List of Services			
WABM1	Perform feature extraction on activity time series		
WABM2	Classify activity time series		
WABM3	Store activity sensing and biosignal parameter values		
Hardware	HMD, Tablet		

5.2.3 Online User Activity Monitoring

As part of WP4, the Ageing@Work platform needs to keep records on the user's activities while directly connected to the system, or through the mobile app. This process starts just after the user logging into the

system (gain access to any Ageing@Work resources) and the login token may be used to track the activities that the user has performed while connected to the platform.

The online User Activity Monitoring (UAM) in Ageing@Work will be a component designed to monitor and record of user actions while they use the system and peripheral (connected) tools in order to allow the statistical analysis of the user's actions and help in decision making. The kinds of actions to be captured include -but not limited to- opened pages (url visits), use of apps, buttons pressed, text entered or edited and more. This component will keep step-by-step records of user's actions in a searchable storage format. In other words, it will be possible to searched and investigate individual or group activities in order to identify behavioural patterns in the use of the Ageing@Work system (e.g. knowledge exchange statistics).

The main populations of users who will participate in the Ageing@Work platform are HR managers, health and safety personnel and end-users (blue collar workers and office employees). All users will have access to their personal information collected by the system, while some of them will be able to access parts of other people's data like the consumption rate of the interventions (HSP as intervention content creators) and the overall progress of employees (HR managers).

The next figure graphically presents the logical view of the online user activity monitoring tool. User behaviour analytics is an additional functionality that will help decision makers to keep an eye on critical aspects of the system like the behavioural change support (e.g. adoption of a healthy lifestyle, or the reduction of perceived work-related stress).

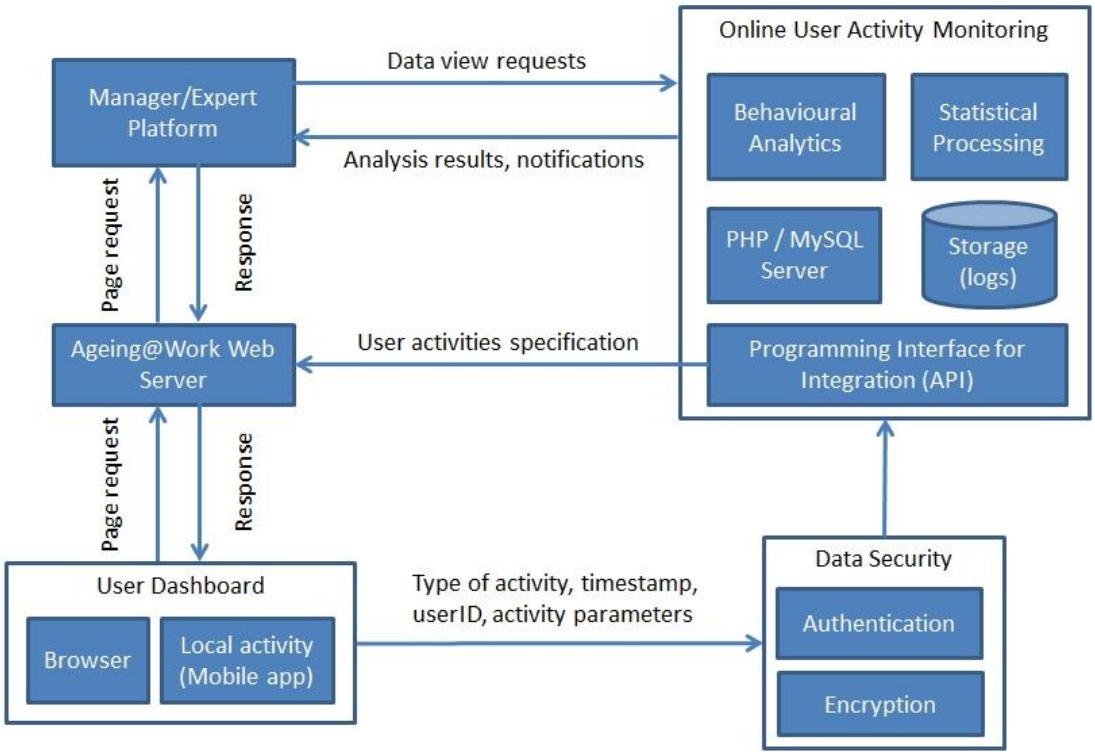

Figure 28. The subarchitecture of the user activity monitoring Tool (logical view)

This is a dedicated software component which analyzes exactly what the Ageing@Work users are doing during their sessions. Health and safety personnel can attach rules like risk factors to specific behaviours and be alerted with a warning on their dashboards (WP3) when high-risk user behaviours are detected (e.g. users not participating in the platform, not consuming the proposed interventions, etc.).

Log file are stored in a storage device different than the rest of the platform. A PHP/MYSQL server makes the user's online activity monitoring available to the rest of the Ageing@Work tools through an API used for integration with the Ageing@Work platform. A list of predefined user actions has to be registered first in the web platform first (what exact user interaction events to monitor). The physical view of the online user activity monitoring is graphically depicted in the following picture and the list of services, input and output on *Table 15*.

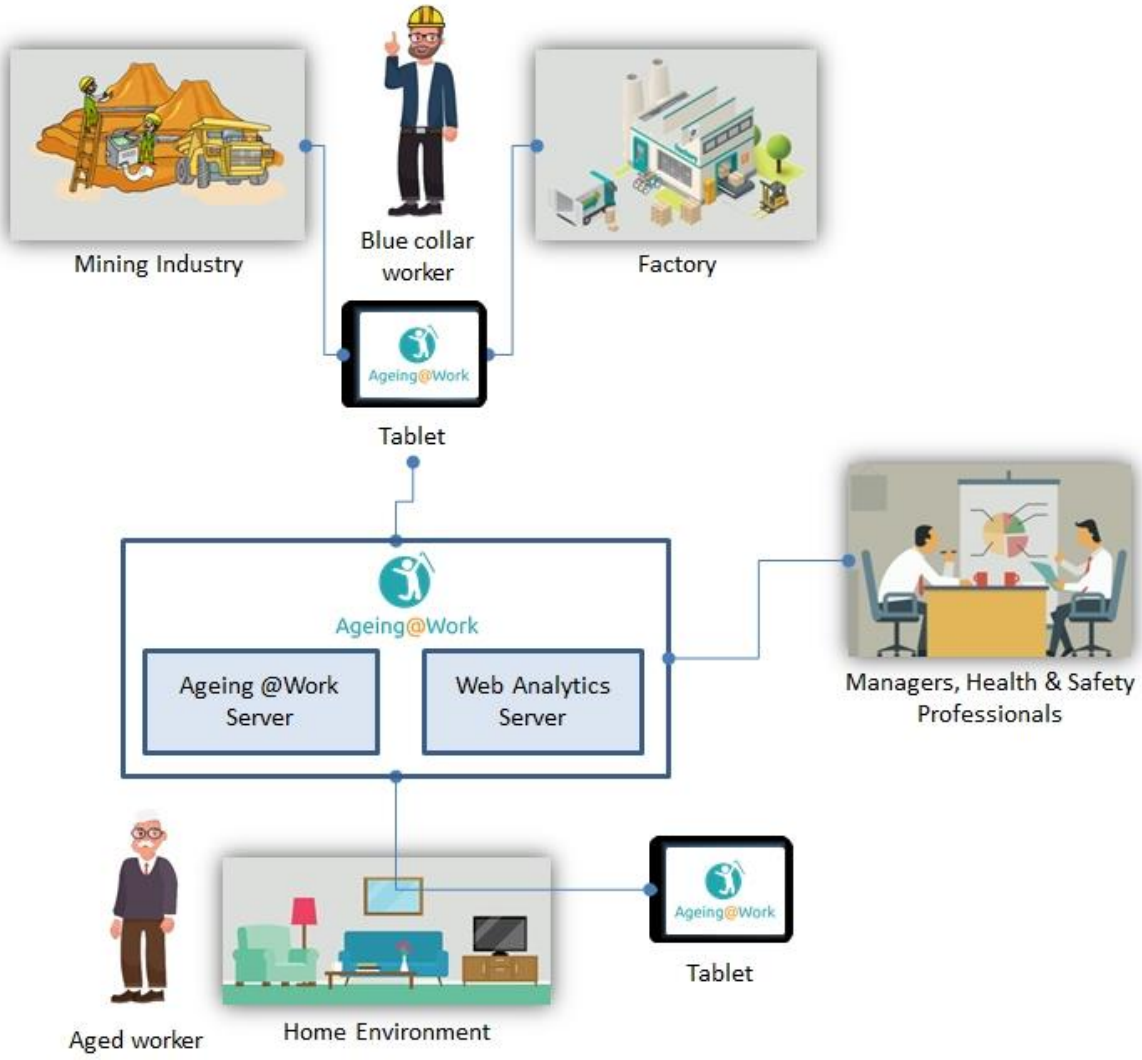

Figure 29. The physical view of the user online activity monitoring

Table 15. Summary of the User Online Activity Monitoring and related services

Name: OAM	User Online Activity Monitoring		
Description	The tool used for online activity monitoring allows the Ageing@Work system to keep records of the user's activity using the standard method of log files. An analysis performed on the log files can provide the managers and Health & Safety Personnel useful information for decision making. There are no real-time monitoring requirements for this component and there are no sensitive data collected, only tool triggering events will be stored (which tool was used, not the purpose of the use).		
Objective	Objective 7: To demonstrate and evaluate the proposed, Ageing@Work framework in realistic conditions with older workers in two major pilot sites, focusing on industrial and mining environments. Obj. 2: Design a novel unobtrusive worker activity and behaviour monitoring framework, coupling work, on the move and home -based tracking elements		
Related Use Cases	All user interaction events performed on the main web platform and the Ageing@Work tools will be saved in log files. These include but not limited to: date and time of logon and logoff actions, pageviews, calls to specific tools and any changes made on the user's personal profile (public part). Indirectly, all Use Cases will generate content (online actions over the Ageing@Work toolset) during pilot studies.		
Related Technical Specifications	TechSpec001, TechSpec003, TechSpec006, TechSpec017, TechSpec018, TechSpec019, TechSpec020, TechSpec021, TechSpec022, TechSpec029, TechSpec031, TechSpec045, TechSpec074, TechSpec075, TechSpec078, TechSpec079, TechSpec080, TechSpec081, TechSpec091, TechSpec113, TechSpec117, TechSpec120, TechSpec128, TechSpec129, TechSpec130, TechSpec131, TechSpec132, TechSpec133, TechSpec137, TechSpec142, TechSpec145, TechSpec146, TechSpec150, TechSpec154		
Input	• Details of the user's driven events • Timestamps	**Output**	Scenario log file with annotations

Sub-components	• PHP/MySQL • API • Visual Analytics • Database • Basic Statistics	**How they are connected**	The API will integrate a predefined list of UI events in the web platform, the event notifications produced by the user monitoring mechanism will be saved in a database different than the rest of the AGEING@WORK system and the behavioural analytics will be available to the managers and admins in a separate UI.
List of Services			
OAM1	Keep track of and observe the influx of page views on the Ageing@Work web platform.		
OAM2	Produce a timestamp based on the server's internal clock and staple it with the rest of the event data in a single entity (log file record).		
OAM3	Visualize the results using visual analytics principles.		
OAM4	Create and apply filters for viewing the logs (user groups, start-end dates and countries of origin).		
OAM5	Allow admin users and managers to explore large sets of log data produced by a group of end-users or even an individual user in a privacy preserving way.		
OAM6	Allow admin users and managers to download the log files in an XML or CSV file formats for further statistical processing –if needed.		
Hardware	Server (physical or virtual)		

The way the online user monitoring services are being consumed by the Ageing@Work platform can be seen in the next UML diagram (*Figure 30*).

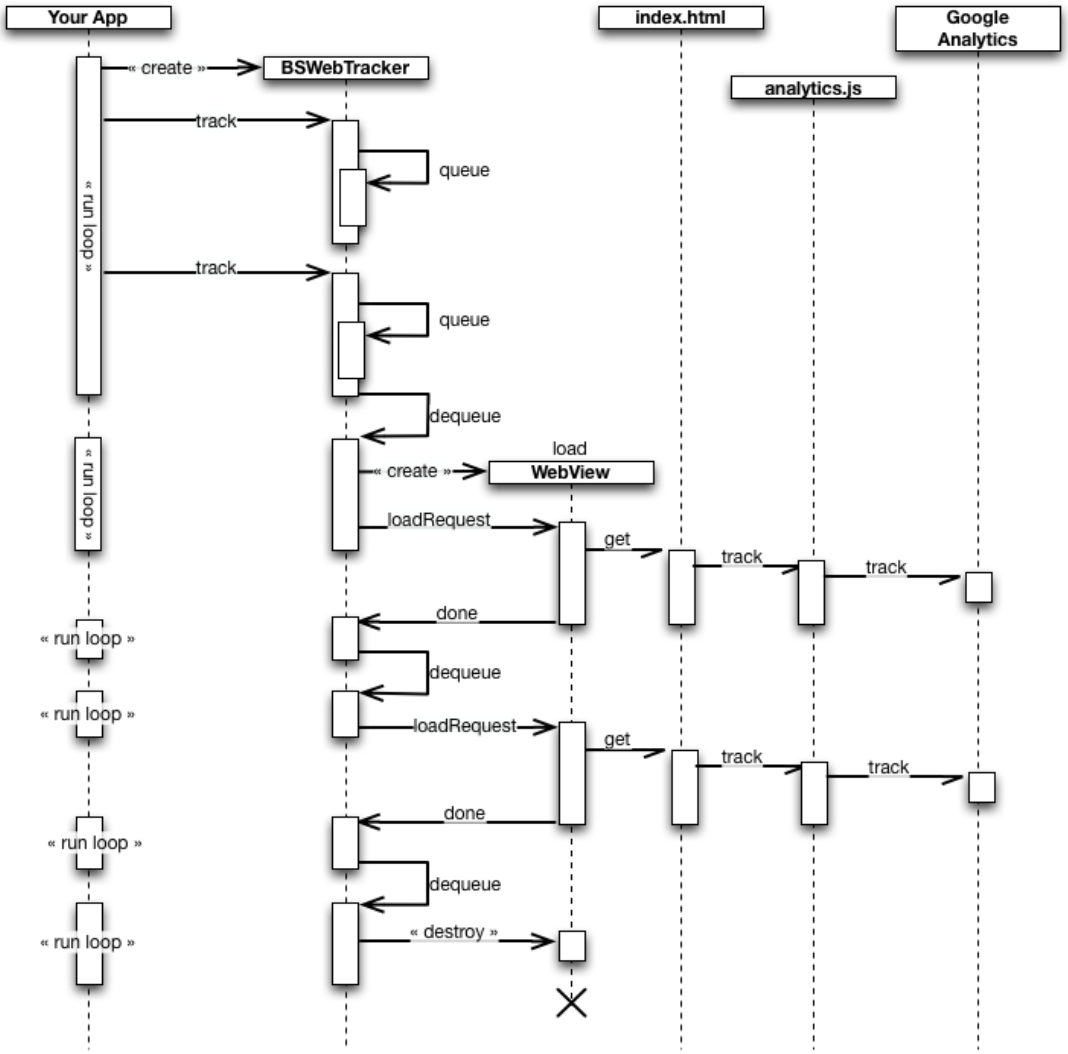

Figure 30. A typical process view of the user online activity monitoring10

The way the user online activity monitoring will be developed from a programmer's point of view can be seen in *Figure 31*. It is worth to note that the web analytics platform will be built around MATOMO[11] web analysis tool or equivalent (e.g. Google Analytics or Open Web Analytics[12]) which will support visitor profiles (to allow processing of personal navigation routes), media analytics (e.g. number of AR recorded sessions downloaded), custom reporting and download of data in a standard format (like CSV and XML file formats) for possible further statistical processing by managers. Moreover the Analytics Web API[13] will be used to request all Matomo reports and to manage websites, users and permissions (add, update, delete).

[10] https://cutecoder.org/programming/web-analytics-desktop-app/
[11] matomo.org
[12] http://www.openwebanalytics.com
[13] https://matomo.org/docs/analytics-api/

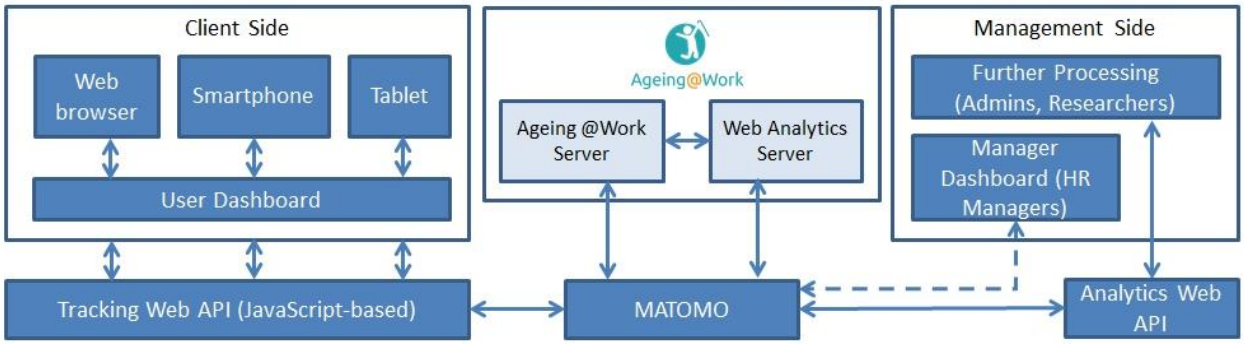

Figure 31. The development view of the user online activity monitoring

5.2.4 eSurveys Engine

The eSurveys engine is a tool dedicated to the management of the electronic surveys to be proposed to the end-users. The resources are groups of closed-questions served as a proposal to workers at a specific frequency, depending on the type of feedback requested and the settings. For example, some surveys may need to be repeated every six months (Quality of Life questionnaire), while others may be proposed to users every single month (some stress detection battery).

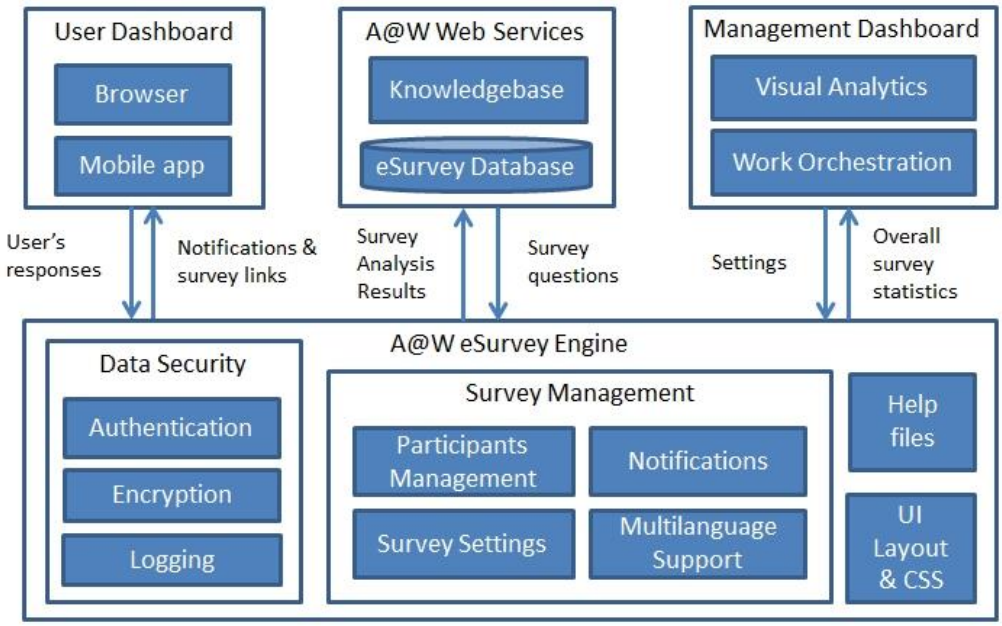

Figure 32. The subarchitecture of the Ageing@Work eSurvey engine (logical view)

The main components of the proposed architecture can be seen in Figure 32. After receiving a notification (including a link), users may use their mobile devices or any other hardware which support a web browser. The user's feedback is a kind of sensitive information as it may include health-related information and personal attitudes against important issues. This is the reason all data coming forth and back need to be

handled through the data security component which is responsible for user authentication, encryption of the sensitive data and generation of the logs files.

The Survey Management is a collection of services which include the management of participants (who is taking which survey, who will be invited next, etc.), the automatic generation and broadcast of notifications to the invitation receivers, handle the settings of surveys, including the language settings.

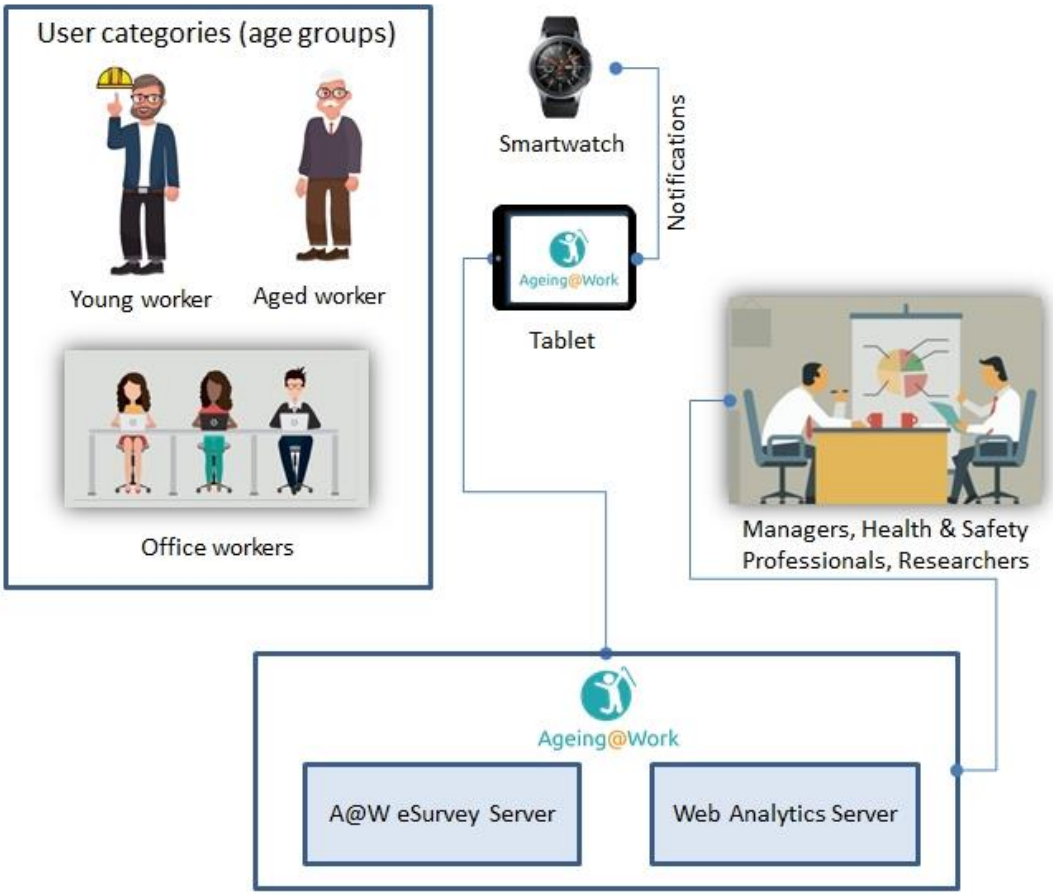

Figure 33. The physical view of the Ageing@Work eSurvey engine

Table 16. Tab of the eSurvey engine and related services

Name: SUR	Ageing@Work eSurvey Engine
Description	The tool is dedicated to the management of the electronic surveys to be proposed to the end-users.
Objective	This component is indirectly related to the project objectives which are based on the concept of services personalization. In order to personalize the AGEING@WORK services and interventions first we need to sense the current physical and mental health of participants, the estimate the Quality of Life,

	quality of sleep, etc. The system will need to have updated estimations of those critical parameters in order to be able to personalize the interventions and physical meetings may not be always the optimal solution for that. The project objectives which this component serves are: • Obj. 1: Enable extensive personalization capabilities to the Ageing@Work supportive approach • Obj. 3: Provide workers with personalized work ergonomics and process design services • Obj. 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics
Related Use Cases	USE CASE 2: PARTICIPATORY WORK ORCHESTRATION. Based on the most recent results of the questionnaires related to workability, quality of life and health, the system will be able to produce personalized recommendations. USE CASE 3: SUPPORT FOR MUSCULOSKELETAL PROBLEMS. Similarly to UC1, the system will rely on the user's feedback on important monitoring parameters to match the muscoskeletal symptoms in an appropriate way. USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH. Similarly to the previous two, health and well-being related batteries will be proposed regularly to Use Case 4 participants to update the user profiles and allow the system to respond accordingly. USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT. Although not explicitly implied by the objectives related the Life Long Learning, Ageing@Work can use the eSurvey to evaluate the learning outcomes of the workers who participate in the learning/training activities. In addition to the Use Cases defined above and in the D2.1, the eSurvey engine could be used during the pilot studies in order to help with the evaluation of the system usability, technology acceptance and other parameters related to specific use cases (evaluation parameters).
Related Technical Specifications	TechSpec027, TechSpec035, TechSpec063, TechSpec130, TechSpec131, TechSpec143

Input	• Survey settings • Questions (in a database)	**Output**	• User's responses • eSurvey activities recorded as part of the log files
Sub-components	• Data Security toolset • Survey management (CMS) • Help files and online support materials • Uer Interface	**How they are connected**	The user dashboard receives invitations and sends survey results (user's feedback) on the AGEING@WORK survey management. Data security works in close collaboration with the survey management and the user dashboard to protect sensitive information.
List of Services			
SUR1	Produce and push notifications for users to take a survey within a predefined time window (depending on the survey)		
SUR2	Receive user's responses (reactions to survey questions) and save them in a database for future reference		
SUR3	Produce overall statistical survey results for individual users and groups of users		
SUR4	Adapt the surveys settings according to settings provided by the managers (settings file)		
SUR5	Apply encryption to eSurveys data		
SUR6	Authenticate users before access to the survey engine (when used outside of the mobile app)		
SUR7	Apply encryption to eSurveys data before transmission to cloud services and storage		
SUR8	Update the logging mechanism for user actions performed on the survey contents		
SUR9	Adopt the contents of the surveys according to the preferred language (English, German, Spanish)		
Hardware	Server (physical or virtual)		

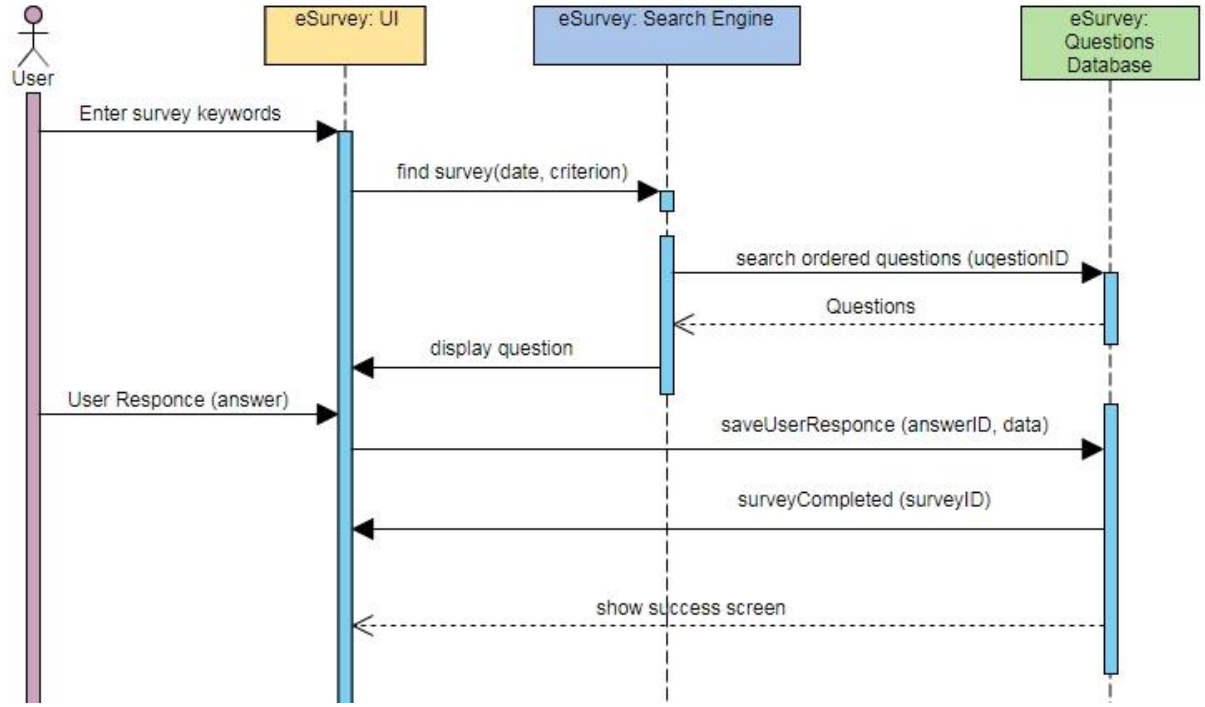

Figure 34. The sequence diagram of the Ageing@Work eSurvey engine

5.2.5 Encryption, Authentication and Security

The Encryption, Authentication and Security (EAS) component is responsible for safeguarding data access and transmission, and ensure secure access control to AGEING@WORK services for workers and management personnel (*Figure 35*).

From a technical standpoint, the EAS component comprises a number of modules that work together to ensure security requirements. The encryption component provides secure data transmission of sensitive data, both within premises of the work site as well as between work and home, for those users that choose to remain available at home. Standard SSL technology is used in all remote connections to mitigate against eavesdropping and man-in-the-middle attacks. In addition, all sensitive data are cryptographically secured upon storage to the AGEING@WORK models. The authentication module presents a simple login interface to the user to allow ease of use when signing in to the AGEING@WORK system.

In addition to the above, all sensitive data-using sessions are managed through a Privacy Guaranteeing Execution Container (PGEC) module, which ensures that sensitive data are handled only as long as it is necessary to complete the task at hand. Finally, the EAS component ensures that private data are anonymized before being used at the management level, in accordance to the opt-in permissions of each worker.

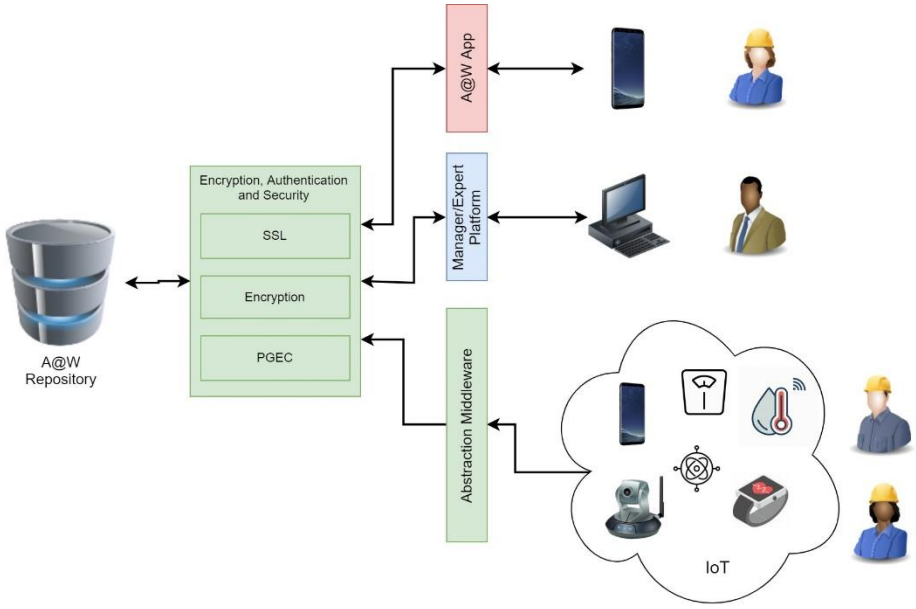

Figure 35. The subarchitecture of the Encryption, Authentication and Monitoring component (logical view)

Table 17. Summary of the Encryption, Authentication and Monitoring and related services

Name: EAS	**Encryption, Authentication and Security**		
Description	The Encryption, Authentication and Security module ensures that sensitive, private data of the workforce are safeguarded and implements mechanisms to prevent intrusions and data breaches.		
Objective	Objective 1: Enable extensive personalization capabilities to the Ageing@Work supportive approach Objective 6: Co-design tools for managers and OSH specialists for improved age-friendly workforce management		
Related Use Cases	USE CASE 2: PARTICIPATORY WORK ORCHESTRATION USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH		
Related Technical Specifications	TechSpec145		
Input	session requests, sensitive data streams	**Output**	encrypted data streams, session responses, execution container

Sub-components	Encryption and SSL module	**How they are connected**	Input: Session request Output: Encrypted session
	PGEC module	**How they are connected**	Input: PGEC request Output: PGEC container information
	Anonymization module	**How they are connected**	Input: Private data-containing records Output: Anonymized data records
List of Services			
EAS1	Initiate encrypted session		
EAS2	Initiate PGE container session		
EAS3	Anonymize data stream		
Hardware	HMD, Tablet		

5.3 Productivity Enhancement Tools

This group of functional component is about tools for enhancing the productivity and workability of the ageing worker. Its objective is to provide services for AR bi-directional communication for remote collaboration, AR services for situational awareness and Life Long Learning Tools (Could-knowledge sharing infrastructure) for helping the workers learn new tasks and skills. The following subsections explain the purpose and structure of each subcomponent.

5.3.1 Augmented Reality Telepresence Tool

Directly related to Objective 5 of the project, this tool will enable ageing workers to collaborate efficiently in a remote setup, to support functionalities like teleconferencing, to receive and offer realistic descriptions of industrial processes. Moreover, the AR tools could also support Life-Long-Learning by providing captured (recorded) sessions of telepresence meetings during unforeseen issues, complex machine maintenance, and support. These materials will be loaded into the Knowledgebase component and will be used by workers who will be willing to learn how to learn new tasks and how to operate/service machines.

The AR telepresence tool will allow bi-directional communication between a worker on site and another one who will connect remotely (e.g. an ageing worker stand-by at home). It is expected that this tool, along with the knowledgebase and the VR tool, will support the productivity of the ageing workers.

From a technical point of view the AR Telepresence tool is described in the following picture. There will be a basic set of background services to allow the AR view work properly, and those include the sensing of the use's location and orientation, the object (machinery) detection in order to let the system know which machines are involved in the scene, the image segmentation which will allow the 3D virtual object to be rendered in the correct position in relation to the world 3D coordinates (shopfloor coordinates).

Next, the AR view will be responsible for synthesizing the view of the user through the AR glasses and includes the graphical User Interface (UI), the pushed (by the system) notifications, the projection of the element that the distant user may be pointing at, and finally the sound processing (alarms and the speech synchronization between the distant collaborators).

To serve the need of educational content provision, the AR component may also offer the possibility to capture telepresence sessions in 2D videos and to upload those materials to the knowledgebase. This functionality will be performed by a lightweight Session Management subcomponent. This architectural element will be also responsible for initialing the telepresence session and for annotating the output 2D video recordings (with metadata like machine ids involved in the study, problems solved, timestamps, worker skills, a description of the physical context, etc.).

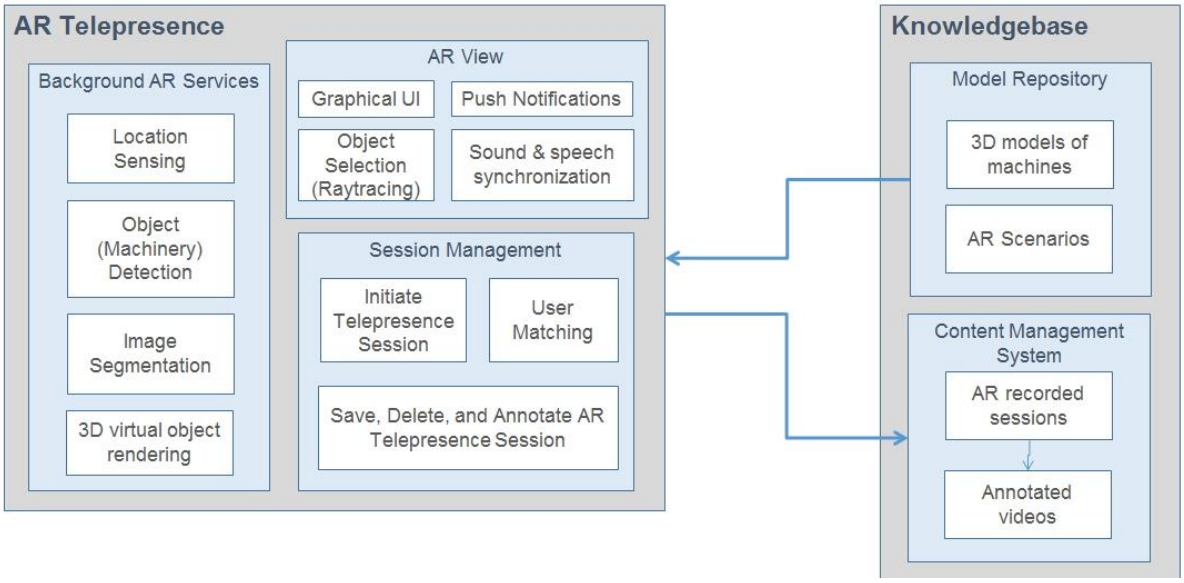

Figure 36. The subarchitecture of the AR Telepresence Tool (logical view)

Error! Reference source not found. graphically presents the logical view of the AR Telepresence tool and it major components. The Background AR services is a group of subcomponents which provide the required back-end functionality like the location sensing (where the user stands in relation to the shopfloor), the object detection mechanisms (identification of the machinery involved in the current AR scenario), the image segmentation (applied on the captured images from the mobile device camera to identify the hot

areas in the machinery interface) and the 3D virtual object rendering (projection of virtual objects in the AR viewpoint). The AR view consists of the user interface, the notifications mechanism (initiated from the system and projected in the AR scene), the mechanism to select an object (raytracing techniques) or machine interface element by distance (home user) and the bi-directional communication between the two far-ends using sound (teleconferencing).

The physical view of the AR Telepresence infrastructure is presented in *Figure 37*. According to the Telepresence use case description, the in-site user (young worker) may rise an issue using the AR Telepresence tool and uses the AR glasses to podcast the image (head camera from the HMD unit) to an experienced user (aged worker) from which he/she asks for advice and support. On the other end, the experienced user can interact through the tablet. The Ageing@Work system works in between to make the telepresence tool work as expected (search the experienced worker with appropriate skills to support the faced issue, initiate the telepresence meeting, and load the 3D models and the scenario to run).

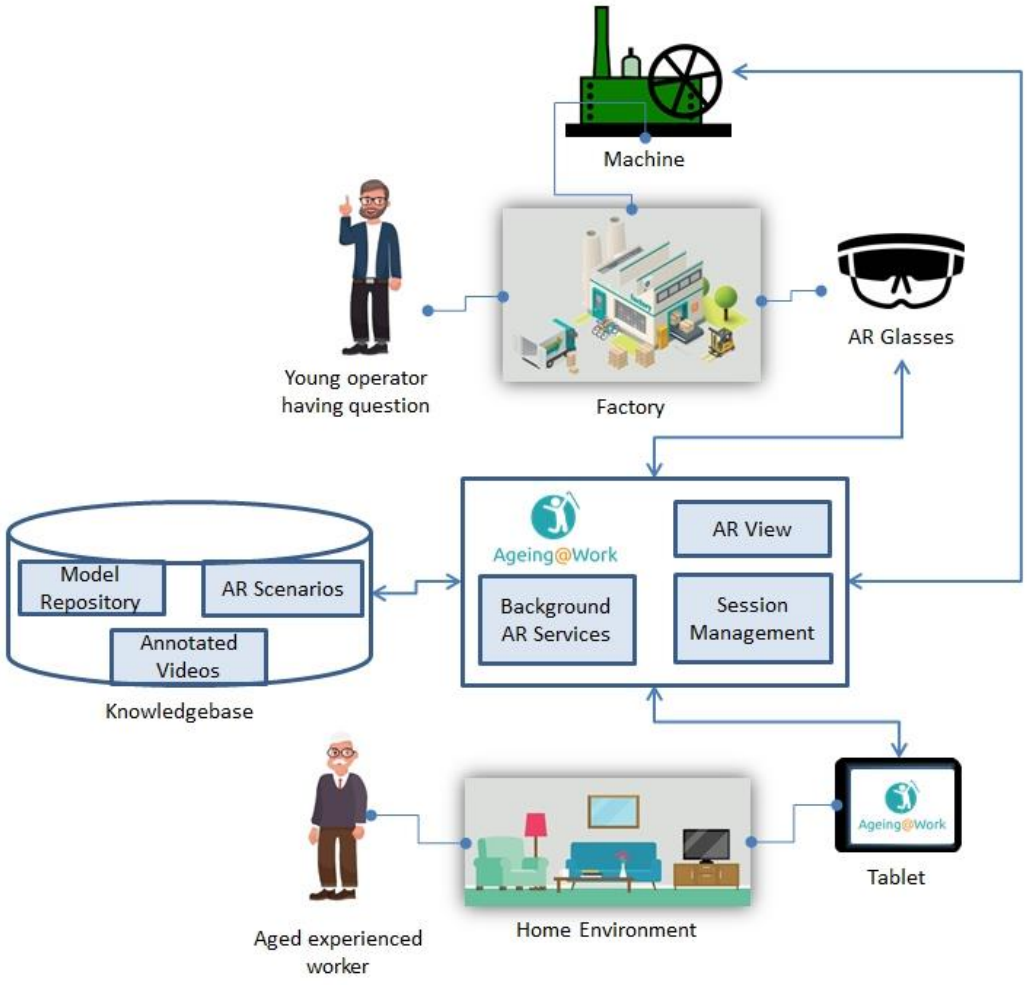

Figure 37. The physical view of the AR Telepresence Tool

The following table summarizes the services that the AR telepresence will offer, the required input, the expected output and the related use cases this tool will be used in.

Table 18. Summary of the AR Telepresence and related services

Name: ART	Component AR Telepresence		
Description	The Telepresence tool comprises the necessary modules that enable AR-enhanced remote collaboration between remotely located and on-site staff, including real-time video and audio transmission, synchronized annotation and remote/on-site collaboration features.		
Objective	Obj. 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics		
Related Use Cases	USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT. The AR telepresence tool will be used to enable remote collaboration between experienced workers and younger ones. It will also be used as source of recorded collaboration sessions between a worker in the shopfloor and an aged worker connected remotely to offer advice and supervision of critical or complex processes. The aged worker will be able to record the telepresence session and later decide if there is an educational value on it before uploading the video to the knowledgebase. USE CASE 1: CHECK-LIST PLATFORM. The AR telepresence tool could also be used by workers in case on unforeseen issues the distant collaboration with the experienced worker will resolve the issue.		
Related Technical Specifications	TechSpec010, TechSpec011, TechSpec016, TechSpec045, TechSpec057, TechSpec061, TechSpec062, TechSpec063, TechSpec064, TechSpec095, TechSpec096, TechSpec122		
Input	• scenario file • orchestration schedule • processed (annotated) 3D Workplace model • scenario file • worker VUM	**Output**	• scenario log file with annotations • video capture
Sub-components	Background AR Services: • Location sensing • Object recognition • Image segmentation • 3D object rendering	**How they are connected**	The location sensing and object recognition will identify the right scene to setup. Image segmentation will help to identify where the 3D objects should be projected.

	AR View: • Graphical UI • Notifications • Object selection • Sound & speech functionality	**How they are connected**	Visual and sound notifications are projected in the UI. Object selection is performed by distant user who is highlighting (finger tap on the tablet screen) a 3D object on HMD. The telepresence experience is completed by sound bidirectional communication.
	Session Management • Initiate Telepresence session • Use matching • Manage session flow	**How they are connected**	The initiation process calls user matching to find the right partner (skills & availability) for a telepresence meeting. The user can accept, pause, or skip the call. The session can be also recorded in the knowledgebase.
List of Services			
ART1	Initiate and establish secure connection between on-site/remote devices		
ART2	Capture object and feature annotations from user of remote device (e.g. tablet)		
ART3	Register 3D objects with 3D working environment for on-site HMD		
ART4	Render 3D annotations for HMD using lighting-adaptive rendering		
ART5	Provide notifications for scheduled telepresence sessions		
ART6	Record, store, delete and annotate telepresence sessions in video recordings (in a web-friendly format) to be used in the knowledgebase		
Hardware	HMD, Tablet, PC		

The way the AR Telepresence services are being consumed by the relevant architectural components (according to the three use cases) can be seen in the UML diagrams of *Figure 38*, *Figure 39*, and **Error! Reference source not found.**.

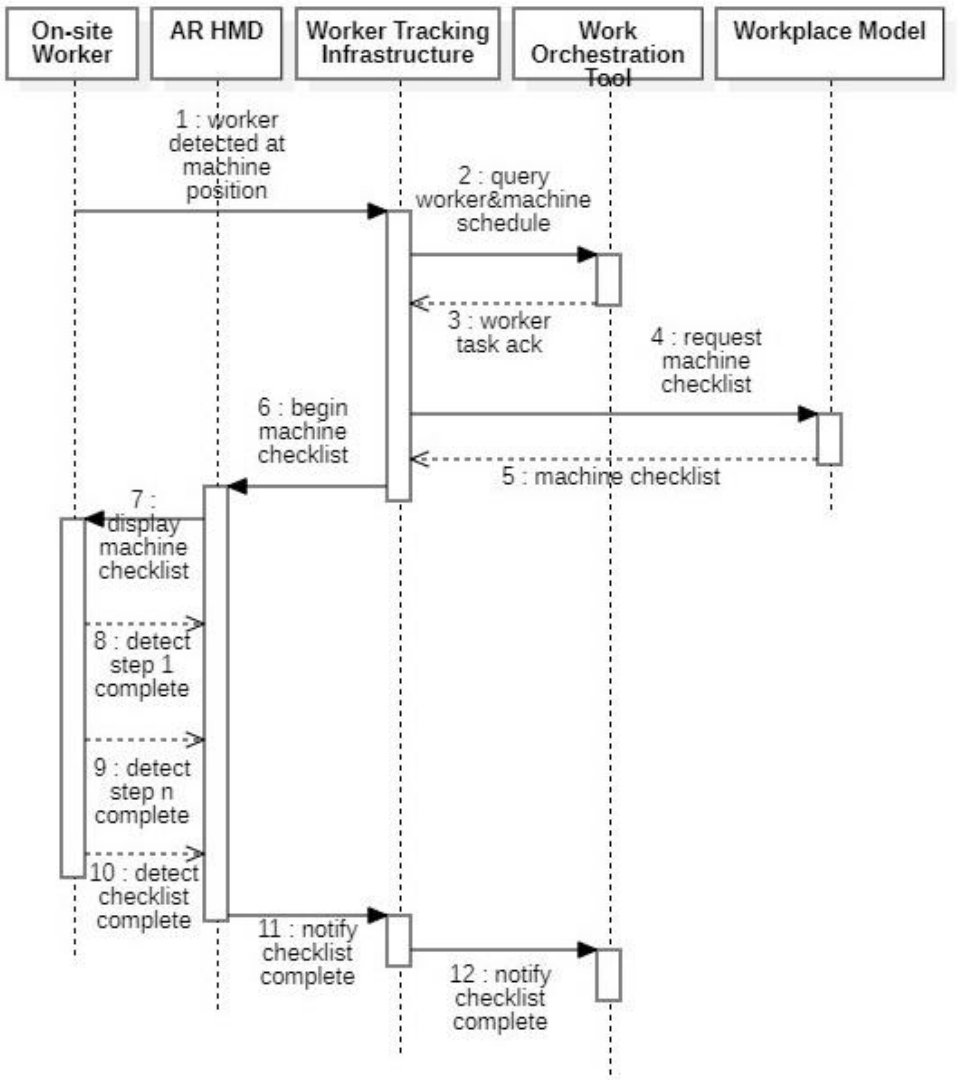

Figure 38. The process view of the AR Telepresence Tool for the use case 1 (Check list platform)

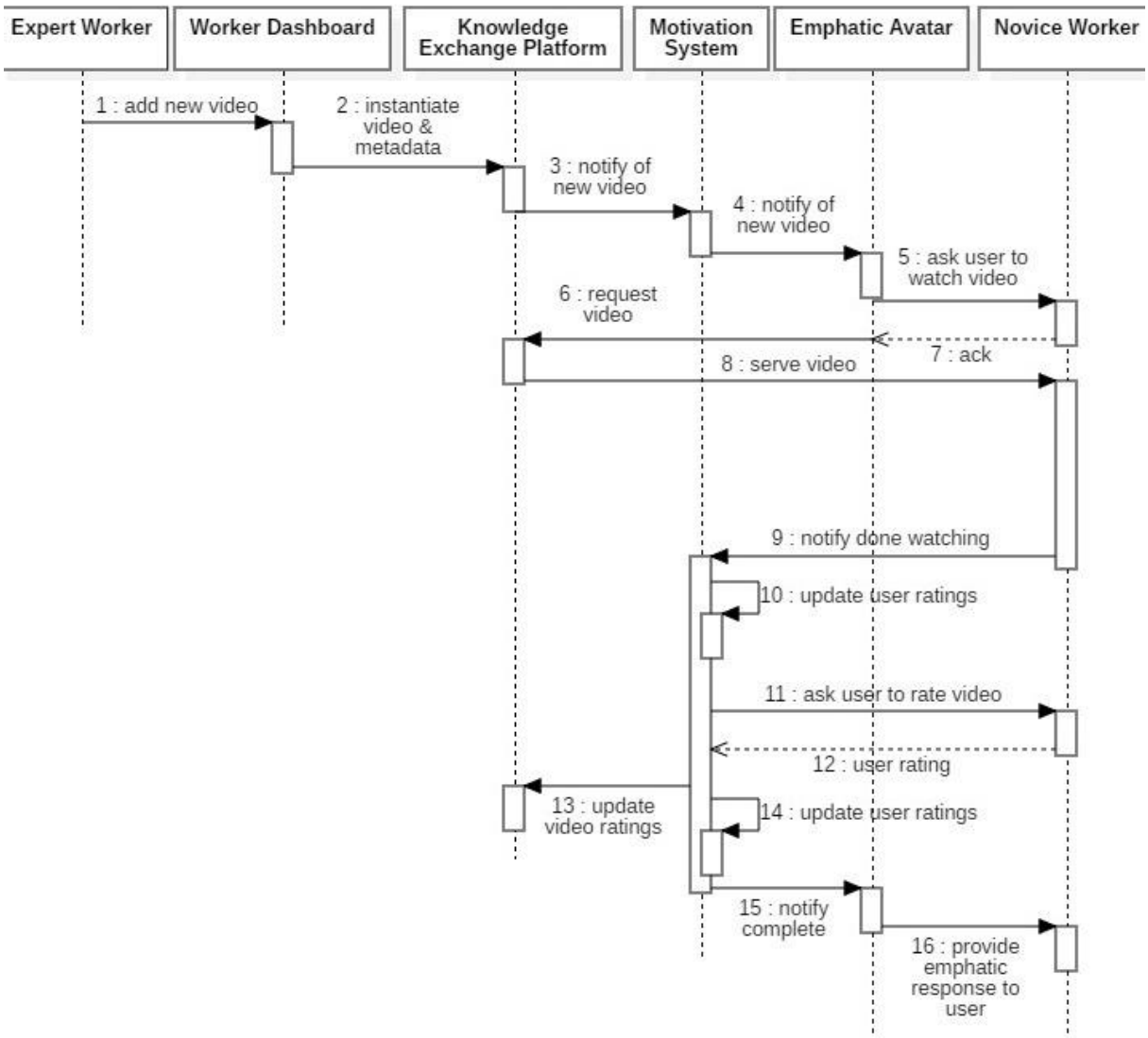

Figure 39. The process view of the AR Telepresence Tool for the use case 5 (Knowledge exchange platform)

The next figure illustrates the system from a programmer's point of view (*Figure 40*). This focuses on how the system is built internally and describes the system components and includes package diagrams as well. The technological elements needed to implement the system include: software, libraries, frameworks and main classes.

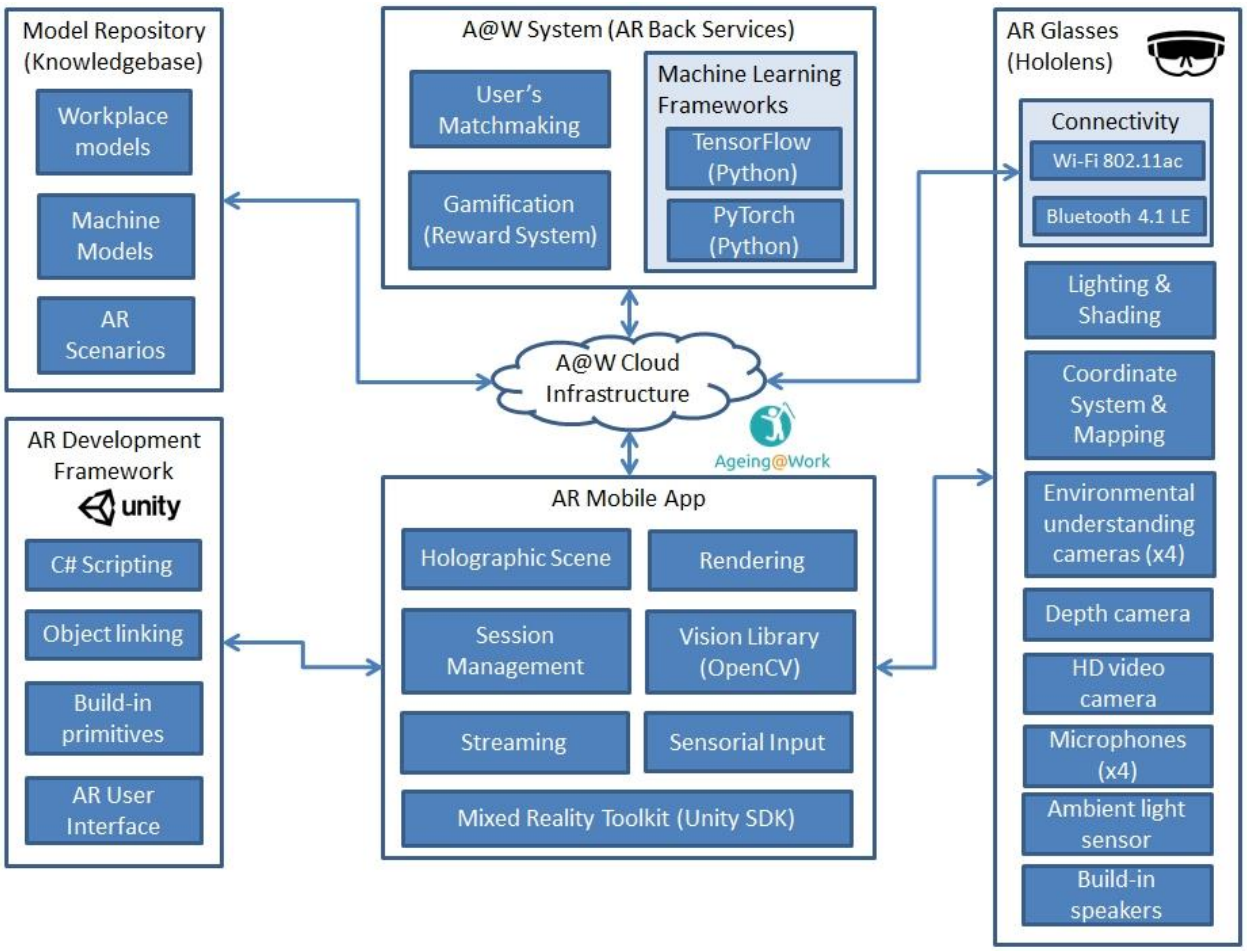

Figure 40. The development view of the AR Telepresence Tool

5.3.2 AR Situational Awareness Enhancement Tools

The AR Situational Awareness Tools (ARSAT) component is responsible for providing notifications and alerts to the worker or operator through a mobile device or HMD that will help increase their awareness, with respect to important events regarding parallel or critical tasks that may take place during the worker's shift, as well as provide guidance in order to promote adequate completion of necessary actions by potentially inexperienced operators, or in cases of emergency.

From a technical standpoint, the ARSAT component comprises a series of interconnected modules that enable improvement of workspace awareness. Initially, video feed from a camera may be provided as input to the object detection and tracking algorithm, which outputs the outline and 3D pose of objects of interest on the workspace. Subsequently, the features are classified using additional input from workspace, machine and process models, so as to provide identification of machine controls and indicators that are relevant to the task at hand. In the next step, the set of identified controls and indicators are filtered based on an estimated probability that a change has skipped the attention of the operator, using an additional feed from the operator's HMD. Ultimately, the filtered set of controls is provided as input to

the AR rendering module, which provides lighting-adaptive rendering of annotations to draw the attention of the user to those changes that have the highest priority or importance.

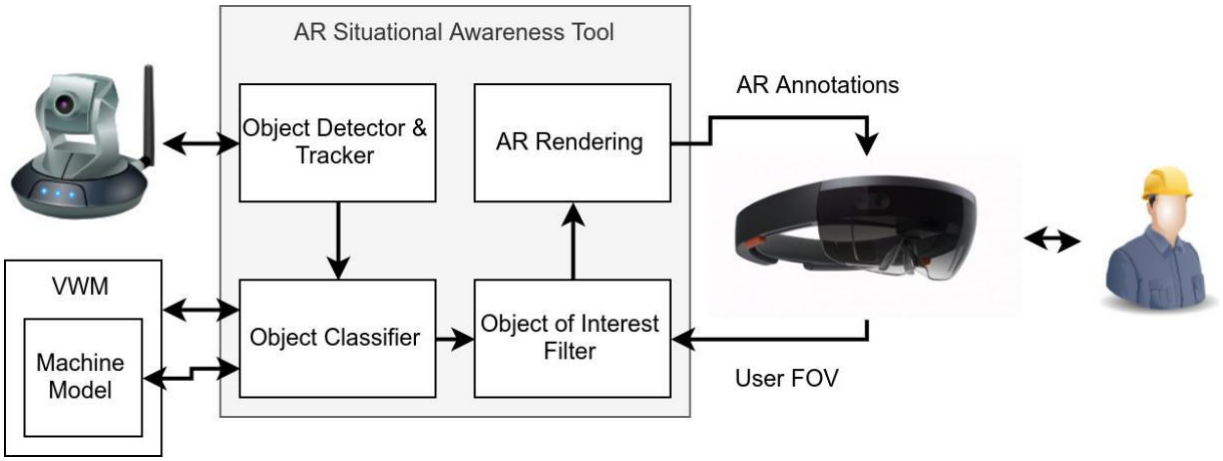

Figure 41. The subarchitecture of the AR Situational Awareness Tool component (logical view)

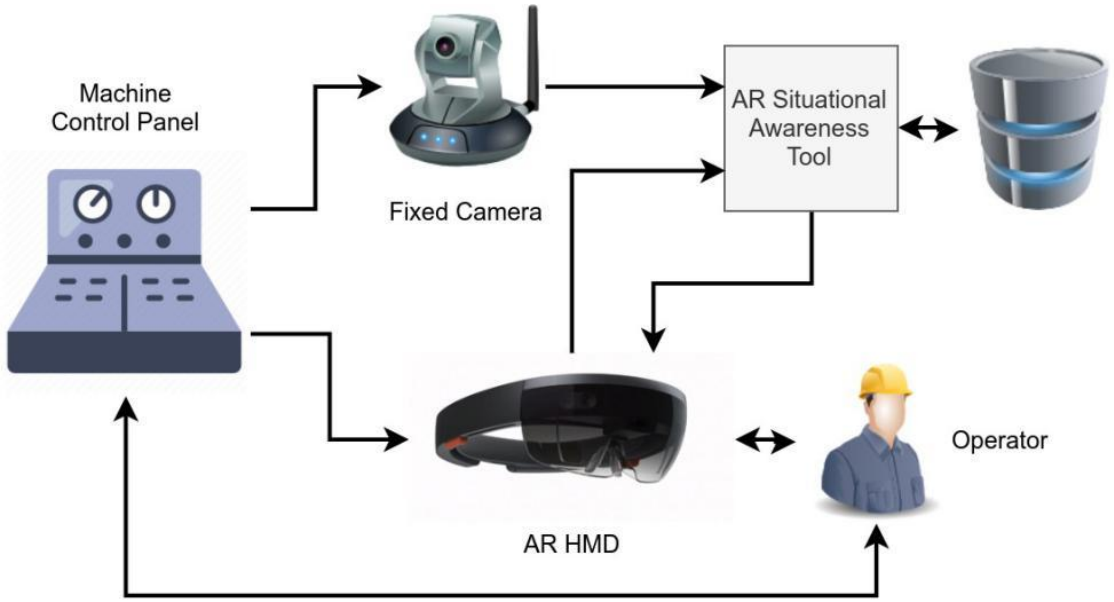

Figure 42. The physical view of the AR Situational Awareness Tool component

Similarly to the above, the ARSAT will be able to provide guidance to operators to assist them in following standard procedures in operation or emergencies. Alongside, the ARSAT component will help workers into the management of multiple parallel processes, as e.g. in the case where a worker has to operate and monitor multiple machines during her/his shift. In such cases, the ARSAT component will be capable to also provide relevant notifications through the worker's mobile device (smartphone) or smartwatch.

Table 19. Summary of the AR Situational Awareness Tool and related services

Name: ARSAT	AR Situational Awareness Tools		
Description	The ARSAT component enables increased operator and worker productivity by improving the situational awareness of a worker/operator as well as providing contextualized assistance related to machine operation.		
Objective	Objective 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics		
Related Use Cases	USE CASE 1: CHECK-LIST PLATFORM: The ARSAT component can assist the operator through highlighting machine controls that are related to each check-list step, as well as indicate, through lighting-adaptive rendering, the proper control operation. USE CASE 6: PRODUCTIVITY ENHANCEMENT TOOLS: The ARSAT component an be used so as to enhance the worker's situation awareness of the worker during her/his shift, either through smartwatch-based notifications, or through AR-based highlights on important information if applicable. USE CASE 7: EMERGENCY/PANIC BUTTON: The ARSAT component could also assist the plant's manager with some highlight for safety critical information.		
Related Technical Specifications	TechSpec001, TechSpec003, TechSpec004, TechSpec005, TechSpec006, TechSpec007, TechSpec008, TechSpec009		
Input	workspace video feed, VWM, wVUM, processed (annotated) 3D Workplace model, scenario, machine description	**Output**	HMD annotations
Sub-components	Object and feature tracker	**How they are connected**	Input: workspace video feed, 3D workspace model, machine description Output: detected object poses and outlines
	Intelligent workspace change detector	**How they are connected**	Input: workspace video feed, 3D workspace model, machine

			description, real-time machine state Output: notification for machine state change / completed machine operation
	Annotations generator	**How they are connected**	Input: detected object poses Output: rendered geometrical objects workspace model, machine description
List of Services			
ARSAT1	Object detection and tracking		
ARSAT2	Intelligent workspace change detection		
ARSAT3	AR annotations generator		
Hardware	HMD, Tablet		

5.3.3 VR and AR Life Long Learning Tools

Life Long Learning Tools will help the worker adapt to changes in the working environment through corresponding, ICT-empowered training processes. These tools consist of components that can support a tutorial process from start to finish. More precisely the ageing worker can record the steps needed to finish one or more tasks and finally create a tutorial. The tutorial can then be encoded and shared using the knowledgebase API. A new worker can download the tutorial and get trained by following the tutorial steps and the indications recorded by the expert. The lifelong learning tools can used in both VR and AR environments.

The recorded tutorial creation session can be encoded to JSON format as a list of tutorial step objects. Each object should contain necessary data to describe a tutorial step, such as the object unique ID, the type of interaction, a human readable comment and the associated voice recording which will be encoded in MP3 file format. The software implementation can be performed in the Unity3D real time development platform, so the tutorial environment can be encoded in Unity Asset Bundles which are archive files that contain platform-specific Assets (such as Models, Textures, Prefabs, Audio clips, and entire Scenes) that can be loaded by Unity at run time.

The less experienced worker will be able to connect to the knowledgebase and choose the desired tutorial. The system will load from the Asset Bundles files of the 3D environment and will set up the scene in VR or

AR. The tutorial JSON description will be decoded and an ordered list of the tutorial steps with the associated voice recordings will be created. Then the tutorial replay mode will begin and the system will indicate to the user the next tutorial step action. At the AR environment this can happens by utilizing the AR awareness tools and the background AR services (*Figure 43*). At the VR environment this can happens by indicating the static objects (e.g. buttons), by changing their material and the dynamic objects (e.g. levers, knobs), by animating ghost objects with the proper interaction to be done with the real objects.

At the AR environment, the tutorial process could be segmented to discrete steps automatically or user controlled. At the automatic steps segmentation scenario this can be done by utilizing the background AR services of the AR Telepresence tool such as object detection, location sensing, image segmentation and 3D visual object rendering (*Figure 43*). After the initial registration of the environment, the AR scene is set up and 3D models form only virtual colliders without visual form in order to detect interactions. At the user-controlled scenario, the tutorials provide visual information to the user about the next steps, but no automatic evaluation is performed, instead the AR telepresence or AR capture is utilized.

The following figure presents in a visual way the features of the platform:

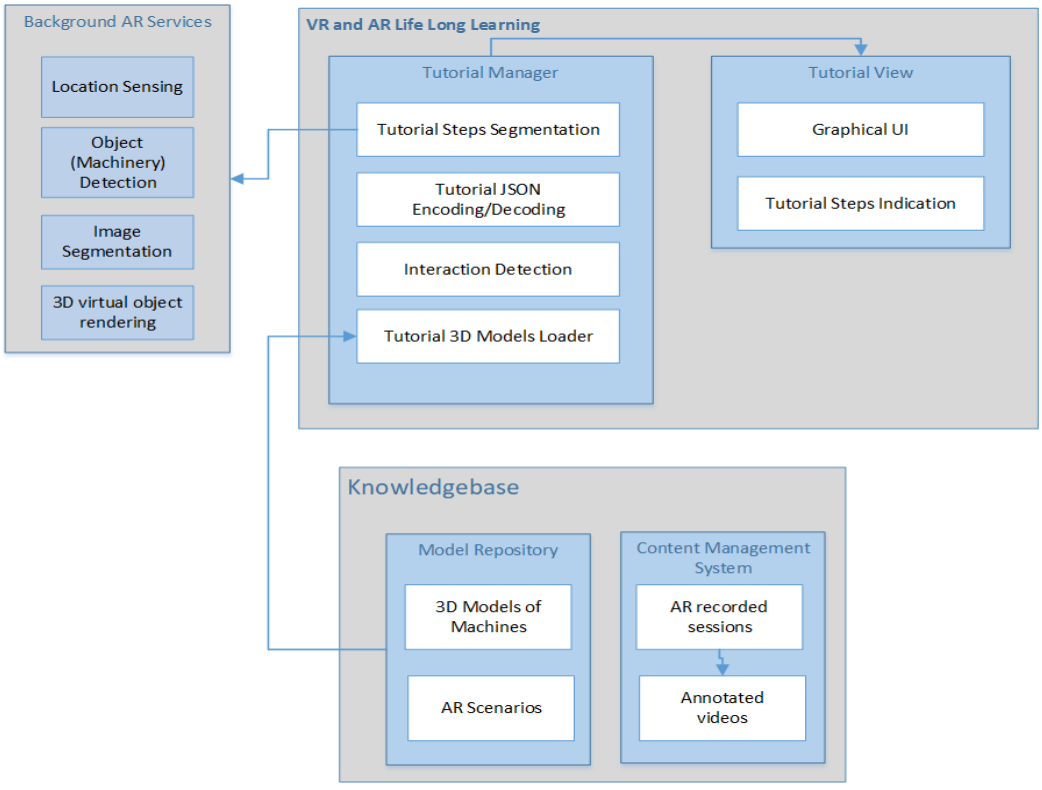

Figure 43. The subarchitecture of the VR and AR Life Long Learning Tools (logical view)

The following table summarizes how the VR and AR Life Long Learning Tools fulfil the Objective 5.

Table 20. Summary of the Life Long Learning Tools and related services

Name: VRARLLT	Component VR/AR Life Long Learning Tools		
Description	The VR and AR Life Long Learning Tools provide the necessary framework so that the more experienced (older workers) can create a VR or AR tutorial and upload it to the knowledge share API. On the other side the less experienced (new) workers can download a tutorial and get trained at home using a VR headset or on-site using an AR headset. In addition, the life-long learning tools can provide training sessions to older workers on new machines that they may need to learn to operate.		
Objective	Obj. 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics		
Related Use Cases	USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT. The VR/AR tutorial framework tool will be used from both the experienced worker, as a tool to create a tutorial, and from the less experienced worker as a tool to replay and get trained by a tutorial. The experienced workers will upload the JSON encoded tutorials data to the knowledge exchange platform, and the less experienced workers can search and download the appropriate tutorial that they want to get trained by.		
Related Technical Specifications	TechSpec046, TechSpec047, TechSpec048, TechSpec049, TechSpec051, TechSpec056, TechSpec084, TechSpec087, TechSpec088, TechSpec100, TechSpec101, TechSpec102, TechSpec146, TechSpec147		
Input	processed (annotated) 3D Workplace model, JSON file with associated voice recordings (in tutorial replay mode)	**Output**	JSON file with associated voice recordings (in tutorial creation mode)
Sub-components	Tutorial Manager: • Steps Segmentation • JSON Encoding/Decoding • Interaction Detection	**How they are connected**	The 3D models loader object gets the appropriate models included in the tutorial, from the knowledge base. The interaction detection object detects interactions in the VR/AR environment. It will also detect the correct sequence of steps needed to complete the tutorial at the tutorial replay mode. When used in AR this tool uses subcomponents of the

	• 3D Models Loader		Background Services component of the AR telepresence tool.
	Tutorial View: • Graphical UI • Tutorial Steps Indication	**How they are connected**	This sub-component is guided by the Tutorial Manager sub-component. The tutorial steps and actions detected by the tutorial manager are converted to visual and sound notifications projected in the UI showing the progress of the tutorial. The indication of the objects and the required actions is performed by material indication and semi-transparent animations.
Hardware	PC, AR/VR Headset		

The following UML diagrams (*Figure 44* and *Figure 45*) can be used to describe both use cases. The first diagram presents the use cases from the aged expert worker side and the second one, from the new worker side.

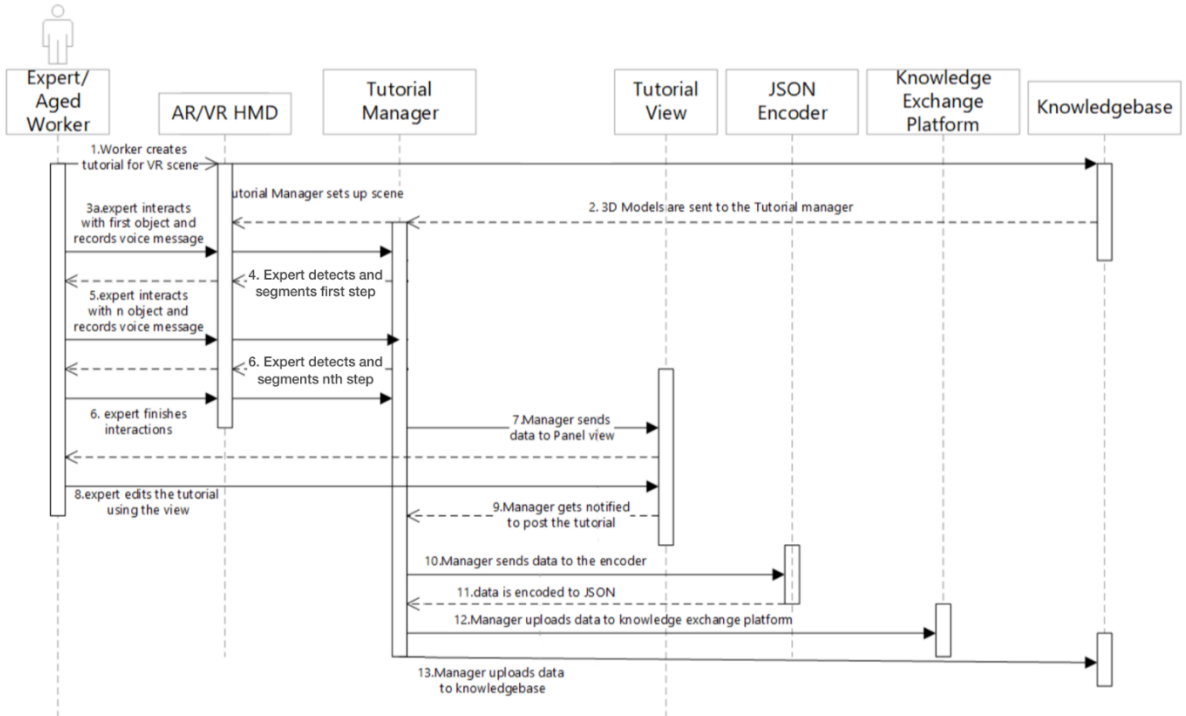

Figure 44. Expert worker creates a new tutorial and uploads it to the Knowledgebase

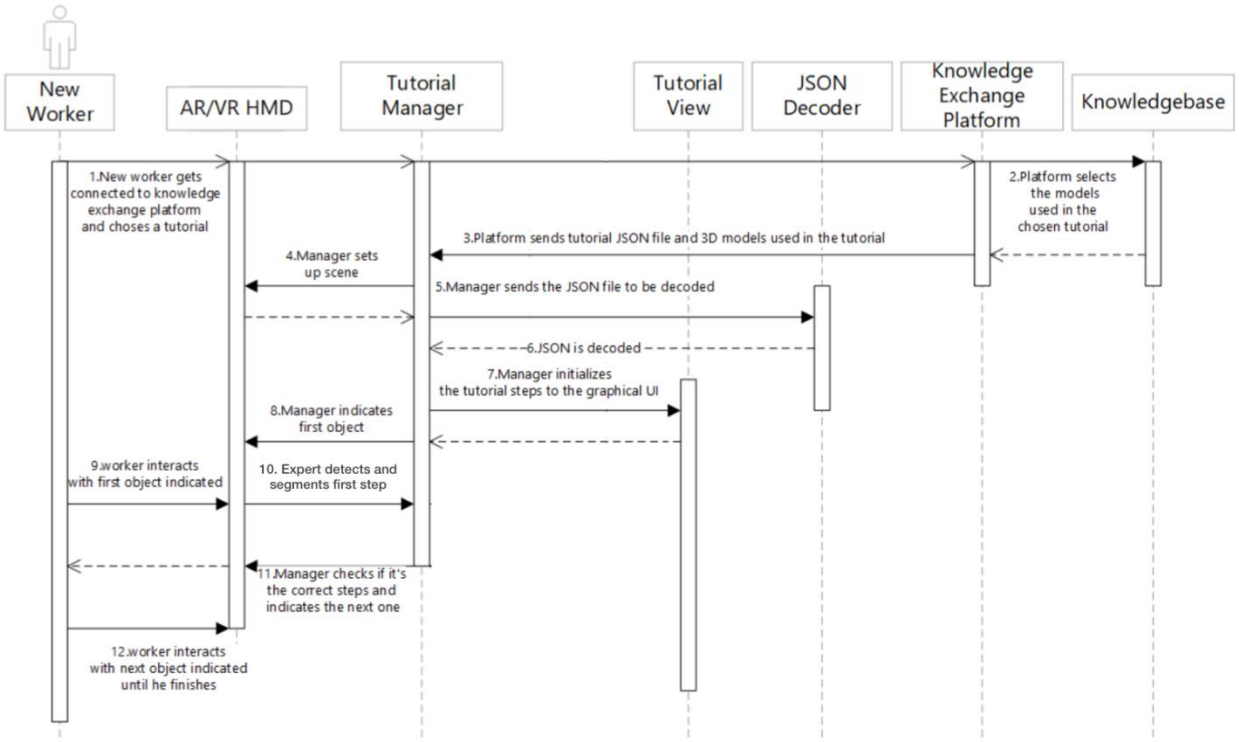

Figure 45. New worker selects a tutorial from the Knowledgebase, accesses and interacts with it

5.3.4 Knowledge sharing tools

Within the scope of T6.3, a knowledge sharing platform is to be implemented to accommodate for both training and engaging workers as well as supporting the interaction between them. The platform aims to support worker's engagement in the manufacturing process, by enabling them to interact and share contextually relevant knowledge, ideas and good practices.

From a technical point of view, the platform can be based on the NodeBB forum engine, which is a full-fledged community platform. It is implemented on NodeJS, a popular and powerful JavaScript framework. NodeBB is also mobile-ready, easy to use and configure via an intuitive administration panel and provides extensibility features in the form of plugins and widgets. In addition to being open-source, it has a big and active community which maintains the software, which in turn means frequent and stable releases with new functional and, most importantly, security features.

In the context of T6.3 and to better facilitate the training of workers, a custom form can be integrated into the platform, with the necessary elements every training has to include and which in turn produces a uniform template to better navigate the contents of each training form. More relevant tools will also be developed and become integrated into the platform, to provide a seamless experience enhancing the knowledge sharing and communication between workers.

To cater for the social aspect of the tools, the reputation system already incorporated in the platform will be further enhanced to include gamification elements. Blended with social media features, like up/down-voting, following other people and posting to other social media, the platform will aid workers' engagement and reward them for contributing.

These tools will communicate through proper routes with the Knowledgebase, in order to store and retrieve valuable technical information, training material as well as best practices for both the manufacturing process and workspace procedures. As a side effect (and a really important one!) the platform also enables the creation of user groups to better organize communication and manage the flow of information, workspace and trainings announcements.

The following figure (*Figure 46*) presents in a graphical way the features of the platform.

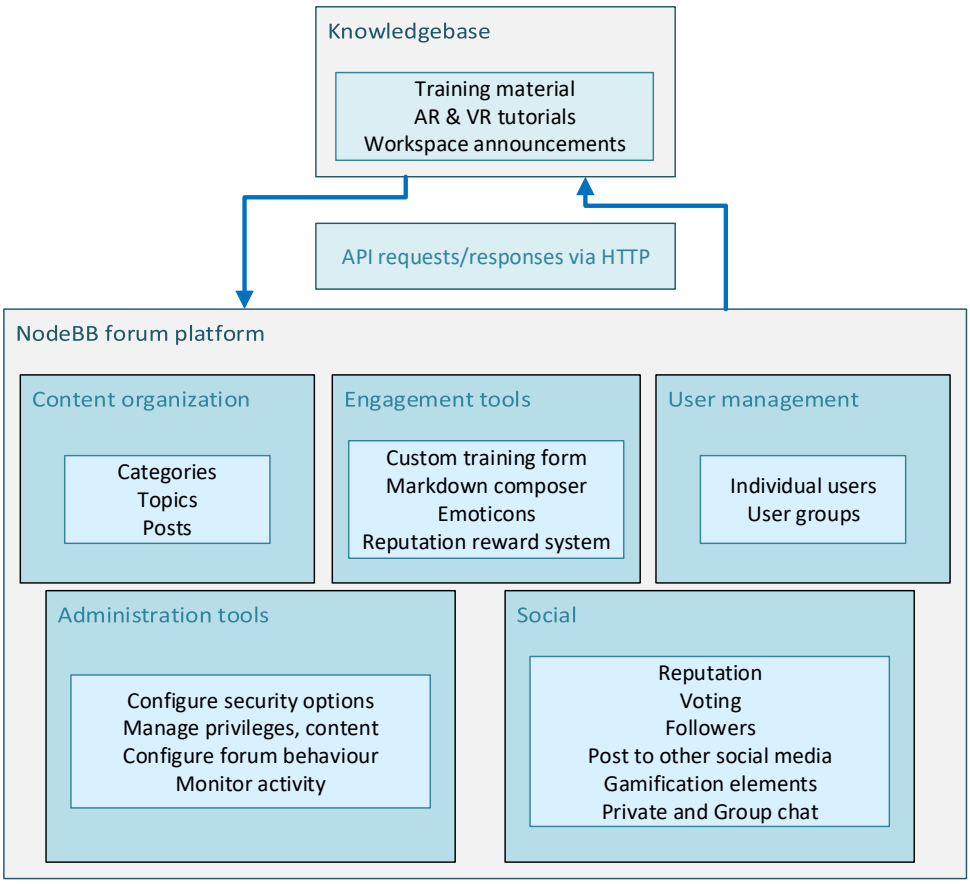

Figure 46. Knowledge sharing tools - Features overview

Table 21. Summary of the Knowledge sharing tools and related services

Name: KST	Component: Knowledge sharing tools

Description	The knowledge exchange platform comprises the modules that provide bidirectional access to the Knowledgebase as well as the elements that provide for the user an engaging and easy to use experience.		
Objective	Obj. 5: To support workers' engagement in the manufacturing process, by enabling them to interact, gather and share contextually relevant knowledge, ideas and good practices		
Related Use Cases	USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT: Novice worker access the web platform and creates a new question for the machine A for the process X [Flow 1]. Expert access the web platform and responds to a worker question (perhaps to the above) [Flow 2]. The platform rewards workers for contributing by answering questions they have expertise on.		
Related Technical Specifications	TechSpec050, TechSpec089, TechSpec090, TechSpec091, TechSpec099, TechSpec148, TechSpec149, TechSpec155, TechSpec156		
Sub-components	Content organization: • Categories • Topics • Posts	**How they are connected**	Content is organized in Categories > Topics > Posts easing organization and navigation for the users
	Engagement tools • Custom training form • Markdown composer • Emoticons • Reputation reward System	**How they are connected**	Custom training form provides a uniform way to present tutorials and training material. Markdown composer makes for an easy input tool, to quickly write and format new posts. Emoticons are a game-like little feature promoting comfort of use. Reputation system, rewards users for contributing to the platform and engaging with the community.
	User Management • Individual users • User groups	**How they are connected**	Individual users may belong to user groups. Admins may set different privileges at the

			platform for individuals and/or user groups.
	Administration tools • Configure security options • Manage privileges, content • Configure forum behavior • Monitor activity	**How they are connected**	The administration tools provide an easy and intuitive way to manage the platform, without needing to dive into the code. They also include monitoring tools to always be in control of the platform's status.
	Social • Reputation • Voting • Followers • Post to other social media • Gamification elements • Private and Group chat	**How they are connected**	These features enhance interaction and collaboration between users.
List of Services			
KST1	Store/Retrieve information and data to/from the Knowledgebase		
KST2	Upload images, files and training material to the Knowledgebase		
KST3	Individual and group chatting		
KST4	Personalized user profile page		
KST5	Notify users for material marked to be "watched"		
KST6	Reward users for contributing to the platform and engaging with the community		
Hardware	Smartphone, Tablet, PC, Server		

The aforementioned use-case is presented in the following UML diagram (*Figure 47*).

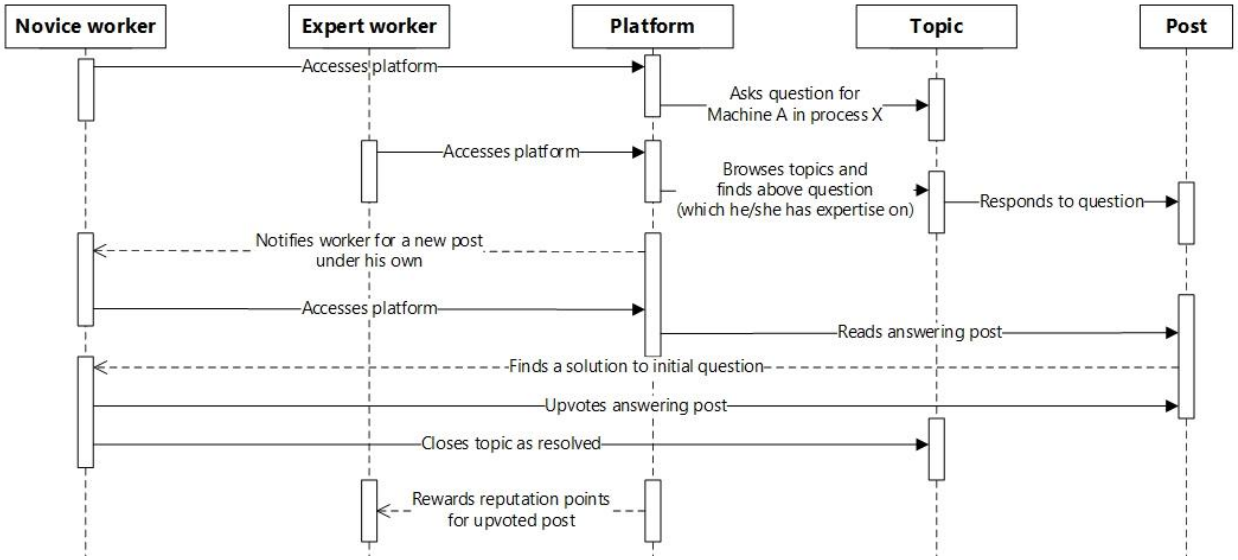

Figure 47. A novice worker accesses the platform and asks a question, which an expert worker replies later on.

5.4 Manager/Expert Platform

This component comes into the Ageng@Work architecture to group together the Manager's Dashboard the Participatory Work Orchestration Optimization Support Tool and the Data Aggregation Tool. Two other components to mention as part of the manager platform is the Visual Analytics platform used to visualize the results and allow users (managers) to interact with graphs (filter data, create data views, etc.), and the algorithmic part of the optimization mechanism that is the Optimization Algorithms applied on the shift plans in order to propose the optimal solutions.

5.4.1 Participatory Work Orchestration Optimization Support Tool

This component is responsible for supporting work orchestration decisions by applying convex optimization (minimization of cost functions over given time frames) in two levels:

User level: Having as input the personal profile of the worker including his/her abilities, working skills and the forthcoming scheduled tasks the system will provide personalized recommendations like work from home, have long breaks or change working position for a while. As set of optimization criteria and convex optimization algorithms will determine the operation of the system, while the automatically produced recommendations will have to be accepted by the user first and then shared with the HR manager to ask for approve.

Shopfloor level: In a group level, a multicriteria optimization approach will be applied on tasks assignments to help managers organize forthcoming shifts in an optimal way. In this mode, the Participatory Work Orchestration Optimization Support Tool will take into account all the available information, including worker profiles, machinery involved and planned tasks to solve complex job assignments and task scheduling problems.

The tool is connected with the visual analytics component to present large amounts of collected data and evidence of the optimization algorithms to support the recommendations. This component will be merged into the Management Dashboard. The most common minimization problems will be tested according to the hierarchical representation of the related solutions as seen in Figure 48.

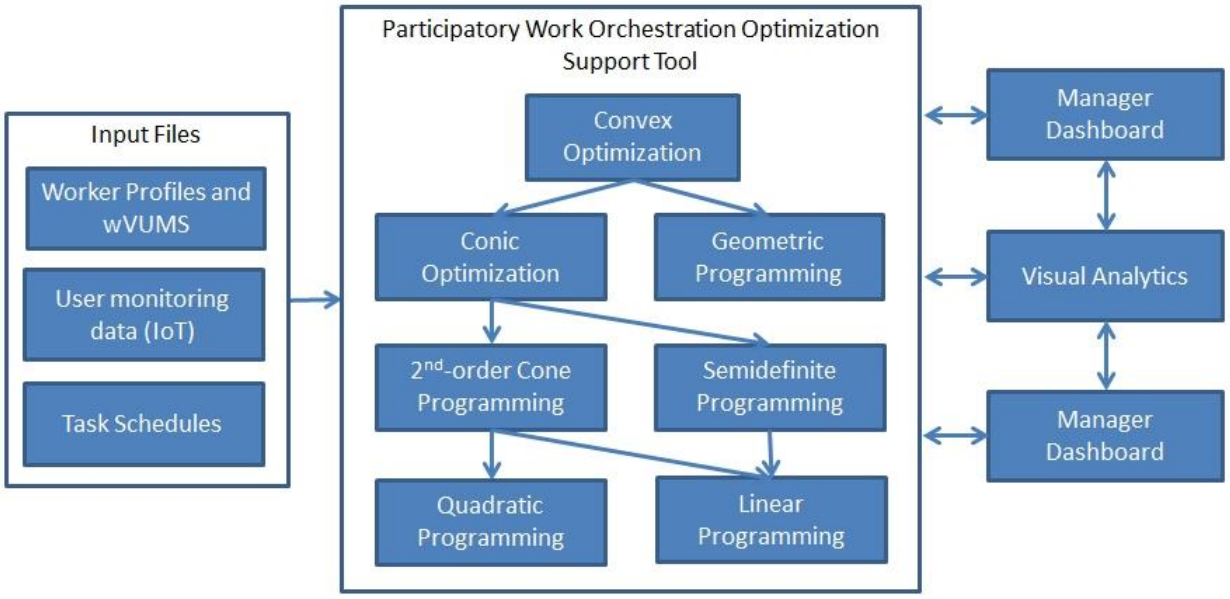

Figure 48. The subarchitecture of the Participatory Work Orchestration Optimization Support Tool (logical view)

Table 22. Summary of the Work Orchestration Optimization Support Tool and related services

Name: WOO	Participatory Work Orchestration Optimization Support Tool
Description	This Participatory Work Orchestration Optimization Support Tool will take as input user models tasks scheduled shifts and all other related information in order to support work orchestration decisions for both the end-users (worker) and the managers.
Objective	Objective 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics Objective 6: Co-design tools for managers and OSH specialists for improved age-friendly workforce management
Related Use Cases	USE CASE 2: PARTICIPATORY WORK ORCHESTRATION: The system will automatically generate personalized recommendations for optimal shift schedule for workers

	USE CASE 6: PRODUCTIVITY ENHANCEMENT TOOLS: This is the second case in which the system will automatically generate recommendations for mangers taking onto account all available information for all workers involved in a group		
Related Technical Specifications	TechSpec017, TechSpec018, TechSpec019, TechSpec020, TechSpec021, TechSpec022, TechSpec023, TechSpec024, TechSpec025, TechSpec026, TechSpec027, TechSpec028		
Sub-components	• A classification of Convex optimization algorithms • A report generation component to deliver the results to the visual analytics platform	**How they are connected**	The Participatory Work Orchestration Optimization Support Tool receives from the AGEING@WORK database all related information and finally generates recommendations. Although not explicitly reported as components, there are two 'modes' (ways to operate): one for the worker and one for the manager
List of Services			
WOOS1	Search and retrieve form databases all information related to a shift (machine profiles, wVUMs, scheduled tasks, current shifts plans, reported requests, etc.)		
WOOS2	Apply convex optimization algorithms to solve complex job assignments and task scheduling issues		
WOOS3	Report results in a suitable format for the visual analytics platform		
WOOS4	Apply user-reported settings for using more than one convex algorithm according to the type of optimization problem under study		
WOOS5	Produce personalized results for the data of a single user (worker)		
WOOS6	Produce results for the data of a group of users or even a whole shopfloor		
Hardware	AGEING@WORK Server		

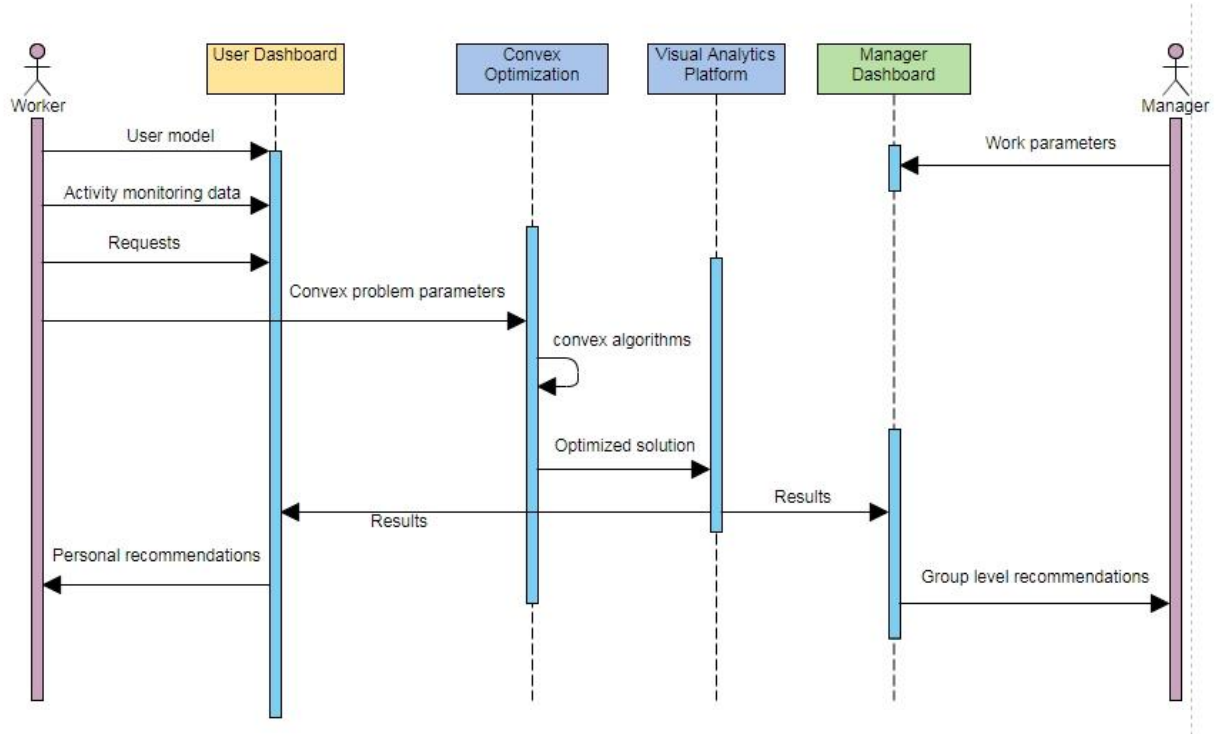

Figure 49. UML diagram of the shift optimization process

5.4.2 Manager Dashboard

The Manager Dashboard was designed to provide managers and Health & Safety Professionals access to data processing results in shop-floor level or for a group of workers, a view that presents information relevant to the achievements of worker groups they manage (award system), a simple to use interface to insert/edit the reward system rules and an intervention authoring environment. The last one will be used by Health & Safety Professionals to propose various kinds of interventions according to the type of user needs. Those include proposals for physical activities for workers who need exercise or are at risk of muscoskeletal problems, notifications for hydration, interventions quality of sleep and quality of life. Moreover, a tool to manage the life-cycle of the interventions will be provided (initiation, edit mode, publish, recycle). Managers will be using this tool as a 'control room' to access the contents of various data sources, including the anonymized and authorized access to the worker's data (after permission given by the workers).

Similar to the User Dashboard, the Visual Analytics instance within the Manager Dashboard could be able to show future trends of critical parameters, notify the managers for risky incidents and to present the progress on industrial tasks on progress. *Figure 52* presents the subarchitecture of the Manager Dashboard.

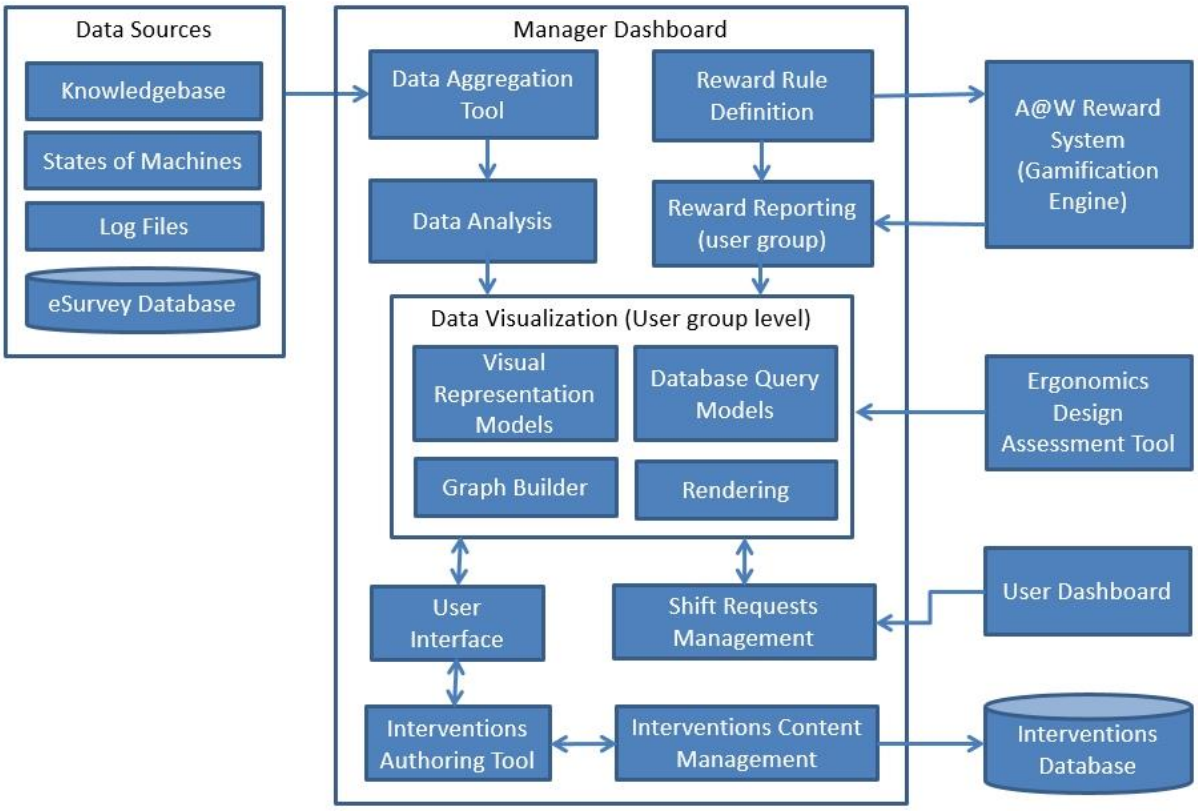

Figure 50. Manager Dashboard Logical View

Table 23. Summary of the Manager Dashboard and related services

Name: WD	Manager Dashboard
Description	The Manager Dashboard is a web-based environment designed to allow managers to access parts of anonymized worker's data (after permission by the users themselves), to access the Knowledgebase and the ergonomics reports, to monitor the industrial processes in progress and to handle worker's requests. On the other hand to allow Health & Safety Professionals to author and publish interventions for users.
Objective	Objective 6: Co-design tools for managers and OSH specialists for improved age-friendly workforce management
Related Use Cases	USE CASE 1: CHECK-LIST PLATFORM: The Manager Dashboard will be used to enter parameters of the safety check-list.

	USE CASE 2: PARTICIPATORY WORK ORCHESTRATION: Managers will access the Dashboard to manage shifts, resources and workplans. Moreover, they will check the status of the worker's requests and report their final decision (accept or not). USE CASE 3: SUPPORT FOR MUSCULOSKELETAL PROBLEMS: Health & Safety Professionals will access the manager's dashboard to author and manage interventions for muscoskeletal problems and will monitor progress/benefits. USE CASE 4: SUPPORTING HEALTH AND WELL-BEING – VIRTUAL COACH: Same as UC3, but for health and well-being. USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT: The Manager Dashboard will be used to create and manage content for the Knowledgebase. USE CASE 6: PRODUCTIVITY ENHANCEMENT TOOLS: Managers will have access to the shift progress, performance of worker groups and the overall shop-floor status. USE CASE 7: EMERGENCY/PANIC BUTTON: Managers and safety personnel will receive notifications through the Manager Dashboard in case of emergency.		
Related Technical Specifications	TS074, TS075, TS076, TS077, TS078, TS079, TS080, TS081, TS081, TS084, TS086, TS087, TS088, TS102, TS103, TS107, TS108, TS109		
Input	All data sources, namely: • AGEING@WORK Database (data from User Activity & Behaviour Monitoring, States of Machines, user profiles, Log files, etc.) • Online activity monitoring database • eSurvey Database • Knowledgebase • Award System Database	**Output**	The output consists of a number of views: • Interactive charts to present the data visualization results • Personal award collection view • Ergonomics assessment outcomes report • History (timeline) of user's requests (to the manager)

Sub-components	• Access to data sources • Data visualization • Personal profile management • User Interface • Message exchange with the Manager Dashboard	**How they are connected**	The various data sources provide data to be visualized in the interactive charts of the Worker Dashboard. Moreover, additional components like the shift management and the knowledgebase search engine are closely connected.
List of Services			
WD1	Initiation and management of requests for days-off, work from home and be in charge.		
WD2	Visualization of personal information related to health and QoL		
WD3	Access the Knowledgebase search engine and explore the results		
WD4	Access recent events in a timeline (from log files)		
WD5	Access the current states of the machines under surveillance (during shift)		
WD5	Access the awards collected by following the wished behaviour		
Hardware	Tablet, Smartphone		

From a development point of view the Management Dashboard is similar to the User Dashboard meaning that both will be implemented using common web development tools, possibly under a Bootstrap framework (*Figure 53*).

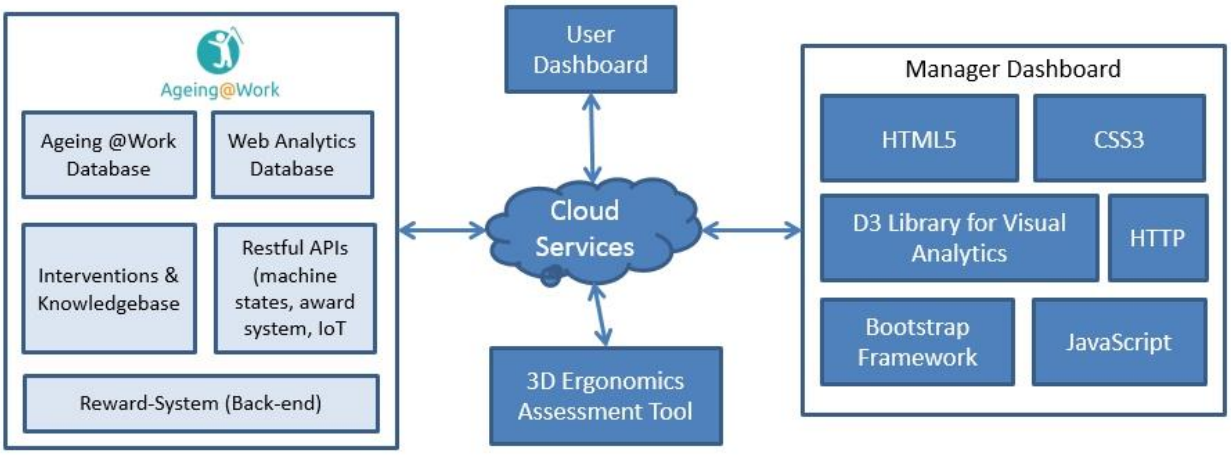

Figure 51. Manager Dashboard Development View

5.4.3 Visual Analytics

The Visual Analytics platform is designed for information visualization that focuses on analytical reasoning facilitated by interactive visual interfaces. It is designed and implemented as a single component, but it has two instances: one to be used in the Manager/Expert Platform and one more to be used in the mobile app (for end-users). The difference is that the former will be accessed only by managers, while the latter only by the factory and office workers. Each user category will have different access privileges according to its role in the system.

The Visual Analytics component consists of the Data Visualization and the Data Analysis unit which receives raw data from the User Activity & Behaviour Monitoring tool, the Online User Monitoring unit, the Knowledgebase and the eSurvey engine. Moreover, the states of the machines –when available- will be forwarded to the visual analytics platform in order to graphically notify users about the current state of the machine (both end-users for the check list use case and the managers to see the current shift progress on the manager's dashboard). Last, but not least, the log files containing the user's activities on the Ageing@Work platform and its peripheral software components will be also graphically presented to the responsible users (workers to see their personal routes and managers to check the progress on use case activities).

The Data Visualization component receives the processes data from the Data Analysis component and constructs through the Graph Builder a graphical representation of large datasets. The filters applied through the reasoning during data analysis will drive the SQL queries and will finally render the graphs to be projected to the two client applications (Manager's and User's dashboards) as seen in Figure 52.

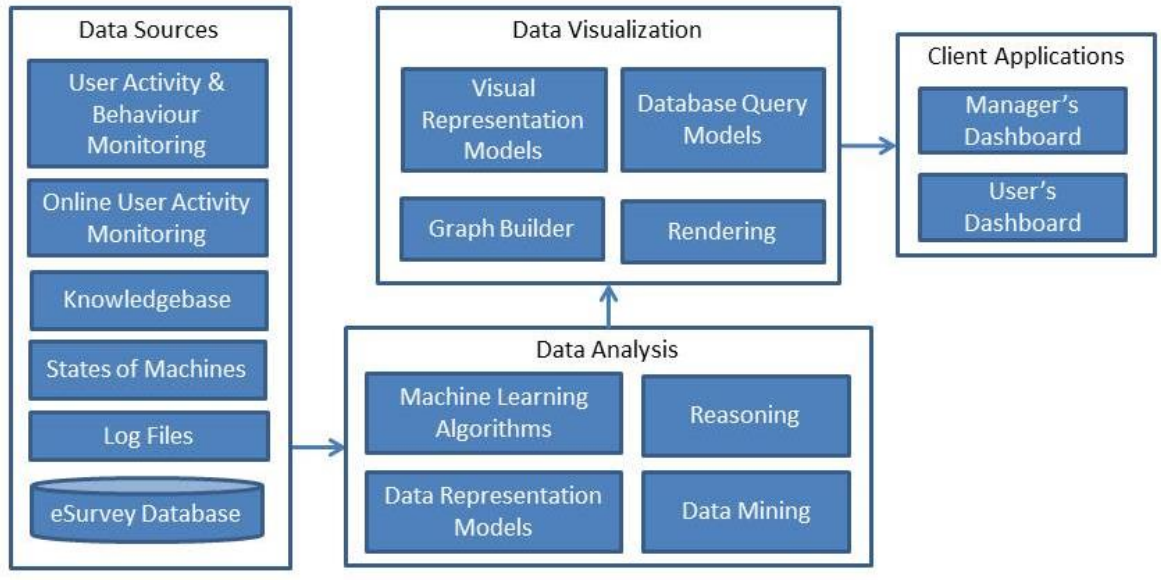

Figure 52. The subarchitecture of the Visual Analytics component (logical view)

The physical view of the visual analytics installation can be seen in *Figure 55*. According to this schema, all kinds of users produce data as they interact with the physical or digital world. This data is captured by the end-devices and IoT sensors and finally is being sent to the web analytics servers of the Ageing@Work system, along with the data from the eSurveys and machine states API. The System will add the information from the Knowledgebase and the logfiles and finally all data generated by the project can be projected to the managers and the end-users through the visual analytics servers installed in each pilot site.

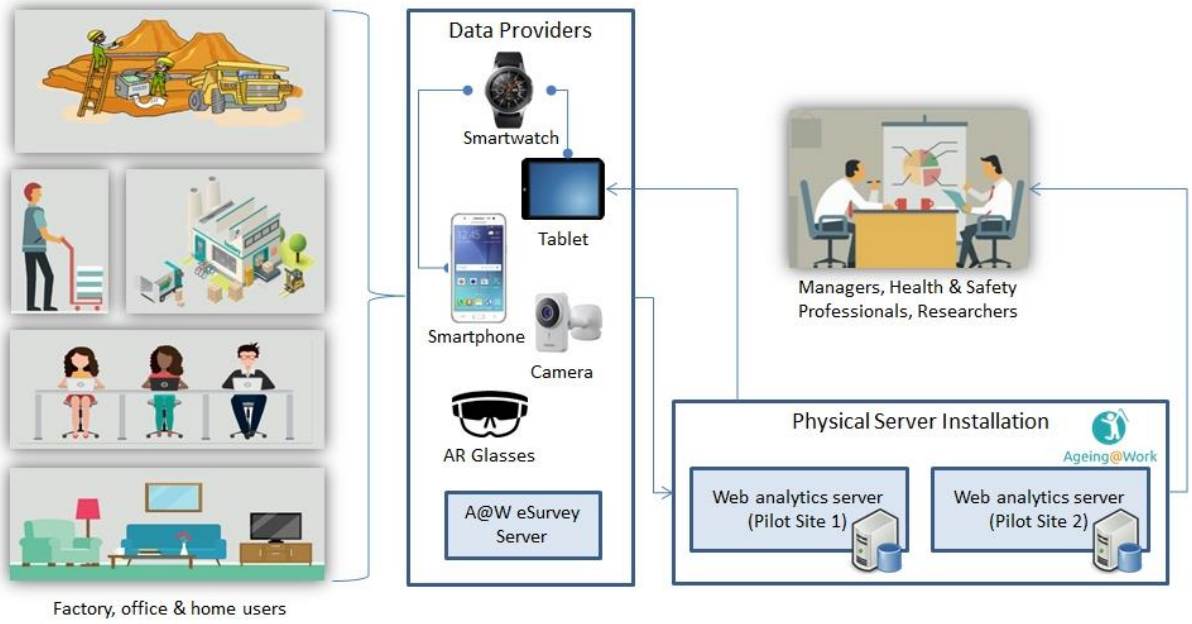

Figure 53. The physical view of the Visual Analytics Platform

Table 24. Summary of the Visual Analytics and related services

Name: VAP	Visual Analytics Platform
Description	The Visual Analytics platform will take advantage of technology developments like analytical reasoning, pattern recognition and data transformations to generate data representations and visualization for analytic reporting. Consumers of the visual analytics services are both managers and end-users, each one with different access privileges.
Objective	Obj. 5: To research and develop advanced personalized ICT-based workability and productivity enhancement tools based on Virtual and Augmented Reality, AI and Visual Analytics.

	Obj. 2: Design a novel unobtrusive worker activity and behaviour monitoring framework, coupling work, on the move and home -based tracking elements. The output of the monitoring services mentioned in the second project objective is being delivered through the Visual Analytics platform.		
Related Use Cases	Virtually all Use Cases which collect process and visualize information related to user's activity and data collected by the IoT devices.		
Related Technical Specifications	TechSpec002, TechSpec004, TechSpec005, TechSpec019, TechSpec022, TechSpec023, TechSpec024, TechSpec027, TechSpec028, TechSpec028, TechSpec037, TechSpec040, TechSpec041, TechSpec043, TechSpec072, TechSpec074, TechSpec075, TechSpec076, TechSpec078, TechSpec080, TechSpec095, TechSpec107, TechSpec108, TechSpec137, TechSpec157, TechSpec159		
Input	• Sensors from mobile devices (smartwatches & mobiles) • IoT devices • AR Glasses • eSurvey Engine	**Output**	• Interactive charts to project: ○ Processed user monitoring data ○ Machine states & current shift status
Sub-components	Background AR Services: • Machine Learning algorithms • Data miner and Reasoner • Graph builder • Renderer	**How they are connected**	The Machine Learning algorithms are being performed on the collected datasets and after analysis the graph builder prepares the interactive charts which are projected to the dashboards through the Renderer.
List of Services			
VAP1	Data being available to multiple users at the same time (data distribution)		
VAP2	Preparing to display on the end-device a scene consisting of more than one graphs (with screen real-estate concerns)		
VAP3	Graph building and output rendering		
VAP4	Synchronizing groups of graphs (when h same filtered data are being applied on them)		
VAP5	Data mining services		

ART6	Commonly used machine learning algorithms like linear and logistic regression, Naive Bayes, kNN, Random forest, etc.
Hardware	• Mobile devices for collecting data) • Servers for processing the visual analytics

The main process behind the Visual Analytics Platform can be seen in *Figure 54*. There are three actors which provide input data into the platform: the users themselves, the user activity monitoring mechanism and the programming interface of the machines which provide the states of the machines. The first actor provides data on user's behaviour through the user dashboard, while the other two can operate independently and provide data directly to the Visual Analytics Database. Next, the data visualization algorithms will generate the interactive charts to be projected into the client app (hosted in end-devices like PCs, Tablets, Smartphones and possibly Smartwatches).

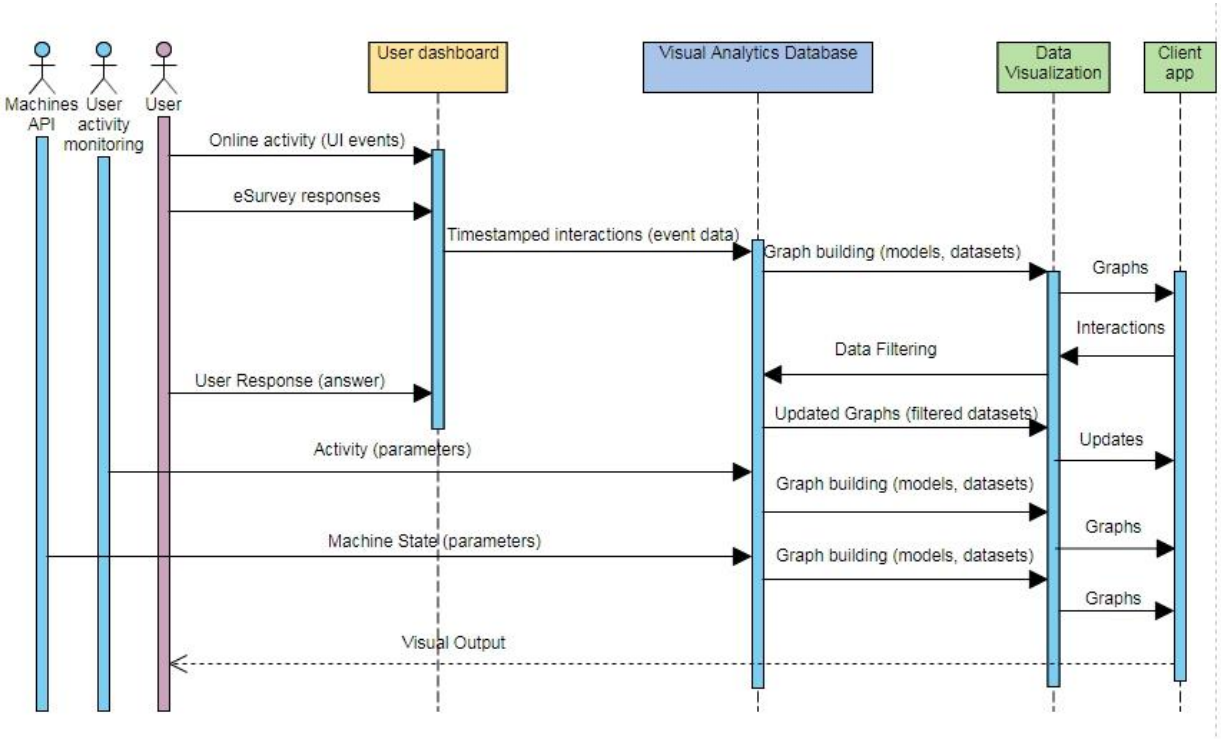

Figure 54. The process view of the Visual Analytics Platform

The development view of the Visual Analytics Platform can be seen in *Figure 55*. From a programmers point of view there will be a single back-end to perform the low-level functionality (developed in PostgreSQL, MySQL and Node.js technologies). On the other hand, there will be more than one Front-End implementations, depending on the end-device and the type of installation. There will be at least a full Visual Analytics platform implementation for PC to be used by managers, and another one -optimized for mobile devices- to be used by end-users and thus it has to be a lighter version. By lighter it is meant a

software component designed to consume as low as possible system resources. Moreover, it will have to adjust the output (Visual Analytics layout) to the smaller screens of mobile devices.

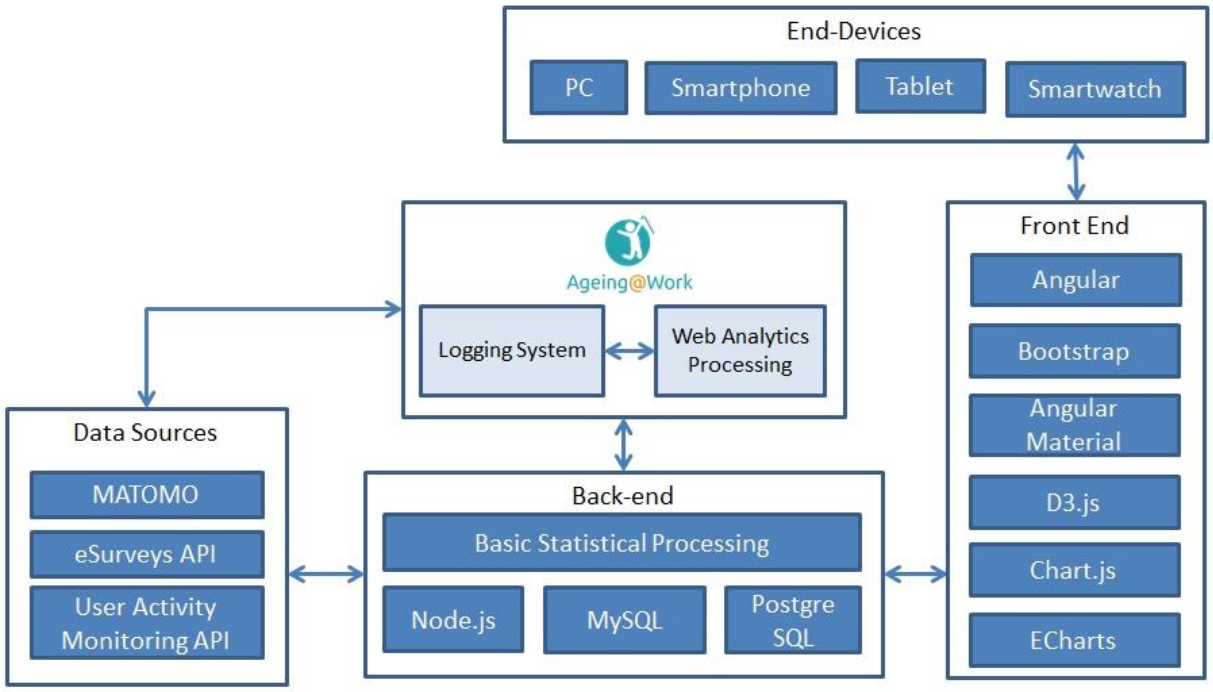

Figure 55. The development view of the Visual Analytics Platform

5.4.4 Data Aggregation Tool

The main goal of the Data Aggregation Tool (DAT) component is to provide a centralized node that performs the necessary data aggregation and pre-processing on data coming from diverse sources within the work site, in order to enable effective access of the management dashboard and visual analytics components to said data, thus enabling plant managers to maintain an effective schedule and better understand the needs of their workforce. In particular, the sources that are considered are the Worker and Workplace models (themselves being updated by the monitoring middleware), as well as the AGEING@WORK Reward System and the Ergonomics Optimization Support Tool.

The DAT component provides a number of interconnected services in order to successfully achieve aggregation of input data. At first, the anonymization module is responsible for detecting and obfuscating personally identifiable information that may be present in the data. Anonymization is performed in line with strict privacy maintaining policies maintained by the project, and in accordance with opt-in permissions given by the workers. Subsequently, the anonymized data will be input to the data normalization component, where consistent records can be derived for each parameter of interest by normalizing potentially diverse and inconsistent data sources. In the penultimate step, the anonymized and normalized data stream can be used to derive descriptive statistical figures with respect to important metrics of interest, as well as highlight any issues arising out of the distribution of the data that may require

managerial attention. Ultimately, the resulting data will be formatted and made available through an API for access by the Management Dashboard and the Visual Analytics tool.

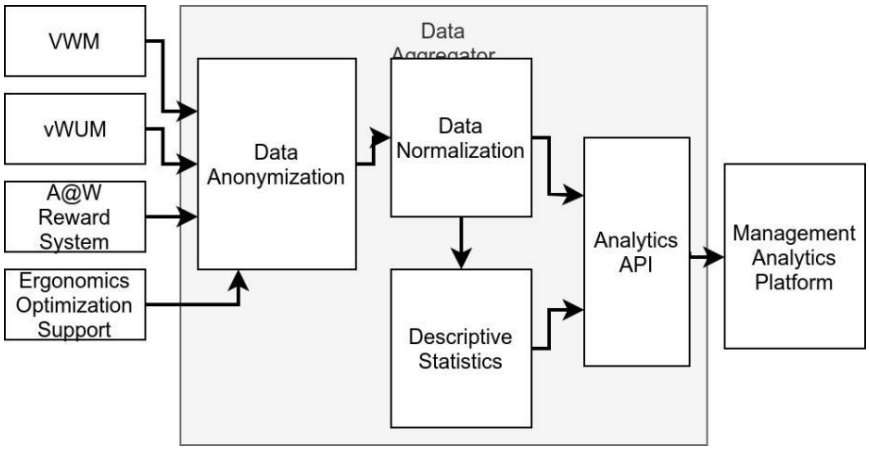

Figure 56. The subarchitecture of the Data Aggregation Tool component (logical view)

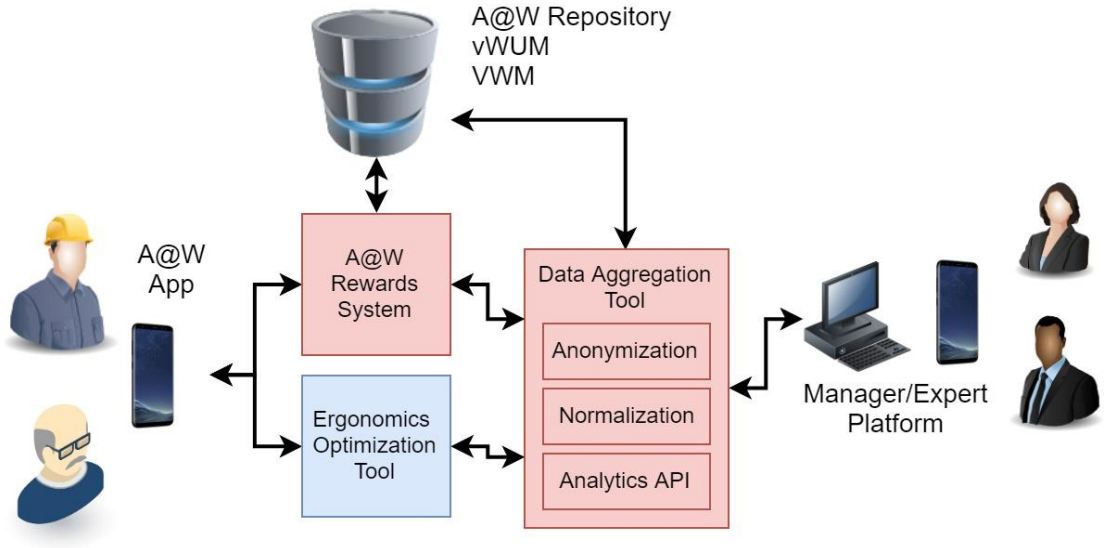

Figure 57. The physical view of the Data Aggregation Tool component

Table 25. Summary of the Data Aggregation Tools and related services

Name: DAT	Data Aggregation Tool
Description	The Data Aggregation Tool (DAT) is responsible for aggregating data from diverse sources within the work site and processing them performing the steps of anonymization, normalization, statistical analysis, as well as making them available through an API.
Objective	Objective 6: Co-design tools for managers and OSH specialists for improved age-friendly workforce management

Related Use Cases	USE CASE 2: PARTICIPATORY WORK ORCHESTRATION: The DAT component aggregates availability data from the workforce and provides to the management a detailed overview of the availability of workforce over time, according to skills and assigned tasks		
Related Technical Specifications	TechSpec023, TechSpec024, TechSpec025, TechSpec026, TechSpec083, TechSpec139, TechSpec140, TechSpec141, TechSpec143, TechSpec144		
Input	vWUM, VWM, Ergonomics Data, Reward System Data	**Output**	client query responses
Sub-components	Data Anonymization module	**How they are connected**	Input: Personally Identifiable Data stream Output: Anonymized data
	Normalization module	**How they are connected**	Input: Diverse data streams, vWUM, VWM, Ergonomics data, Reward system data Output: Normalized data streams
	Descriptive Statistics Module	**How they are connected**	Input: Normalized data streams Output: Descriptive statistics
	Aggregate Data API	**How they are connected**	Input: Pre-processed data, client requests Output: response to data query
List of Services			
DAT1	Data normalization		
DAT2	Data anonymization		
DAT3	Analytics API		
Hardware	PC		

5.5 Ergonomics Optimization Support Tool

The ergonomic optimization support tool is a functional module intended for the analysis of the workplace for a specific worker. Using the physical characteristics of both the workplace and the worker, the tool will simulate the task performed by the worker.

The posture and body movements for each performed task will be analyzed using widely extended ergonomics tables that are dependent on the type of work being evaluated. This is, ergonomic analysis tables for an office workstation is not the same ergonomics analysis tables as for a workstation in which the worker is assembling the PCBs of a device, as is the case at the SIEMENES factory in Germany. Or as it can be the work in the quarry of an operator who is controlling that the stone is being transformed correctly, as it can be found in the quarry of Madrid.

The Ageing@Work ergonomics optimization tool will first target the worker as its primary user and will provide a user-friendly interface to this end, coupled with the personalized virtual coach and the worker dashboard (WP5). Based on the virtual worker's personal model (wVUM) and their virtual workplace model, be it in the factory or at home, simulations-based assessment of ergonomics will take place. The outcome will be first a grade on the important parameters that: (a) may hinder the person's productivity and workability, as well as (b) may introduce or worsen adverse symptoms that can have effects to the overall quality of life of the person (e.g. back pain worsening due to body stance when working with a machine or at the production line). While at home, the worker will be able to improve workplace ergonomics also (e.g. home office settings).

Secondly, the result of the ergonomics optimization analysis will be used by the managers' platform, concretely it will feed the work orchestration DSS.

Table 26. Summary of the Ergonomics Optimization Support Tool and related services

Name: EOST	**Ergonomics Optimization Support Tool**		
Description	Ergonomics analysis support tool that will allow the workplace optimization for a certain worker		
Objective	Obj. 3: Provide workers with personalized work ergonomics and process design services		
Related Use Cases	UC 3 (Musculoskeletal problems): An objective analysis will be done and the critical postures highlighted.		
Input	Virtual workplace model (vWorkplaceM) Virtual worker model (vWorkerM) Ergonomics assessment tables	**Output**	3D Simulation Result on ergonomics assessment

Sub-components	• Ergonomics orchestrator
	• Ergonomics 3d Simulator
	  ○ 3D simulation
	• Simulation report generator
	  ○ Result of ergonomics assessment
		How they are connected	All the tools described here will run server-side, totally automated.
			The Ergonomics Optimization Support Tool will load the models from the centralized repository, and store the results back at the same centralized repository
			The Ageing@Work App and Expert platform will then load the results from there whenever they need to be displayed to the users

List of Services			
EOST1	Collect virtual workplace model Collect virtual worker model Select the ergonomic assessment tool to be used for that kind of workplace/task		
EOST2	Feed the 3D simulator with the collected virtual models and ergonomic assessment tool		
EOST3	Run the simulation and assessment		
EOST4	Generate the report with the results		
EOST5	Show the results to the worker		
EOST6	Send the results to the manager Decision support system. (Convert the message into the right format)		
Hardware	All the simulations and report generations will be run in a centralized server.		

5.5.1 Ergonomics Orchestrator

The ergonomics orchestrator is the tool responsible with interacting with the rest of the system, loading the inputs, deciding which simulations to run, passing the raw simulation results to the report generator and sending the result of the reports back to the system.

For each workplace model, there are usually many choices that the worker can make, ranging from the height of the chair or table, position of the used tools, order of operations, or posture or movement options (like looking up by bending the neck versus the whole torso). As the optimal setup or choices for each worker can (and usually do) change, part of the job of the Ergonomics Optimization Support Tool is to find this optimal or close to optimal set of choices.

When there is a need for new simulations to be run (usually when a new vWorkerM or vWorkplaceM is added or edited, or when the ergonomics pipeline is updated), the ergonomics orchestrator will load the inputs for which the reports need to be generated, trigger (usually) multiple simulations to be run, inspect the reports and trigger another set of simulations. This process of doing simulations, generating reports and analyzing them is repeated until the best (or possibly the set of close to) solution is found. At this point, the results are sent to the centralized repository for storage until they are requested.

In addition to the optimal solution, and its related report, users will be able to request specific simulations to be run, or simulations with a specific set of constraints. This will allow for the workers to compare its own preferred setup with the optimal according to the system (which might have been missed by the system), or setup some extra restrictions for the workplace (like having the soldering machine at the right, instead of the left, as the mental load to remember this change can be worse than the slight ergonomics benefit). Finally, these specific restrictions will be useful for managers to plan changes to the workplace, like “Would it be better if the chair could be risen an extra 10 centimeters”, without having to actually buy new chairs and tell the workers to try them.

5.5.2 3D Simulator

The 3D Simulator will be used as an imitation of the operation of an industrial process with the purpose to evaluate the ergonomic designs of the machinery involved and the surrounding working environment. The main objective of this component is to analyse a given ergonomics design over a set of given tasks and user models and finally produce a report to present the findings (evaluation outcomes). The simulation report will provide feedback to the workers and the managers at every simulation step of the application scenario.

The necessary information to perform a simulation will be contained in a number of separate files. These files contain all the 3D models, user models and the simulation scenario information needed by the simulator. There are two basic files expected as input:

- The working environment model file, including the 3D models of machinery (could be just a 3D machine model in a very simple case) and the semantics
- The simulation scenario file, which is a detailed description of the tasks the virtual user models have to perform, all contained in a computer-readable format.

The first one (working environment) is an xml or JSON file that describes all the virtual objects contained on the scene (physical environment), their binding to their meshes, as well as their physical characteristics, like their sizes, degrees of freedom and kind of functionality. This model file is needed in order to construct the virtual scene which contains the ergonomics design under evaluation.

On the other hand, the simulation scenario is a file (xml or JSON) that describes in detail the virtual user action sequence. It contains special information for basic activities like "move to location", “press button”, “pull a handle”, :lift an object”, “look at position”, “grasp an object” and more. This information is needed by the 3D simulator in order to "guide" the virtual worker of what to do during the task (or shift). The same file also adds some success/failure conditions to the task sequence. Consider the following examples

"If the virtual worker's position is further than 0.5 m from the target machine, then fail (the current task)"

If the object (e,g. relay) is higher than virtual worker's hand plus the elbow brace size, then fail (the current task)"

"If the virtual worker fails to perform this task, then repeat another 2 times before fail"

The subarchitecture of the 3D simulator is presented in the following figure. The raw simulation results will be saved in the AGEING@WORK database for future reference, while a user-friendly simulation report will be produced for workers & managers. After user permission, a copy of the simulation results may be saved in the Knowledgebase in order to be available for other users in the same community (pilot site).

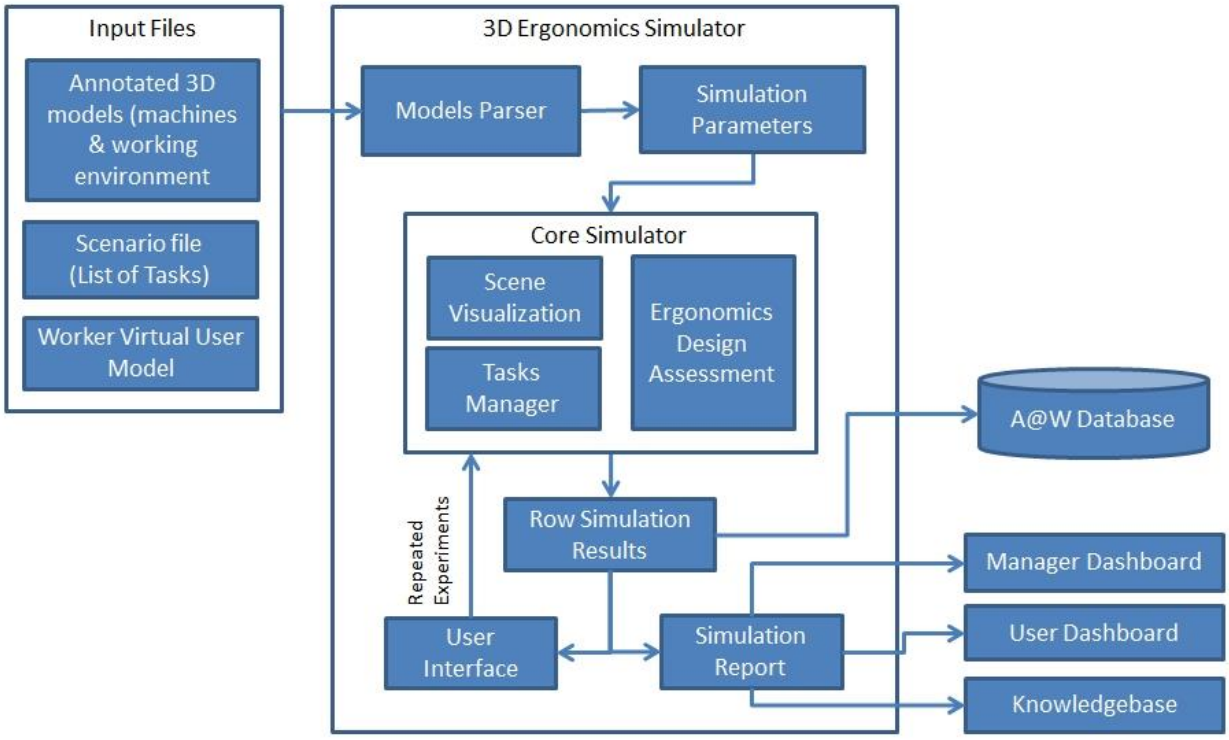

Figure 58. The subarchitecture of the 3D Simulator (logical view)

The working environment of the 3D simulation can be created on the basis of Unity[14] , a game engine for 3D, AR and VR. It is highly customizable and supports sound (persisting irritating noise, or ability to hear possible alarm over ambient sound) and vision (glares or reflections that could obscure some things, or text that needs to be read that is too small or with too little contrast). In any case, the output of the simulator (and thus, the input of the report generator) will be a stream of body postures and other ergonomics-related data, like weight lifted, for each of the postures the virtual worker makes. The specific format of this report will probably be either a CSV-like format, or JSON.

Table 27. Summary of the 3D Simulator and related services

[14] https://unity.com

Name: 3DS	3D Simulator		
Description	The 3D simulator will take advantage of the state-of-the-art game engines (like Unity) to simulate industrial tasks in the related working environments using 3D models of the machinery and human operators. This component will generate evidence that a certain ergonomics design is optimal for the needs of specific users.		
Objective	Obj. 3: Provide workers with personalized work ergonomics and process design services		
Related Use Cases	UC 3. SUPPORT FOR MUSCULOSKELETAL PROBLEMS: The 3D simulator will be used mainly in UC3 to offer users a tool to simulate the working environment and the machine involved in daily tasks under the purpose of ergonomics design evaluation.		
Related Technical Specifications	TechSpec029, TechSpec033, TechSpec034, TechSpec035, TechSpec039		
Input	• Annotated 3D models (machines & working environment with semantics) • Scenario files (detailed task descriptions in computer-readable format) • Worker Virtual User Model	**Output**	• Raw simulation data (task completion times, estimated productivity KPIs, success rate) • Simulation report (a summary of the simulation results in human-readable format)
Sub-components	• Model parser • Core simulator • UI • Simulation report producer	**How they are connected**	The model parser reads the input files and feeds the core simulator with all the parameters needed for simulating tasks. The simulation results (parameter values) are stored both in the Knowledgebase and the dashboards (users and managers).
List of Services			
3DS1	Parsing simulation parameters from model files (working environment, machinery, user models, scenario files)		

3DS2	Display task-by-task progress as a timeline in the UI
3DS3	Generate ergonomics assessment results
3DS4	Save results and simulation data to AGEING@WORK database and Knowledgebase
3DS5	Repeat branch of simulations automatically (for a group of ergonomics designs)
Hardware	Cloud-based Server

A view of the development construct of Unity Engine can be seen in Figure 59.

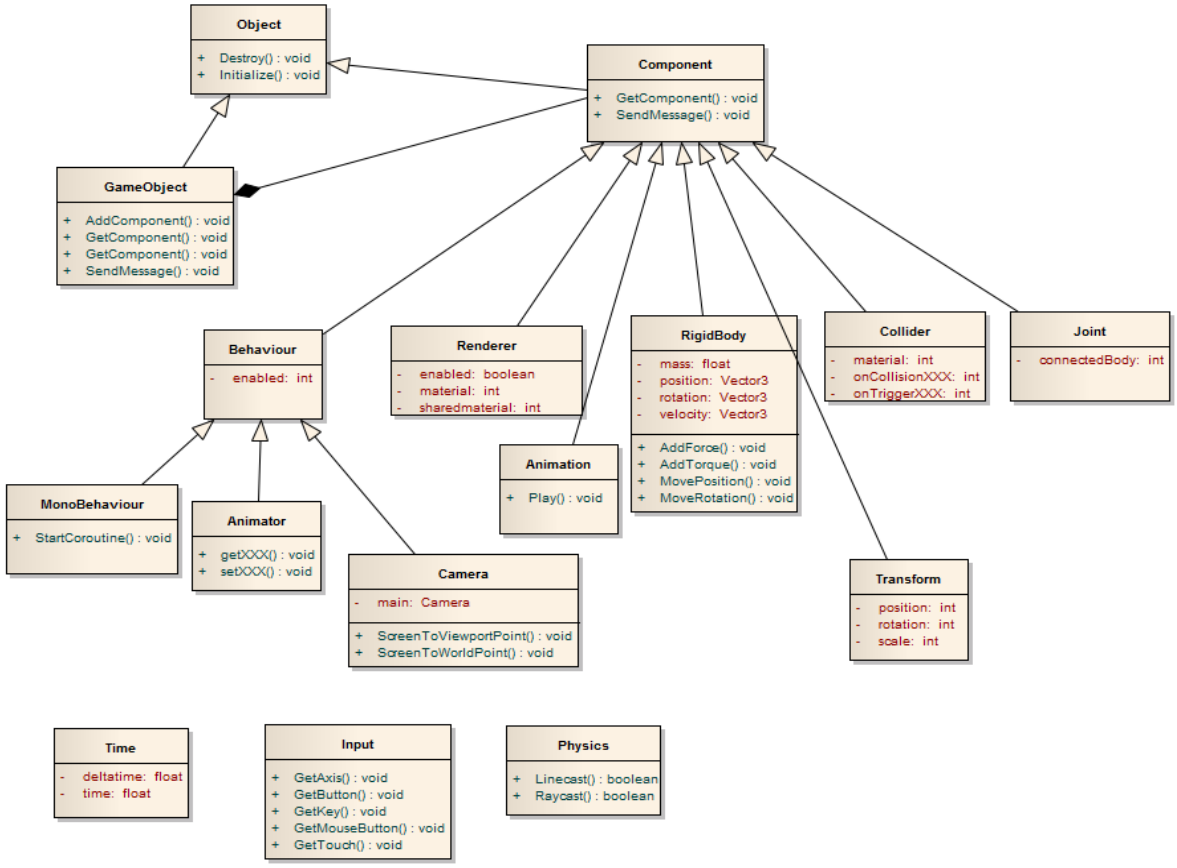

Figure 59. Unity Class diagram[15]

The calculation of the ergonomics assessment result will be based on many different assessment tables, and as none of them aims to analyze all the possible issues that the Ergonomics Optimization Support Tool will try to detect, a combination of assessment tables will need to be used in out case.

[15] Unity3D module class diagram (2014), https://www.programering.com/a/MDO4UDNwATY.html)

Each ergonomics table will have a single (or small set of) score as output. These scores will be condensated into a single score with weighted averages, additionally giving more importance to worse scores (as a job position with mostly good postures for all body parts is preferable to one with very bad neck posture, but ideal for other human body parts).

This single score is useful for both the ergonomics orchestrator and the final user. However, the rest of the individual scores and even the individual issues inside each table will not be discarded, as this is information that is still useful for the orchestrator (as support information) and for the end users, to explain specific problems and help managers decide what could be changed in the workplace to make it better.

5.6 Motivation & Reward System

The reward system can be implemented as a gamification engine that is a tool to apply game elements in a non-leisure context like the Ageing@Work. The user experience will be gamified to a certain extend including humor, challenges, some luck incidents and competition, but the overall approach will not be considered as a game. The basic concept in healthcare domain, such as Ageing@Work, is to transfer motivational elements to health education, symptoms sensing and diagnostic processes, treatment adherence, etc. It is expected that the reward system can directly link the existing health and symptoms management processes with target user groups and can fulfil their intervention adherence and training needs.

In this section we describe the main components of the Motivation & Reward system. Firstly, we introduce the **Gamification Engine** architecture as the main paradigm to capture the attention and to boost the motivation of users. Secondly, we present the manager's prospective of the application through the **Manager's Dashboard** and, finally, we introduce the planned development of the APIs provided by the Motivation & Reward system.

Table 28 is an attempt to present the motivators for elderly workers, HR managers, and Health & Safety Experts which can be implemented by applying gamification elements into the networking services of the Ageing@Work system. The concept in here is to make a connection between those motivators with the awarding system of the gamification engine.

Table 28. Motivators created by gamification

Motivator by user type	**Short description**
Older Workers	
EW_M1	Realize that there are more people like them (aged workers) who have similar needs
EW_M2	Find a place to express themselves and feel free to make questions

EW_M3	Make them better aware on medical conditions and other side effects of possible health-related issues
EW_M4	Train working skills to remain competitive
EW_M5	Keep themselves active and socially present, fight exclusion
EW_M6	Share their knowledge and accumulated experience with younger workers
EW_M7	Stimulate collaboration with other workers and help avoiding faults due to memory issues and/or difficulty to maintain attention
Young Workers	
YW_M1	Gain knowledge and advice from older workers to overcome problems
YW_M2	Learn to respect the experience of older workers
YW_M3	Stimulate collaboration with older workers and help avoiding faults due to lack of knowledge or rush
Health & Safety Professionals	
HSP_M1	Offer additional motivation to all categories and age-groups of workers
HSP_M2	Acquire evidence-based knowledge on the effect of their gamified interventions that will facilitate their future work

The Ageing@Work Motivation & Reward System would give awards for certain predefined wished behaviours which can be indicated by certain tasks. A first list of those tasks can be seen in Table 29.

Table 29. Motivators offered by the Ageing@Work Reward System

Motivator by user type	**Short description**
Young and Old Workers	Maintaining an updated user profile (wVUM)
Young and Old Workers	Regularly Participate in the surveys (questionnaires about their QoL, workability, self-administered symptoms management, etc.).
Young and Old Workers	Participate in the Q&A forum (post new entry (question or answer), post a comment, make a Like on other user's posts, etc.).
Young and Old Workers	Share their achievements on the online community

Young and Old Workers, HR managers	Evaluate an ergonomics design and share results
Young and Old Workers, managers	Ask optimal recommendations for work orchestration
Young and Old Workers	Regularly logon into the platform and consume the Ageing@Work services

The above motivators could be implemented by a system able to be integrated into the Ageing@Work platform and it peripheral components, mainly the User Dashboard (Figure 58). The Motivation & Reward System may have its own database to store points and badges awarded by users, game rule definitions and a list of end-users who participate in the game campaign ('players'). All transactions with the other parts of the Ageing@Work system are perfumed through a programming interface (Gamification API) used for integration.

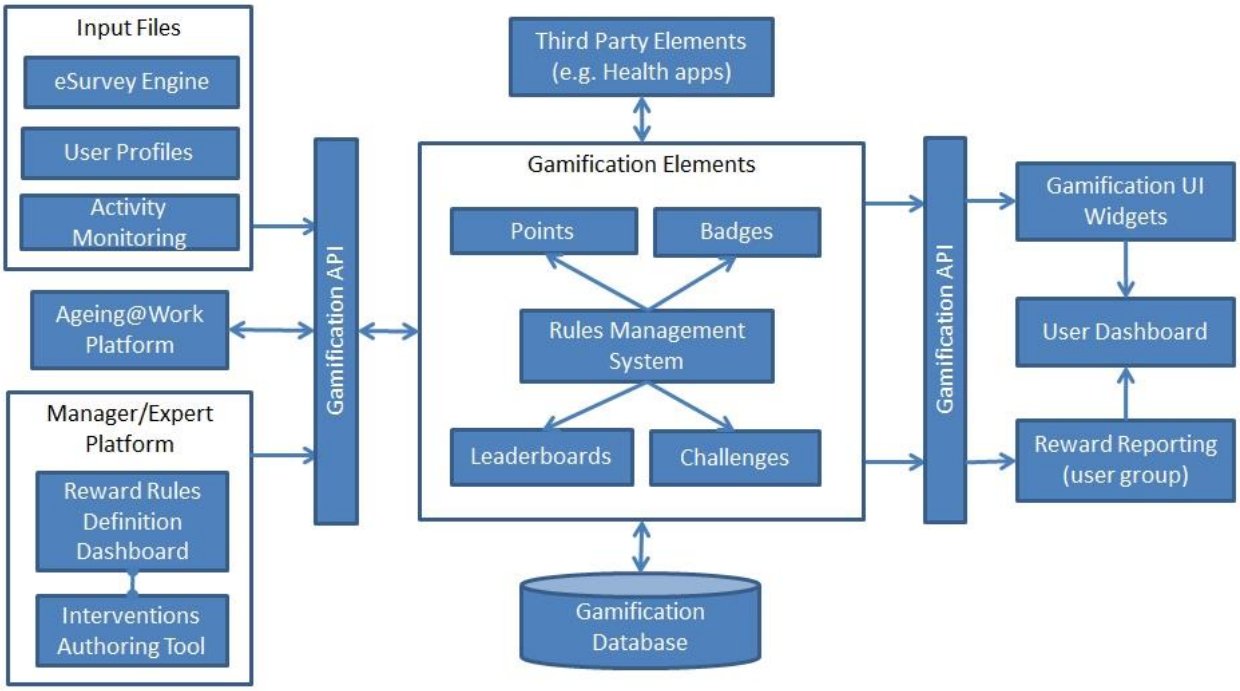

Figure 60. The subarchitecture of the Motivation & Reward System (logical view)

5.6.1 Rule Management System

This is the core element of the Motivation & Reward System and it is responsible for maintaining the game rules and monitoring the platform activity. Practically, it may run a loop to check for matches between performed platform activity and game rules. In case a game rule requirement (stored in the gamification

database) is met by the kind of platform activity that was reported by the Gamification API (e.g. a user stretched his/her hands after a receiving a notification by the system), then the rule is triggered and the corresponding award is released (e.g. 10 points for an older worker who gave an answer to a younger worker after the younger workers made a 'Like' on the answer provided).

The Rule Management System may handle the information provided by third party elements (e.g. the Samsung Health) to allow users to be exposed to a different category of interactions as seen in Listing 4.

- Intro material (stage one) for First Time Users
- User can track daily steps towards a daily step target
- User earns points for steps tracked
- User earns credits for meeting the daily step target
- User unlocks achievements based on activity (steps, floors, minutes, distance)
- User levels-up based on points earned and achievements collected
- User can track daily floors climbed towards a daily floors climbed daily target (points earned)
- User can track active minutes towards an active minutes daily target (points earned)
- User can track distance travelled towards a distance travelled daily target (points earned)
- User can participate in time-based individual missions set by Managers (for example 'beat the boss') and earn points / credits
- User can spend credits towards rewards defined by Company that she/he works for (for example 'loot boxes')
- User can compete against colleagues in same team on the leaderboard based on total number of points earned
- User can see team ranking against other teams on the leaderboard based on the average number of points earned
- User can participate in time-based team missions set by Managers
- User can view generic stats across the entire company (user view)

Listing 4. A list of possible additional app experiences to be gamified

5.6.2 Award Rules Definition Dashboard

The Reward Rules Definition Dashboard is a view especially designed for game-administrators or game-masters (a role to be undertaken by HR managers and Health & Safety Experts) to allow them define the rules under which the award will be given to workers who perform well and actively participate in the Ageing@Work platform. Using this dashboard, game-masters could define new kinds of awards, make direct connections to platform activities, start and stop game campaigns, manage participants ('players'), monitor the game performance and get automatic reports. The Reward Rules Definition Dashboard could be integrated into the Manager/Expert Platform.

The Award Rules Definition Dashboard of the Motivation & Rewards system allows users to perform different type of interactions as presented in Listing 5.

User Management:
User can create a username and password from system
User can add or select an image to be used as an avatar in system
User can join own team in the system

Enterprise Management:
Company can define a logo
Company can define the team names in the system (admin view)
Company can create time-based individual missions in the system (admin view)
Company can create time-based team missions in the system (admin view)
Company can create and manage rewards (credits, prizes, draws, loot boxes) in the system (admin view)

Company can define links between user's activity and types of awards
Company can manage 'games' (start, stop, pause, reset games)

Country Management:
Company can define the language(s) to be used in the system
Company can define the various gamification elements (steps, floors, minutes, meters, achievements) for the local country.

Listing 5. Example activities game admins can perform in the Award Rules Definition Dashboard

Overall, the gamification paradigm of Ageing@Work starts from a model which moves around older workers and HR managers towards a de-centralized model in which all individual users are given responsibility for the health conditions and interventions planning. Some key-elements to be included in the first version of the gamification engine would be:

- **Challenges (Quests or Missions):** highly personalized challenges which may combine quests, combinations of actions and discrete steps in achieving game goals.
- **Multilanguage support**: More than one languages will be possible to be inserted into the gamification back-end as an extra table for translation
- **Security:** Cool off period for each action (e.g. unlimited 'Likes', minimum time between 2 posts, reduce action spamming)
- **Levels:** Game elements used to split the level of difficulty and share objectives in groups. Levels functionality will be implemented according to the following rules:
    - A default level of difficulty will be predefined at game creation time.
    - Each rule will be applied differently in each individual level: the effort to win points will be different by using multipliers.
    - The progress for k level will be presented to the end-user (worker) as a progress bar to indicate the distance to the target and the progress made so far n personal or group level (depending on the quest)

Each game element will have the properties: **Title** (String), **Description** (LongString), **OrderId** (Integer), **Requirements** (Integer), **Avatar** (picture)

5.6.3 Reward System API

The Rewards & Motivation system exposes its main services through the use of APIs that allows the full integration with the Ageing@Work platform. In particular, the following APIs will cover the area of **App Experiences, User Management, Enterprise Management** and **Country Management.**

A set of Restful API services would be used to integrate gamification services into the Ageing@Work platform and tools, but more detailed descriptions will be provided in the WP7 tasks.

Moreover, some added-value features would be inserted like the "gamification loop" according to which achieving a sub-goal would trigger the reward system based on a point system. In this line, the expected user interactions depicting the wished behavior (consistency to interventions, sociability, participation in the platform activities, etc.) are linked to the sub-goals of the game to propel the gamification-loop.

5.6.4 Reward System Widgets

Gamification is back-end system by default. On the other hand, the evidence of the game-like experiences would be presented to end-users using some additional UI elements in the worker dashboard and the mobile app. Such elements would be badges (small icons indicating the symbolic awards), a label next to the username to present the total points earned, a leaderboard to present the ranking of 'players' and other similar visual elements.

Gamification interaction history, as well as all changes made in games themselves (e.g. changes in rules made by the HR managers, starting and ending periods of the 'games', etc.) would be logged in gamification database but presented to users through a corresponding UI element.

Moreover, the output of the gamification engine (e.g. overall progress made by all users) can be accessed by the HR managers to help them in decision making processes.

5.7 Ageing@Work Centralized Repository

A central repository will be created to act as the main information hub of the Ageing@Work system. The repository will facilitate the storage and aggregation of data and model outcomes and such that it can be securely shared, updated and exploited by every partner working in different modules of the Ageing@Work platform. By controlling data and models in a central repository, redundancy and its associated efforts will be eliminated. The centralized repository will be based on a knowledgebase and will mainly include the virtual worker models and the virtual workplace models.

5.7.1 Knowledgebase

In order to support the learning tools a knowledgebase has to be implemented. Access to the knowledgebase will be open to every other component, in order to easily store and retrieve information.

Based on NodeBB's architecture, a read and write REST API will be implemented to enable transferring knowledge through standard HTTP requests from the *generators* to the *storage* to the end *consumers*. The API will be further enhanced to support different calls and operations according to the needs of other modules and become the channel into which information between different components is exchanged.

The selected database used to store and retrieve information is the MongoDB, a popular and reliable NoSQL database program, which provides ease of use, a powerful query language and great scaling capabilities. As a NoSQL database, MongoDB is schema-less, storing information in JSON style documents, without complex joins which ensures that the structure of a single object is clear and easy to grasp and work with. As a consequence, and together with the scaling capabilities of MongoDB, further enhancements to support the growth of the platform can be easily implemented allowing to shift focus from the technical details to things with real business value.

To ease communication between a component and the API, the design specifications of the latter have to be documented. To this end, the Open API Specification (OAS – formerly known as Swagger) is used, in order to report the API's capabilities and functionalities in a uniform, industry standard way.

Main features of the API capabilities include storing and retrieving new information, training material, AR & VR tutorials, Bixby and workspace announcements and procedures into and from the knowledgebase. Moreover, the Knowledgebase will provide search capabilities, to retrieve information based on criteria, as well as exporting data in JSON format for future use. The following figure (*Figure 61*) presents visually the logical view and features of the Knowledgebase.

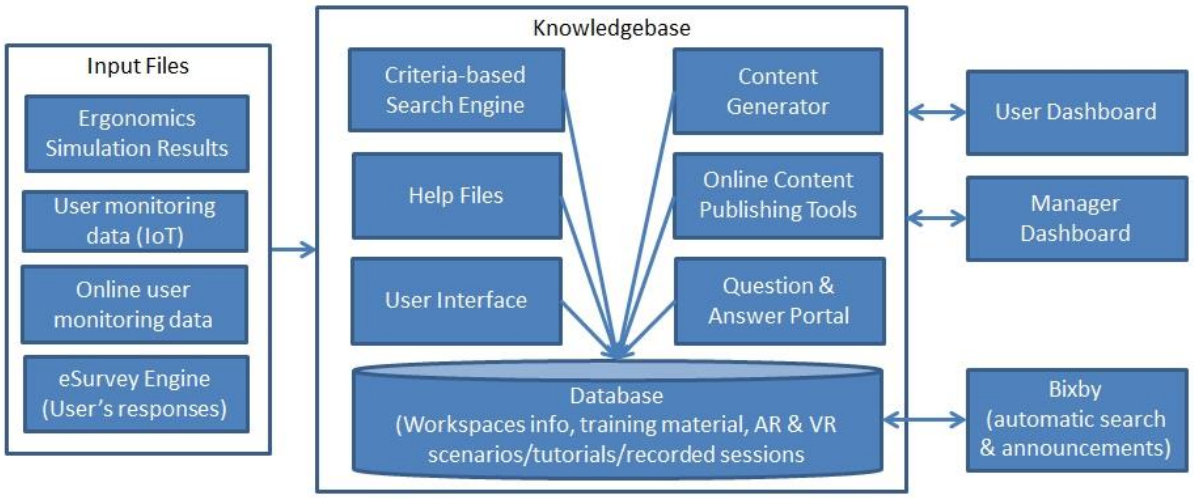

Figure 61. Logical view and main features of Knowledgebase

The following table summarizes how the Knowledgebase fulfils Objective 5.

Table 30. Summary of the Knowledgebase and related services

Name: KBAPI	Component: Knowledgebase

Description	The Knowledgebase comprises the data regarded as *Knowledge*, along with the supporting components, a MongoDB database to store this knowledge and a REST API to communicate between the database and all the other components.		
Objective	Obj. 5: To support the learning tools and make them lifelong, while also being accessible to every other component.		
Related Use Cases	USE CASE 5: KNOWLEDGE EXCHANGE PLATFORM AND INTERGENERATIONAL COLLABORATION SUPPORT: Expert Opens VR scene (result from AR & VR Lifelong Learning Tools) and creates a tutorial. Then s/he uploads the tutorial to the Knowledgebase [Flow 2]. Worker uses a component (e.g. VR tutorial tools), browses all VR tutorials available in platform, selects the desired one and replays it [Flow 1]. User talks to Bixby assistant about a machine problem, Bixby calls the REST API and searches about specific machine, the API responds with relative information [Flow 3].		
Related Technical Specifications	TechSpec045, TechSpec046, TechSpec047, TechSpec048, TechSpec049, TechSpec051, TechSpec060, TechSpec061, TechSpec062, TechSpec088, TechSpec146		
Sub-components	MongoDB database • New workspace information • AR & VR tutorials • Bixby announcements • Workspace announcements	**How they are connected**	The MongoDB database stores all information and data consisting workspace Knowledge.
	REST API: • Store/Retrieve information and data • Search based on criteria • Export data in JSON format • Swagger specification	**How they are connected**	The REST API provides through standard HTTP calls the necessary connection with the Knowledgebase. Swagger provides the documented specification in order for other components to easily access the Knowledgebase.
List of Services			
KBAPI1	Store/Retrieve information and data to/from the Knowledgebase		

KBAPI2	Search based on criteria for specific material
KBAPI 3	Export data in JSON format
KBAPI 4	Display Swagger documentation
Hardware	PC, Server

The aforementioned use cases are presented in the following UML diagrams (*Figure 62*, *Figure 63* and *Figure 64*).

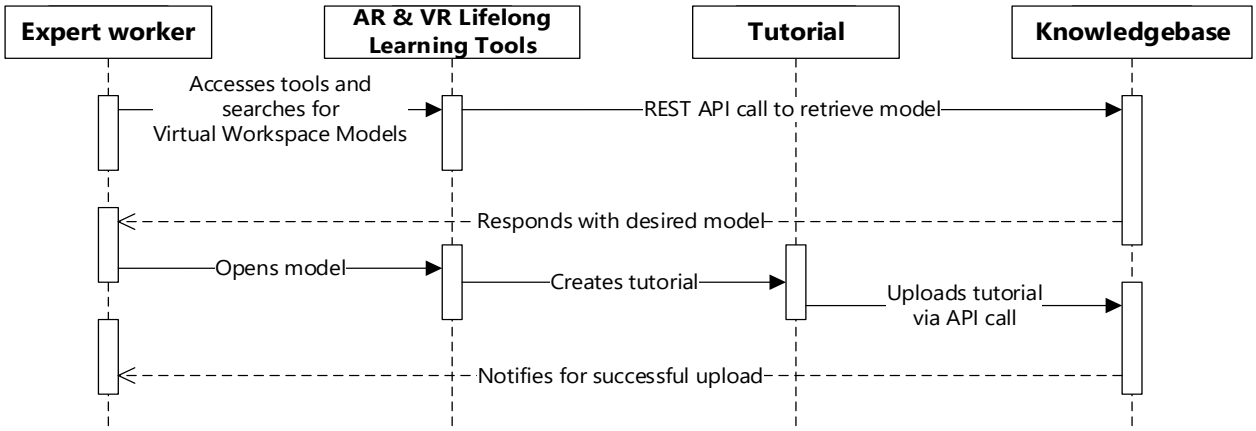

Figure 62. Expert worker creates a new tutorial and then uploads it to the Knowledgebase

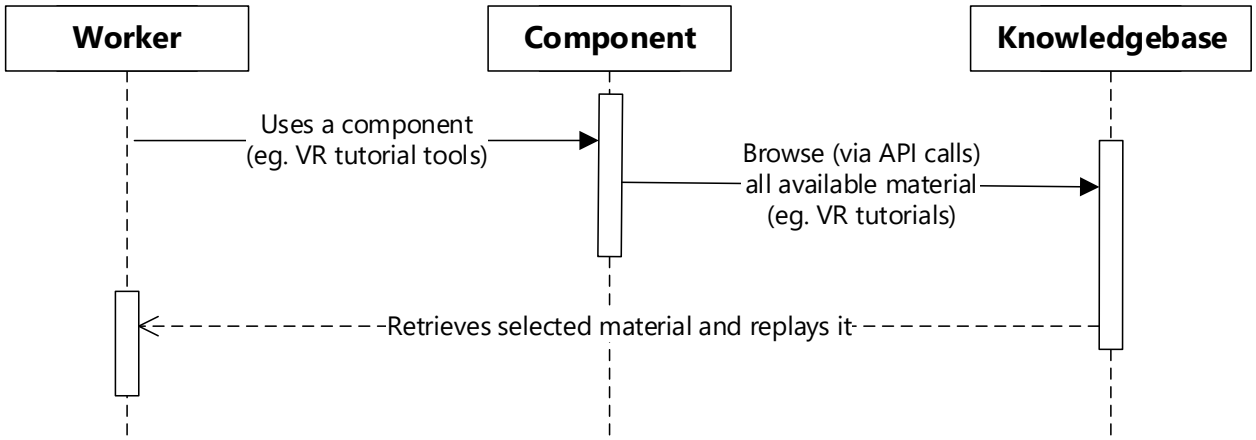

Figure 63. Worker using a component, browses through data in Knowledgebase, searches and accesses desired material

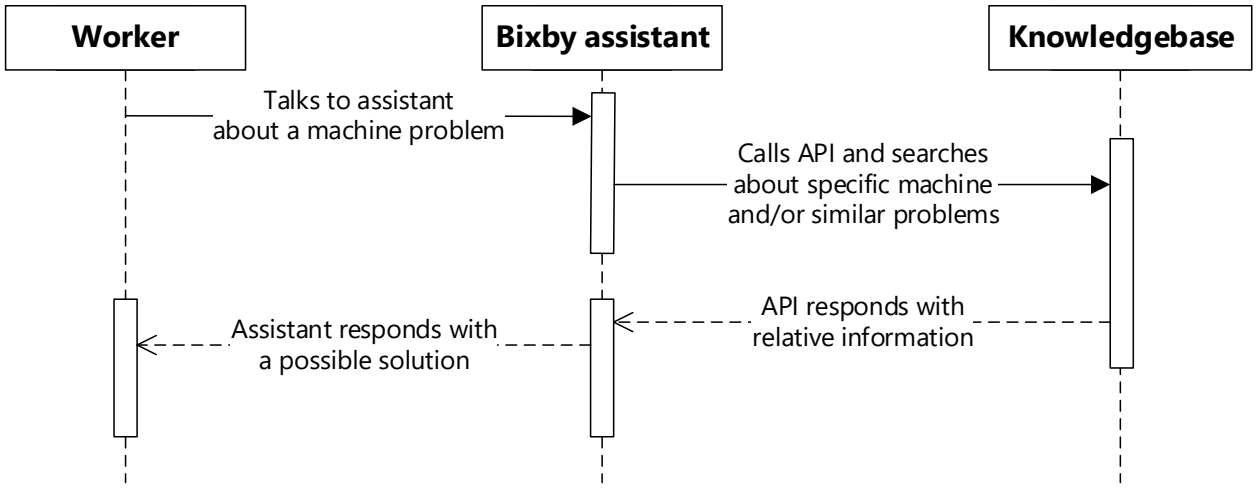

Figure 64. Worker talks to Bixby assistant about a problem, for which the assistant searches a solution in the Knowledgebase

5.7.2 Virtual Worker Models

User modeling is a way to simulate and reproduce human-computer interaction without actually using real persons. The development of Virtual User Models (VUMs) describes –at first- the building up a conceptual understanding of the user and its roles in the Ageing@Work system. Starting from VERITAS[16] project technology the VUMs are collections of personal data associated with a specific user or user categories/groups which share common characteristics (e.g. Workers with muscoskeletal problems). VUMs in VERITAS were related mostly to physical activity of the users and thus included physical parameters, while in Ageing@Work the concern is not only related to physical parameters but also to mental and social ones. Thus, moving from VERITAS to Ageing@Work project, VUMs need to be adjusted to a different set of user requirements. In any case, the main goal of worker VUMs is the customization and adaptation of the Ageing@Work services to the worker's specific needs (mining industry, shopfloor and office).

The concept map of the wVUM as it was designed for the needs of the Ageing@Work project is presented in *Figure 65*.

[16] https://www.iti.gr/iti/projects/VERITAS.html

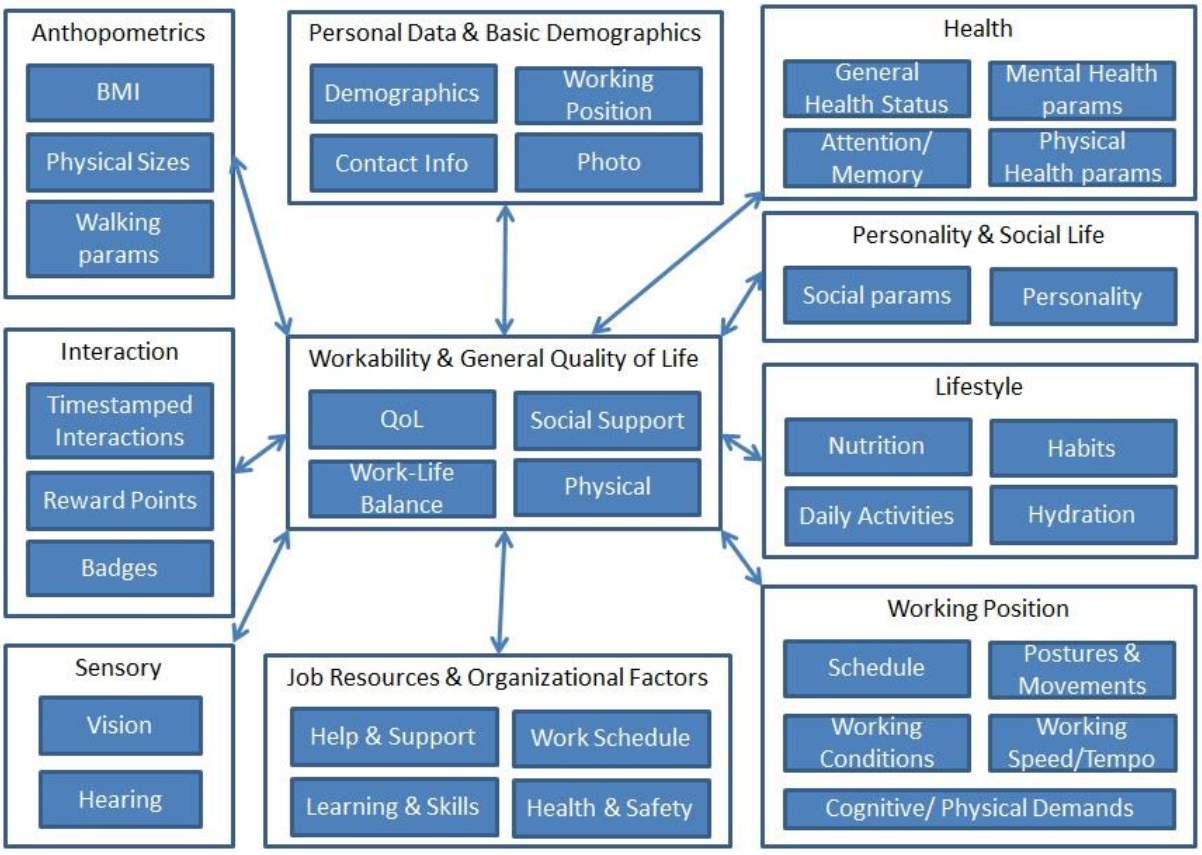

Figure 65. The subarchitecture of the wVUMs component (logical view)

5.7.3 Virtual Workplace Models

Within WP3 of the Ageing@Work project, and more specifically in the context of T3.3, virtual workplace models for both the target factories and the domestic workplaces shall be established in order to support mainly workplace ergonomics optimization and work orchestration support tools of T3.4 and T3.5 respectively, and also be available as resources in the knowledgebase for the rest of the project. The virtual workplace model is consisted from the 3D representation of the environment and a semantic layer, which contains the information about the work procedures and machine functionalities.

The realization of the 3D representation of the environment will be done through several 3D scanning technologies, utilizing stereo cameras, depth and lidar sensors along with 3D processing methods to deal with several uncertainties, noise, outliers, non-uniform sampling and missing parts. The resulted 3D models will be augmented with an additional semantic layer of the work procedures and machine functionalities. The semantic layer can be added through the software Jack or alternatively utilizing a custom framework developed in Unity3D specifically designed for the project.

The virtual workplace model will be delivered as input resource for ergonomics optimization support tool, thus it will be already in a format that is compatible with the tool that will be used to perform the ergonomics optimization analysis. The formats are the environment file of Jack software (.env) in case of using the same software for ergonomics analysis and unity package in case of using the custom framework

developed in Unity3D. The orchestration support tool requires a virtual workplace model representation as well. This time the information should be abstracted in order to provide a human readable representation. Such a representation is a 2D top view of the workplace joined with the area labeling and working positions along with internal metadata about the specifications of each post, which will be delivered both from the virtual workplace model and the ergonomics optimization support tool.

Figure 66 graphically presents the sub-architecture of virtual workplace models and their major components along with creation procedure and data distribution. The creation procedure is described here in order to provide a better understanding of the virtual workplace models sub-components. Starting from the creation procedure the first step is to capture the desired environment geometry and texture utilizing 3D scanning technologies such as stereo cameras(e.g. ZED), Depth sensors (e.g. Intel RealSense D435i), LiDAR sensors (i.e. Leica BLK360) or systems that combine sensors (e.g. FARO Focus).

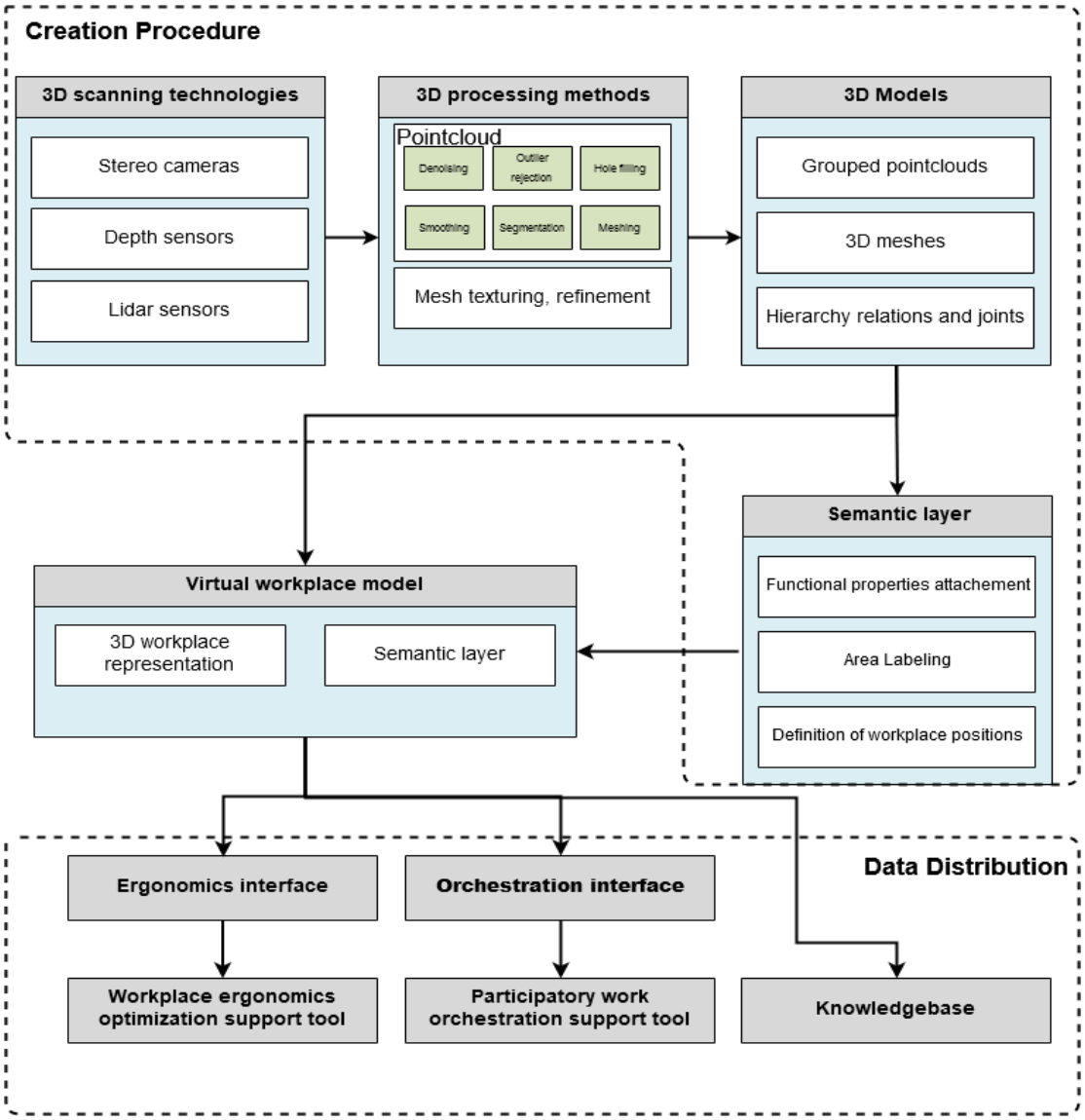

Figure 66. Virtual workplace models creation procedure, sub-architecture and data distribution

The initial capture is followed by several steps of 3D processing including denoising of the point cloud, outlier rejection, hole filling, plane smoothing, segmentation, meshing and mesh texturing. The final result is a collection of individual objects that are stored as meshes or pointclouds and altogether represent the static information of the 3D geometry of a workplace. Afterwards, the semantic layer is added starting from the definition of moving parts and their hierarchy relations to other objects. Then the functional properties are attached to desired objects in respect to the underlying platform (Jack or Unity3D). Both the 3D scene and the semantic layer are the main components of the virtual workplace models. Complementary components are the two interfaces in order to support both ergonomics optimization and work orchestration support tools with their specific needs.

The ergonomics optimization support tool (Sec. 5.5) is mostly by definition supported and the interface stands for minor customizations needed for specific cases. The work orchestration support tool requires a more abstract view of the virtual workplace model in order to check the feasibility and the requirements of specific tasks, thus the interface in that case is responsible for applying that abstraction of the information. Finally, the virtual workspace models will be stored in the knowledgebase for future usage in various other project modules.

Table 31. Summary of the Virtual Workplace Models and related services

Name: VWM	Component Virtual Workplace Models
Description	The virtual workplace models are in essence a digital copy of the real workplace environment in respect of the 3D structure and work-related functionalities. The virtual workplace models provide structured information required for both the ergonomics optimization and the work orchestration support tools.
Objective	Obj. 1: Enable extensive personalization capabilities to the Ageing@Work supportive approach
Related Use Cases	USE CASE 1: CHECK-LIST PLATFORM. The VWMs will be used internally and provide the required information of machine checklist. USE CASE 2: PARTICIPATORY WORK ORCHESTRATION. The VWMs will be used internally by the participatory work orchestration support tool to acquire the required information of available work posts and their associated specifications to conduct the feasibility test of the requests. Similarly, the VWMs will provide the orchestration support tool with the required information of job position specifications. USE CASE 3: SUPPORT OF MUSCULOSKELETAL PROBLEMS. The VWMs will provide ergonomics optimization support tool with the required information

	about the workplace environment in order to conduct simulations and get results related to workers with musculoskeletal problems. USE CASE 6: PRODUCTIVITY ENHANCEMENT TOOLS SURVEILLANCE WITH SMARTWATCH. The VWMs will provide the information of the machinery model needed. USE CASE 7: EMERGENCY/PANIC BUTTON. The VWMs will provide the necessary context information of the location of the worker in need. The context information includes the machinery model and the job position along with their specifications.		
Related Technical Specifications	TechSpec046, TechSpec047, TechSpec048, TechSpec061, TechSpec142, TechSpec143, TechSpec144		
Input	Raw 3D scans of the workplaces, descriptions of work procedures, CAD models, Video footage	**Output**	3D models and pointclouds associated with functionalities and semantic layer
Sub-components	3D workplace representation: • 3D models • Pointclouds Semantic layer: • functionalities • Labels • Job position specifications	**How they are connected**	The collection of 3D models and pointclouds is structured in a way to represent the workplace and the labels and functionalities are associated with these 3D objects or parts of them. From the functionalities and work process descriptions the specifications for each job post will be derived.
List of Services			
VWM1	3D scan of the workplace environments		
VWM2	Refine scans, segment and convert to 3D meshes if needed		
VWM3	Structure collection of 3D models, pointclouds, CAD models to represent actual workplace environment		
VWM4	Add semantic layer (functionalities, labels) according to provided descriptions and video footage		

VWM5	Encode 3D geometry information along with semantic layer in suitable formats for ergonomics optimization and work orchestration support tools
Hardware	Stereo cameras, depth sensors, LiDAR sensors

Due to the internal use of VWMs from other components, no meaningful UML diagrams can be presented here. The integration with the associated components is visible to their corresponding UML diagrams.

6. Implementation & Integration Roadmaps

6.1 Integration Roadmap

The present section describes the plan for bringing together the subcomponent described earlier into one and single piece, so that the Ageing@Work system will be able to deliver the wished functionality to end-users and managers ensuring that the different modules function together as a solid system. The overall process is presented in *Figure 67*.

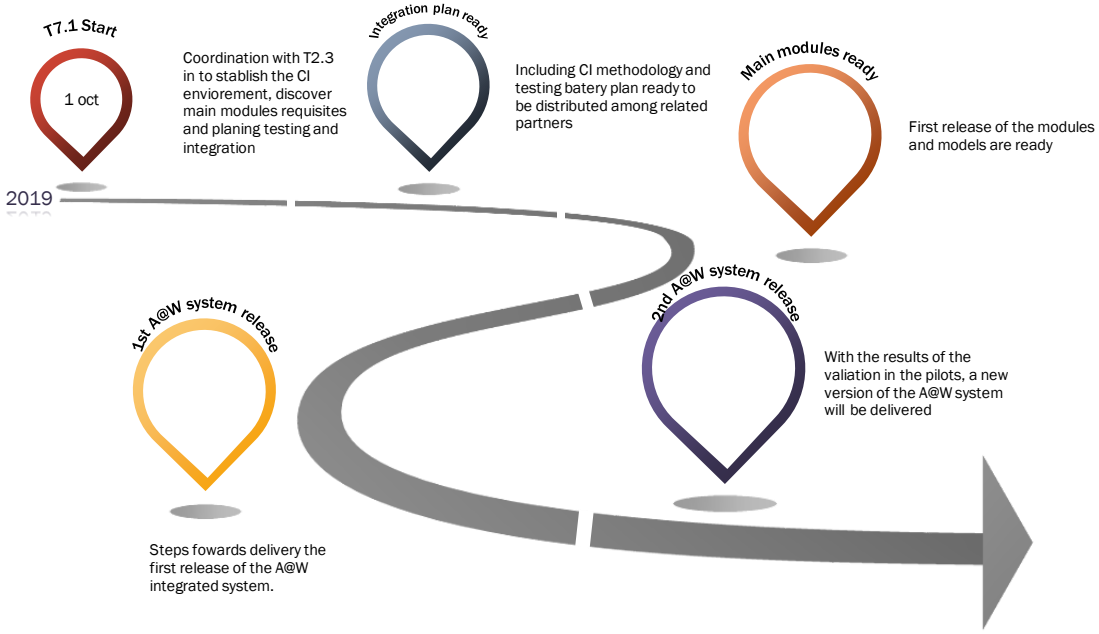

Figure 67. Integration Roadmap: Five steps, from definition of the modules to the 2nd release of the Ageing@Work system

There are five discreet steps to be followed one after another before the closing of the development activities:

- Step 1: Start in October 2019 with software modules and services definition and a plan for testing and integration
- Step 2: Introduce CI methodology and testing to result with a final version of the integration plan agreed among technical partners
- Step 3: Next step is to complete the development of the first version of the main modules and models required to make Ageing@Work system work
- Step 4: Functional integration of all the hardware and software components of the Ageing@Work architecture in order to have in hand a robust construct
- Step 5: After testing the prototypes under realistic conditions, the Ageing@Work components will be updated according to the evaluation results

Agile software development practices will be followed to ensure a continuous integration process and to perform automated building, testing and deployment of the provided modules. GIT technologies will be used as a version control system for tracking changes in the source code of software component under development. This solution is optimal for the needs of the Ageing@Work project as developers are distributed among various countries, there is the need to coordinate and monitor the development activities and finally a bug-reporting system is needed to help pilot site responsible persons and technical personnel to report and discuss functional issues (*Figure 68*).

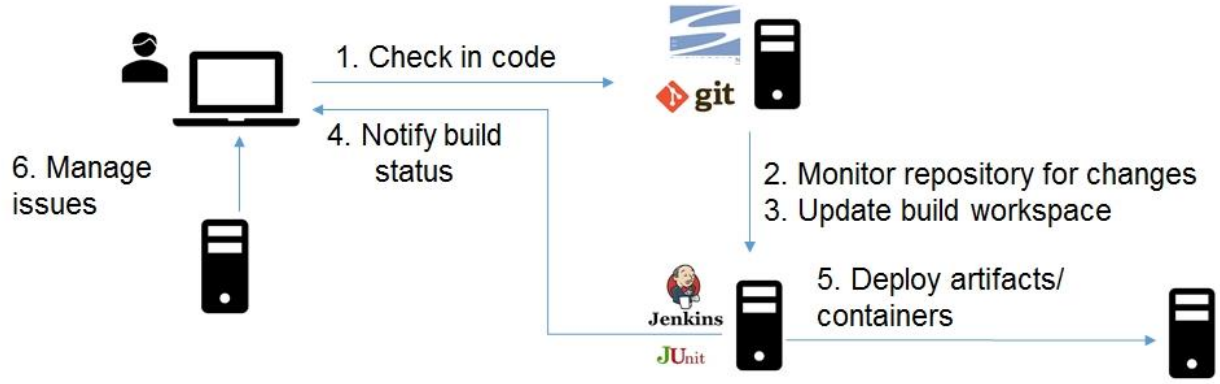

Figure 68. From source code development to manage issues

6.2 Software Quality Assurance

The ISO/IEC 2510:2011 will be followed to ensure high quality in software development. The model characteristics of this system/software quality model can be seen in the following picture (*Figure 69*).

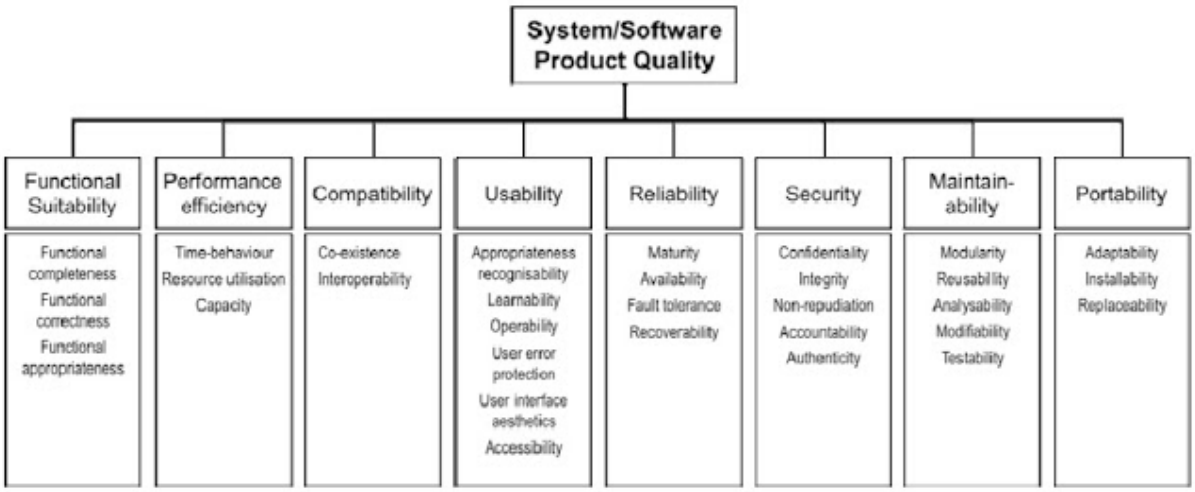

Figure 69. Parameters of the System/Software product quality

The ISO/IEC 2510:2011 system/software quality model provides:

- Internal metrics associated with static internal properties of a system such as number of function calls, number of rules, etc.
- External metrics associated with dynamic external properties. These are the metrics that are observable when the user interacts with the system (response time, results, etc.)
- Quality-in-use metrics evaluate to which a system meets the needs of the user
- Measure the functional suitability, performance efficiency, usability, security, maintainability and portability

ISO 25010 Characteristics	Description	Method for measuring quality metric
Functional Completeness	Assess the implemented functionalities with respect to requirements and project objectives	Observational test
Functional Correctness	Assess whether the Ageing@Work platform provides the correct results with the needed degree of precision	Log analysis, observational test
Functional Appropriateness	Assess whether the implemented functionalities facilitate the accomplishment of specified tasks and objectives	Log analysis observational test

UPM with the support of module developers will create test cases for the assessment of the intermediate prototype

Module	Responsible	Ready for testing by (date) ?
Ergonomics Simulator [SIM]	MySphera	M22
VR Learning Environment [VR]	UPAT	M26
AR Telepresence Tool (used as a distant support tool) [AR]	CERTH	M26
Knowledge Sharing component [Knowledgebase]	UPAT	M26

Virtual Coach (Virtual avatar) [VCoach]	CERTH	M16
Gamification Engine (used as a reward system) [Game]	Samsung	M20
Dashboards (for workers, HR managers, Administrators, & Researchers) [UI]	UPM CERTH	M16
User & Real-time Environmental Monitoring [SENSING]	KUL	M26

Module	Responsible	Ready for testing by (date) ?
Safety module (anonymizer, encrypted) [Safe]	CERTH	M28
Participatory Work Orchestration Support Tool Administrative suggestions	MySphera	M16
Virtual Worker Models repository [wVUM], integrated into the Knowledgebase	CERTH	M22
Virtual Workplace repository [VW],integrated into the knowledgebase	UPAT	M22
Workplace Resources & Processes repository [wR&P], integrated into the knowledgebase	SAMSUNG	M26

7. Conclusions

The Ageing@Work platform is a complex system which includes a wide range of tools and applications for various categories of users. Moreover, the solution will be tested on more than one country and in distant pilot sites with individual characteristics. To address these challenges, attention was paid on the careful design of the overall system and its subcomponents.

This documented presented the first version of the Ageing@Work architecture. An initial set of features and subcomponents have been described in detail to allow developers start implementing the solution. It is expected that all future changes and updates on the architectural components and their functionalities will be reported in the second version of the document in M24.

Another technical work to carry out on the next phase of the project will be to improve the integration between the individual architectural components into a single and robust construct. Programming interfaces will be extensively used for this purpose according to the integration plan presented earlier.

8. References

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