D5.1 –Factory2Fit integration system

FACTORY2FIT

Empowering and Participatory Adaptation of Factory Automation to Fit for Workers

Abstract

Smart factories are characterized by increasing automation and increasing customization. In these dynamic environments flexible and adaptive work organization is crucial, both for productivity and work satisfaction.

The Factory2Fit project will support this challenge by developing adaptation solutions which can engage and motivate people with different skills, capabilities and preferences to be productive members of the work community in manufacturing industries.

This deliverable describes initial results of task 5.1 “Systems Integration and lab testing”. These results represent the integrated framework that will be able to deliver a set of services that are used later in the different pilots, like retrieval of adaptable patterns, simulation of workplaces, adaptive training formulation.

Keywords:

Integration, framework, architecture, user requirements, system requirements, test scenario

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Executive Summary

This deliverable describes the integrated framework of Factory2Fit that will be able to deliver a set of services that are used later in the different pilots defined in the following tasks 5.2 "*Definition and planning of Factory2Fits's pilots*" and 5.3 "Evaluation and assessment of the pilots". This integrated framework will also be tested in this Task 5.1 in a testbed environment at TU Chemnitz.

The definition on the F2F framework based on the requirements from the deliverables D1.2 (Industrial requirements) and D1.4 (Adaptation architecture). Based on the Adaptation Architecture the requirements of the architecture components are summarized to generate at the end the test cases, to verify the functionalities of the Factory2Fit framework.

The Factory2Fit architecture with its components is the generic base of the framework. Each component is described with its software and hardware requirements and its input and output in the overall framework.

The contents of this report are intended for providing a guide, to be able to deploy the framework on the testbed environment in a first step. In the following tasks this framework is used as the base for the Factory2Fit's pilots.

The guidance towards the deployable Factory2Fit framework is structured as followed:

- define an overview of requirements for the components of the framework
- describe the technical aspects of the individual components (software/hardware requirements
- derive the deployment environment for the framework (components on virtual machines)
- define test cases to verify the framework-functionality in the testbed environment

The generic framework is derived from the F2F requirements, the F2F architecture and the description of the individual components. Based on this content a deployable architecture is derived, based on virtual machines with their technical descriptions. In this deployed environment (on the testbed at TU Chemnitz) a set of test cases, described in this deliverable, is used to verify the functionality of the Factory2Fit framework.

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1 Introduction

This section will present a short outline highlighting the purpose of this document, as well as designate the intended readership and finally draw connections to the other Factory2Fit deliverables.

1.1 Purpose of the Document

This deliverable is an initial report on the integration system of the Factory2Fit platform. It describes the integrated framework of the Factory2Fit platform that will be able to deliver services, that are later used in the pilots.

The deliverable deals with the description of the requirements and framework specifications of the integrated modules/components of the Factory2Fit framework. These modules/components are developed in the technical work packages, according to the system architecture and user case requirements defined in WP1.

The outcome of this document is the detailed description of the integrated system for the Factory2Fit platform. The integration will be addressed using vertical methods in order to have functional entities and horizontal approaches in order to facilitate the customization of the platform.

This integrated framework will be tested in a lab environment. Based on the requirements and framework specifications of the integrated framework of the Factory2Fit platform defined in this document, Test Cases for the Lab test are derived and described, to test the functionality of the modules/components and the communication between the modules in a test lab environment.

1.2 Intended readership

The deliverable is a public one, so in addition to sharing the concepts within the Factory2Fit consortium, we want to share the ideas also with a wider audience.

1.3 Relationship with other Factory2Fit deliverables

Deliverables D1.1 *"Enabling technologies"* and D1.2 *"Industrial requirements"* described the enabling technologies for Factory2Fit development work and also the technical, business and user requirements. Together with these two, D1.4 *"Adaptation architecture"* will contribute to the definition of the integrated system of the Factory2Fit framework.

This deliverable describes in detail the modules/components based on the D1.4 deliverable "*Adaptation architecture*", to verify the requirements in a lab test environment as described in the Task 5.1 "System Integration and Lab testing".

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The verified lab environment will later be used within the deliverables 5.2 "*Definition and planning of Factory2Fits's pilots*" and 5.3 "Evaluation and assessment of the pilots", where the verified and tested modules/components will be utilized in the industrial pilots.

1.4 Acronyms and abbreviations

Abbreviation	Description
AR	Augmented Reality
EAB	External Advisory Board
EFFRA	European Factories of the Future Research Association
EU	European Union
KOM	Kick-Off-Meeting
F2F	Factory2Fit
WAE	Workplace Adaption engine
TDE	Task Distribution Engine
SOA	Service Oriented Architecture
RAM	Random Access Memory
VM	Virtual Machine
OS	Operating System
CPU	Central Processing Unit
AR	Augmented Reality
HMI	Human Machine Interface
MB	Mega Byte
ALAE	Automation-Level Adaptation Engine
SSN	Smart Sensor Network
DSS	Decision Support System
PPG	Pre-process Plan Generator

Table 1: List of Abbreviations

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2 User requirements overview

This chapter describes a summary of the requirements relevant for the F2F integrated framework, which is the objective of this deliverable. The requirements are condensed based on the deliverables D1.2 (Industrial requirements) and D1.4 (Adaptation architecture). They define the functional context for the F2F integrated framework.

These requirements are later used to define the test scenarios in chapter 4 (F2F framework test scenarios). The requirements are structured based on the specific components of the F2F integrated framework, to describe the main functionality of the components for a later test in the lab test environment.

2.1 Worker modelling and system adaptation

Factory work is getting more versatile and multi-skilled workers are needed. A dynamic database of workers and their competencies would help in work planning to find competent workers to each task. The database would also support following the individual competence development of each worker.

2.1.1 Task and task distribution scenarios

The Task Distribution Engine (TDE) is able to create and update work schedules by utilizing information about tasks and resources (workers, machines), which is stored in the Factory2Fit Repository. It takes into account multiple criteria by making use of the Worker, Task, and Machine models, in order to assign or re-assign tasks to workers/machines, in case of the arrival of new tasks or when the status of resources change. It provides a web-based user interface for configuration and assessment of the current state by the supervisors. Regarding its integration to the system, it communicates with other Factory2Fit components via web services, such as the Workplace Adaptation Engine and the Automation Level Adaptation Engine.

The functional requirements for the Task Distribution Engine component are listed in the table below:

Req.#	*Requirement criteria*	*Description*
TDE 1	Enable TDE core engine instantiation	Start an instance of TDE core engine.
TDE 2	Start TDE User Interface for management and visualization	A supervisor should be able to log on and interact with the TDE User Interface.
TDE 3	Load required information	TDE should be able to load information of the factory's tasks, workers, machines, and shifts, which are stored in the Factory2Fit Repository, according to the selected operating mode (real-time or simulation).
TDE 4	Communication with WAE	TDE should provide an interface to receive events from WAE in order to get the status of tasks (started-finished).

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		It should be also able to request information or update task information from/to the Factory2Fit Repository.
TDE 5	Communication with Automation-Level Adaptation Engine (ALAE)	TDE should provide an interface to ALAE in order to receive candidate resources (workers or machines) for each task, based on capability matching.

Table 2:Task and task distribution scenarios requirements

2.1.2 Sensor data acquisition

The Smart Sensor Network (SSN) is comprised of sensors for a) monitoring the states of machines and the fluency of production (machine status), b) observing the activities, states and location of workers (worker status), as well as, c) observing the properties of the working environment (context).

The machinery involved in the industrial use cases collect data regarding the behaviour of machines through inherent tracking mechanisms. These data will be utilized to monitor the status of machines and production.

Personal tracking devices from the well-being consumer market will be utilized for observing worker status. These will include the Fitbit Charge 2 wristband and the Samsung Gear S3 smartwatch for measuring a) activity in terms of steps and the intensity of physical activity, b) heart rate including also heart rate variability and resting heart rate, and c) sleep in terms of the amount and quality. See D1.1. *Enabling technologies* (Chapter 6) for a more detailed description of these devices.

The requirements for the Smart Sensor Network component are listed in the table below:

Req.#	*Requirement criteria*	*Description*
SSN 1	Worker data collection	Collection of step count, heart rate, sleep amount, quality and transmission to the F2F repository and Dashboard
SSN 2	Machine data collection	Collection of sensor data and transmission to the F2F repository and Dashboard
SSN 3	Smartwatch questionnaires	Possibility to display questionnaires on the screen of the smartwatch
SSN 4	Smartwatch task display	Possibility to display tasks on the screen of the smartwatch
SSN 5	Individualization of sensor data	Individualization of sensor data (select sensors, select data flow repository/dashboard)
SSN 6	Offline data storage	Local data storage in case of "no connection to WiFi"
SSN 7	Battery life	Battery life: at least one shift, charging during breaks
SSN 8	Stability	Automatic restart of application, no data loss
SSN 9	Support	Technical Manual, contact person

Table 3: Sensor data acquisition requirements

2.1.3 Workplace adaptation engine WAE

The Workplace adaption engine (WAE) gathers information on worker actions and production as well as error situations from the Factory2Fit Repository, and provides changes to machine

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parameters. It is used for the connectivity and interoperability of the connected components. The Workplace Adaptation Engine is designed according "Factory2Fit D1.1 Enabling Technologies" deliverable in order to support the interoperability of all required Factory2Fit components as e.g. equipment, smart devices, sensors, actors.

Following you find the list of functional requirements for the component Workplace Adaption Engine (WAE):

Req.#	*Requirement criteria*	*Description*
WAE 1	Enable WAE instantiation	Basic ability of generation, start/stop of a WAE instance to control the F2F framework communication flow
WAE 2	Configure WAE information models	Basic configuration of the adapted components, connected to the WAE via information models: - Task distribution engine - Virtual factory (visual components) - F2F repository
WAE 3	Configure WAE channels	Generate dedicated channels (implementation of the interfaces) for: - virtual factory (visual components) via OPC-UA - Task Distribution Engine via REST-Webservices - F2F repository via REST-Webservices - Smart Sensor Network via OPC-UA
WAE 4	Configure Mapping for WAE communication	Generate Mappings to configure communication capability between information models: - Task Distribution Engine and Virtual factory - Virtual factory and F2F repository
WAE 5	Control communication of tasks	transferring of tasks and task status between the components "Task distribution engine" and the virtual factory in the lab test environment (component "Visual components")
WAE 6	Worker data communication	transferring of worker data (e.g. AVG heart rate, step count, sleeping quality) between the virtual factory (component "Visual components") and the F2F repository
...		

Table 4: Workplace adaptation engine requirements

2.2 Knowledge sharing

The Factory2Fit Knowledge Sharing solutions encapsulate an array of components designed to facilitate intra-worker remote communication towards efficient collaboration in resolving a variety of problematic/error situations, as well as the sharing of knowledge, good practices, hints and tips in various media formats (e.g. video, text, etc.). The components developed in this topic implement a social media platform designed for usage inside the shop floor, aiming to improve the interaction, communication, socialization and cooperation among workers. Furthermore, augmented reality technology leveraging the latest in wearable head-mounted display holographic technology (i.e.

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Microsoft HoloLens) as well as the capabilities of contemporary smart devices (smartphones and tablets) will enable workers to capture knowledge on-the-fly, enrich their surrounding environment with digital information and intuitively connect to information stored in the Factory2Fit Repository without interrupting their current workflow. In order to motivate workers to participate in this knowledge sharing and utilize the tools in the most efficient manner, gamification techniques are implemented to make small steps of progress visible to the users and thus address the human desire for socializing, learning, competition, achievement, self-expression, or closure.

2.2.1 Social Media Platform

The main purpose of the Social Media Platform is to help workers communicate remotely with their colleagues, exchange ideas on work related issues, provide assistance to co-workers by answering questions made in the forum, and search for uploaded content in order to find a solution to a problem quickly.

The list of functional requirements for the Social Media Platform are provided in the Table below:

Req.#	*Requirement criteria*	*Description*
SMP 1	Support different types of users	Supervisors and/or moderators should have elevated privileges to be able to perform additional actions (e.g. moderate content).
SMP 2	Acquire data about users	Social Media Platform should be able to acquire the information of workers (users in general) that is stored in the Factory2Fit Repository.
SMP 3	Support integrated search	Social Media Platform should be able to perform search to multiple sources (multimedia content, text, documents) in order to help workers to find solutions to problems.
SMP 4	Provide social interfaces	Social Media Platform should allow users to give feedback on posts ('vote up', 'vote down', 'Like' buttons).
SMP 5	Implement a notification system	Social Media Platform should be able to show notifications to the worker (e.g. when the worker receives a new instant message).
SMP 6	Gamification integration	Workers should be able to view their gamification profile, such as collected points, awards, and ranking.

Table 5: Social Media Platform requirements

2.2.2 Augmented Reality Tools

The Factory2Fit Augmented Reality Tools purpose is twofold. At first, the augmented reality technology will be used to contextually link information within the Facotry2Fit Repository with real-life artefacts (e.g. images, machines, machine UIs), overlaying appropriate information on top of real world structures to increase clarity and visibility of the conveyed information within a specific context (for instance, informing the incoming workers of the next shift that maintenance is required on a noticeably highlighted machine part or consumable). Secondly, the AR technology can be used to

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generate new knowledge content (e.g. narrated point-of-view videos demonstrating how to resolve a particular situation), as well as viewing relevant content on demand, even allowing users to take advantage of the spatial perception capabilities of the HoloLens and personalize their augmented interface to best fit their preferences when dealing with error situations. The list of functional requirements for the Augmented Reality Tools (ART) are provided in the Table below:

Req.#	*Requirement criteria*	*Description*
ART 1	Record video content	Workers should be able to record content using the built-in cameras of the devices (either HoloLens or smartphone/tablet) and store the content in the Factory2Fit Repository.
ART 2	View video content	Workers should be able to access a page with every video available on a particular subject, select which video they want to stream and watch the content in a convenient manner.
ART 3	Anchor digital content	Workers should be able to automatically "anchor" digital content related to a specific 2D/3D object so that the augmented content is automatically attached to the physical artefact in a way that demonstrates the content in the proper viewing angle and location, in relation to the physical object's spatial properties.
ART 4	View & Manipulate digital artefacts (HoloLens only)	Workers should be able to select from a list of digital artefacts representing physical objects (e.g. machines or machine components) and place them in appropriate locations in the physical world. Additionally, users should be able to manipulate object properties (scale, rotation) to tailor object placement to preference (for example, overlay digital artefact on top of physical artefact) .
ART 5	Tagging knowledge items on digital artifacts (HoloLens)	Workers should be able to add digital tags onto digital artefacts (i.e. also physical artefacts, if the digital content is "anchored" or overlayed), which must generate a notification alert for users that a tag has been placed. The tags should be noticeably highlighted, allowing workers to quickly address these tags to facilitate exchange of knowledge.
ART 6	View Social Media /Gamification information	The system should grant access to the other components of the Knowledge Sharing Tools, providing a customizable view of the social media platform and the worker's gamification profile, along with a well-designed placement of achievements unlocking during use.

Table 6: Augmented Reality Tools requirements

2.2.3 Gamification Module

The purpose of the Gamification Platform is to motivate workers to pro-actively participate in the knowledge sharing process with meaningful and useful contributions that can benefit the entire work community. The platform promotes game thinking, applying game-design elements such as positive reinforcement, leaderboards and unlockable achievements in the context of engaging with the

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aforementioned Knowledge Sharing Tools. The Gamification Platform will thus be used to monitor worker interaction with the Social Media Platform and the Augmented Reality Tools, awarding profile points for active participation in discussion boards, creating and uploading content relevant to specific requests, building and maintaining a good reputation as an efficient problem solver within the work community and pursuing connections with co-workers. The module should provide easy means to define new gamified tasks, which will auto-generate new sets of achievements (e.g. small icons containing a short description on the task and worth a small amount of points contributing to the worker's earned total) for workers to unlock. The list of functional requirements for the Gamification Module (GM) are provided in the Table below:

Req.#	*Requirement criteria*	*Description*
GM 1	Allow the creation of a gamified task	Supervisor should be able to create a new achievement for workers to obtain, specifying the means by which the reward can be obtained (name, description, score to be gained).
GM 2	Provide overview of gamified tasks created	Supervisor should be able to view all gamified tasks already created.
GM 3	View locked/unlocked achievements	Workers should be able to view all achievements they have unlocked, as well as those they have yet to obtain, along with progress indicators (e.g. 50% complete).
GM 4	Manage achievements view	Workers should be able to configure the way their achievements are displayed, e.g. sort by date, by score, by progress etc. to better allow them to plan how to obtain their next achievement.
GM 5	View co-Workers leaderboard	Workers should be able to view their place in an overall leaderboard, as well as compare their achievements with those of another worker.
GM 6	Customize game profile	Workers should be able to customize how their profile looks, e.g. change their user icon/avatar, elevate specific achievements to appear as badges under their username, etc.

Table 7: Gamification Module requirements

2.3 Training

The training tool is responsible for providing on the job adaptive training to the worker in the factory. We design a video-based training tool, where the knowledge of expert is captured in form of videos and stored in a database. A novice worker can search for relevant video using the various criterions such as image-based search or text-based search.

Req.#	*Requirement criteria*	*Description*
TT01	Capture expert knowledge	Use videos to capture the knowledge of worker
TT02	Efficient search interface	Provide efficient search option using image based search
TT03	Modularity	The training video are organized in module and the sequence of video is retained

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TT04	Retain Holistic sequence	Maintain the relation between the different videos by capturing the order to the steps

Table 8: Training requirements

2.4 Virtual factory layout

The Virtual Factory provides the digital twin that realistic replicates the real factory layout into the digital world. The Virtual Factory allows the workers to actively participate in all the life cycle of the workplace design from the conceptual phase, being trained since the initial design phases and allowing workers to share their experience, until the commissioning and runtime, where workers can accelerate the start of the production and enhance productivity.

Req.#	*Requirement criteria*	*Description*
VF01	Training tool	Developing skills in realistic situations using the Virtual Factory
VF02	Collaboration platform	Supporting the communication of new configurations and enabling participatory design to create new ones
VF03	Knowledge sharing	Allowing the simulation and realistic visualization of proposed configurations and problem solving
VF04	Digital Twin	Supports bilateral communication, monitoring the manufacturing process and providing performance information

Table 9: Virtual factory layout requirements

2.5 Work satisfaction

Work well-being is a common goal for all Factory2Fit solutions. Based on the industrial requirements and the definition of the Factory2Fit concepts, divided as solutions to empower workers and solutions to engage the work community, we have defined *user experience goals* that indicate how the users would like to feel while working. Factory2Fit solutions should be designed so that they enable the user experiences described below. In addition to user experience goals, *ethical guidelines* should be taken into account in the design as well as *safety aspects*. All these supports the design of solutions that will have a positive impact on worker well-being.

Req.#	*Requirement criteria*	*Description*
UX1	Empowerment	The solutions should empower the worker
UX1.1	Feeling of competence	The worker should feel that his/her competence is developing with the solutions
UX1.2	Confidence	The worker should feel confident on his/her own skills and the machines' capabilities
UX1.3	Feeling of achievement	The worker should feel getting things done
UX1.4	Machine rocking	The worker should feel the production running smoothly
UX1.5	Feeing of control	The worker should feel being in control, e.g., influencing on the work/training pace
UX1.6	Self-respect	The worker should get support in understanding his/her skills and limitations

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UX2	Engagement	The solutions should engage the worker to the work community
UX2.1	Feeling of community	The worker should feel being part of the work community
UX2.2	Ownership	The worker should feel accountable for his/her actions and how (s)he is doing his/her job
UX2.3	Freedom of self-expression	The worker should feel free to tell his/her opinions and ideas
UX2.4	Being appreciated	The worker should feel that (s)he is appreciated at the workplace
UX2.5	Having an influence	The worker should feel that (s)he has an influence at the workplace
UX2.6	Feeling of personal development	The worker should feel that (s)he is developing at his/her work and that is supported

Table 10: Work satisfaction requirements

2.5.1 Ethical guidelines

Req.#	*Requirement criteria*	*Description*
ETH1	Privacy	Operators should be able to control access to their personal data.
ETH2	Autonomy	Operators should be able to choose their own way to work and learn.
ETH3	Integrity and dignity	The solutions should not violate the dignity of the operators.
ETH4	Reliability	The operators should be able to trust the solutions and the solutions should not threat their physical or mental health.
ETH5	Inclusion	The solutions should be accessible to operators with different capabilities and skills.
ETH6	Benefit to the society	The solutions should improve quality of life and not cause harm to anyone

Table 11: Ethical guidelines requirements

2.5.2 Safety requirements

Req.#	*Requirement criteria*	*Description*
SAF1	Freedom from accidents	The solutions should be free from risks of accidents.
SAF2	Freedom from long term hazardous effects on persons	The solutions should be free from hazardous substances, noise and radiation and ergonomy should be adequate.
SAF3	Awareness of safety	The operators should be able to recognize hazardous and safe situations.

Table 12: Safety requirements

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3 F2F Framework specification

This chapter describes the overall functional architecture of the Factory2Fit Framework designed to fulfil the requirements defined within the previous chapter. This chapter provides also an overview of main components, hardware/software requirements, interconnection between components, a system requirements summary and a proposed deployment architecture.

3.1 System architecture

Figure 1: Overall system architecture

The overall Factory2Fit architecture has been modified since its original release in M8 of the project. The updated architecture diagram in (see Figure 1: Overall system architecture) shows the latest version of the architecture, in which components and interfaces have been added (shown in blue color), renamed (shown in red color), or completely removed (refer to D1.4 for a side-by-side comparison of the architecture diagrams corresponding to M18 and M8 of the project). As was the case with the previous architecture diagram, the Factory2Fit system is divided into components comprising three layers, namely *Real-time Decision Making and Knowledge Sharing* tools, *Events and Data Storage* and *Contextual Analysis and Semantics* components. At the center of the architecture lies the Factory2Fit Repository, the central knowledge base of the factory in which all information on workers, factory physical resources, virtual simulations and knowledge is stored. The Repository directly interfaces with several of the components in the Events and Data Storage and Contextual analysis and semantics Layers and utilizes the Workplace Adaptation Engine as a universal connector to interface with adaptation and virtual/knowledge sharing tools in the real-time decision making and knowledge sharing Layer, as well as the smart sensors and workplace/machine UIs directly. The modular nature of the architecture allows room for flexibility in adding or removing components according to the needs of the Factory2Fit pilots, ensuring the Factory2Fit system will be operational even if some of its components are missing or non-functional. A complete description of the updated architecture as well as the procedures which led to the latest changes will be delivered in the updated version of D1.4 due in M25.

3.1.1 Smart Sensors Network Online Measures & Monitoring

Description	The *Smart Sensor Network (SSN)* consists of smart devices used for data acquisition and processing. These devices can either be smart bands, smart watches, or other devices. These data will be used as a source for driving the adaptation engines within the use cases of Factory2Fit. Also the *Worker Feedback Dashboard* represents a core component that is provided with data from the SSN and utilizes online measures and monitoring to provide person-related feedback to workers. Some of the sensors data will be stored directly at the *Factory2Fit Repository*.
Software Requirements	• OS: any • MySQL database

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Hardware Requirements	• CPU: dual-core, 2 Gb Ram, 10 GB HDD • Samsung Gear Smartwatch
Input	• Samsung Gear Smartwatch (communication via OPC-UA)
Output	• Factory2Fit Repository (communication via REST services) • Advanced Modelling Tools (communication via REST services)

Table 13: Smart Sensors Network Online Measures & Monitoring component

3.1.2 Advanced Modelling Tools

Description	The Advanced Modelling Tools module aims to support and update several models and patterns by collecting information concerning the worker characteristics, patterns and information about the workplace, stored in the Factory2Fit Repository. The output (updated variables) of the Advanced Modelling Tools module will be stored in the Factory2Fit Repository for use by other components.
Software Requirements	• OS: Microsoft Windows 10
Hardware Requirements	• CPU: Dual-core, 2 Gb Ram, 40 GB HDD
Input	• Worker / Sensorial data stored in Factory2Fit Repository
Output	• Factory2Fit Repository (communication via REST services)

Table 14: Advanced Modelling Tools component

3.1.3 Worker Feedback Dashboard

Description	The Worker Feedback Dashboard module provides data-driven feedback to the workers regarding their well-being at work and work-related activities. The module will receive input from the sensors part of the SSN Online Measures & Monitoring module regarding the relevant worker status, machine status and contextual characteristics that are required for constructing the feedback. In addition to the sensor data, data exchange between the Worker Feedback Dashboard and the Factory2Fit repository modules
Software Requirements	• Microsoft Azure
Hardware Requirements	• Microsoft Azure
Input	• Smart Sensor Network Online Measures & Monitoring (communication via REST services) • Factory2Fit Repository (communication via REST services)
Output	• Factory2Fit Repository (communication via REST services)

Table 15: Worker Feedback Dashboard component

3.1.4 Worker Profile Dashboard

Description	The Worker Profile Dashboard allows the workers to view the personal data that is stored about them in the Factory2Fit Repository. Each worker can only see

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	his/her own data. The worker can change his/her preferences and he/she can control the access rights to his/her data.
Software Requirements	• OS: any • Web Server
Hardware Requirements	• Standard office PC or tablet
Input	• Factory2Fit Repository (communication via REST services)
Output	• Factory2Fit Repository (communication via REST services)

Table 16: Worker Profile Dashboard component

3.1.5 Automation-Level Adaptation Engine

Description	The Automation-Level Adaptation Engine is a core component of the Integrated Decision Support System (DSS). Its functionality within the Factory2Fit framework is twofold: a) to match each worker to the proper Level of Automation (LoA) based on the worker's ability, experience and awareness; and b) to determine the selected manufacturing resources' capability parameters through a holonic reasoning process that makes use of product features, a pre-process plan, and the automation level model. Towards this end, two major sub-components of the Engine have been identified, each tasked with addressing one of the afore mentioned purposes of the module. Therefore, matching of workers to LoAs is handled by the LoA Configuration Engine, while the Digital Planning Holon will utilize a set of rules to infer the proper machine parameters for a specific task or worker assigned as operator.
Software Requirements	• OS: any • Web Server • Web Browser: Google Chrome, Mozilla Firefox
Hardware Requirements	• Standard office PC or tablet
Input	• Workplace Adaptation Engine (communication via REST services)
Output	• Task Distribution Engine (communication via REST services) • Workplace Adaptation Engine (communication via REST services)

Table 17: Automation-Level Adaptation Engine component

3.1.6 Task Distribution Engine

Description	The Task Distribution Engine is a core component of the Integrated DSS. It is responsible for assigning tasks to the most suitable workers and for planning the pending work of the factory, based on preferences and current state. The Task Distribution Engine is able to: a) assign each worker or machine to the proper task; and b) respond to events and real-time occurrences in the shop floor, re-adapting the original work schedule and properly assigning resources and workers to address each task. To this end, it is comprised of sub-modules that are responsible for offline and online task distribution and re-adaptation.
Software Requirements	• OS: Microsoft Windows 10 • Web Server • Web browser: Google Chrome

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Hardware Requirements	• CPU: quad-core , 8GB Ram, 1 GB HDD
Input	• Automation-Level Adaptation Engine (communication via REST services) • Workplace Adaptation Engine (communication via REST services)
Output	• Factory2Fit Repository (communication via REST services)

Table 18: Task Distribution Engine component

3.1.7 Workplace Adaptation Engine

Description	The Workplace Adaptation Engine is responsible for managing the communication between the Factory2Fit Repository and workplaces related resources like the worker (via the SSN), the machines, smart devices, user interfaces or other devices. It will make workplace related information available with a standardized Factory2Fit device model to other communication partners. This model provides the common devices information in a standardized way which will help the easy integration of new devices to the Factory2Fit platform.
Software Requirements	• OS: any
Hardware Requirements	• CPU: 1x1Ghz, 512Mb Ram, 1GB HDD
Input	• Automation-Level Adaptation Engine (communication via REST services) • Task Distribution Engine (communication via REST services) • Workplace (communication via OPC-UA) • Machine UI (communication via OPC-UA) • Factory2Fit Repository (communication via REST services) • Smart Sensor Network Online Measures & Monitoring (communication via OPC_UA)
Output	• Automation-Level Adaptation Engine (communication via REST services) • Task Distribution Engine (communication via REST services) • VR Simulation Platform (communication via OPC-UA) • Factory2Fit Repository (communication via REST services)

Table 19: Workplace Adaptation Engine component

3.1.8 Factory2Fit Repository

Description	The Factory2Fit Repository is a component where static and real-time dynamic data acquired by various sources in the factory floor are stored. Data can be retrieved by the Factory2Fit applications through the appropriate web services. In the Factory2Fit Repository, the information related to the processes, the resources, and their capabilities is saved in an understandable form of a formal ontology, so that all Factory2Fit modules can use them. As the central, most important part of the overall Factory2Fit architecture, the Factory2Fit Repository stores the information created by the other software modules, such as the Pre-Process Plan Generator, the Capability Editor and the Advanced Modelling Tools. Therefore, it will contain static information such as the pre-process plan, factory resources' blueprints, installed sensors, Augmented Reality devices used in operational situations, etc. Furthermore, it will store dynamic information related to the factory operations, such as the worker model, capability model, resource

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	and worker pools, events and contextual information that is related to re-adaptation of the task distribution and training activities etc. Additionally, the Factory2Fit Repository will be able to provide historical information related to factory operations to all Factory2Fit components at request.
Software Requirements	• OS: Microsoft Windows 7 or 10, 64-bit version • Java Runtime • Payara Server • MongoDB
Hardware Requirements	• CPU: quad-core, 4GB Ram, 1GB HDD
Input	• Workplace Adaptation Engine (communication via REST services) • Capability Editor (communication via REST services) • Pre-Process Plan Generator (communication via REST services) • Worker Profile Dashboard (communication via REST services) • Advanced Modeling Tools (communication via REST services) • Smart Sensor Network Online Measures & Monitoring (communication via REST services)
Output	• Workplace Adaptation Engine (communication via REST services) • Capability Editor (communication via REST services) • Pre-Process Plan Generator (communication via REST services) • Worker Profile Dashboard (communication via REST services) • Worker Feedback Dashboard (communication via REST services)

Table 20: Factory2Fit Repository component

3.1.9 Pre-process plan generator

Description	The Pre-process plan generator module will be used to define the product requirements from the product model. It will be dedicated to the analysis of product features, addition of information needed for process steps and the creation of a pre-process plan. The latter is a generic “recipe” that aims to describe how to manufacture a product or part of a product is a step-by-step manner. It describes the required capabilities at a generic level (e.g. “cutting”, “drilling”, “material removing”, etc.) and is linked to the product information in terms of specific feature or part information that is stored in the Factory2Fit Repository. Specific characteristics of a product or part, such as its size, type, weight, geometric dimensions, material and tolerance can be used to define product-related parameters to constrain the manufacturing process, as well as additional requirements that can be used as input for reasoning when searching for suitable resources or workers, with a significant effect on the selection of the appropriate type or range of the resource (e.g. selecting the appropriate gripper for a robotic arm based on the product shape). In a nutshell, the pre-process plan is an ordered graph of activities referring to specific levels of the capability taxonomy stored in the Factory2Fit Repository.
Software Requirements	• OS: any • Web server • Web browser: Google Chrome or Mozilla Firefox

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Hardware Requirements	• Standard office PC or tablet
Input	• Factory2Fit Repository (communication via REST services)
Output	• Factory2Fit Repository (communication via REST services)

Table 21: Pre-process plan generator component

3.1.10 Capability Editor

Description	The Capability Editor module will be responsible for assigning capabilities to resources, as well as adding new capabilities and resources to the Factory2Fit Repository. The properties of the factory resources (e.g. machinery) as well as the properties and skills of workers will be described by the parameters of the capabilities the devices and workers provide. The Capability Editor will allow users to add new devices and workers to the ontology, assign capabilities and parameters to these devices and workers. It will also allow new capabilities to be defined and stored in the ontology, and enable for capability associations to be created between simple and combined capabilities
Software Requirements	• OS: any • Web Server • Web browser: Google Chrome or Mozilla Firefox
Hardware Requirements	• Standard office PC or tablet
Input	• Factory2Fit Repository (communication via REST services)
Output	• Factory2Fit Repository (communication via REST services)

Table 22: Capability Editor component

3.1.11 VC4.0 Simulation Platform

Description	The VR Simulation Platform is one of the components of the "Real-time decision making & knowledge sharing" layer of Factory2Fit. It provides the tools for building the virtual factory model and interfaces with the Integrated DDS (Tasks Distribution Engine) which provides the process tasks to be performed by the virtual factory to create the product by the resources available in the factory.
Software Requirements	• OS: Windows 7 SP1, Windows 8.0, Windows 8.1, Windows 10. Both 32bit and 64bit operating systems are supported, but the application itself is 32bit • Running Visual Components 4.0 in a virtual machine or accessing it using remote desktop are not supported.
Hardware Requirements	• CPU of i7 Intel or equivalent processor • RAM of 8GB or more • HDD with 2GB of available space • Graphics driver (professional graphics card) equivalent to Nvidia Quadro or AMD - FirePRO with at least 2GB dedicated memory • Graphics display resolution of 1920 x 1080 Full HD or higher • Mouse with three buttons (left, middle, right)"
Input	• Workplace Adaptation Engine (communication via OPC-UA)

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	• Factory2Fit Repository (communication via REST services)
Output	• Workplace Adaptation Engine (communication via OPC-UA) • Factory2Fit Repository (communication via REST services)

Table 23: VC4.0 Simulation Platform component

3.1.12 Social Media Platform

Description	The Social Media Platform module includes all the necessary components needed for interaction, communication and socialization among workers in a factory floor. Its objective is to help workers communicate with their colleagues remotely and cooperate on work related issues, such as requesting help or sharing on and off-work interests. The platform is designed for usage inside the shop floor, i.e. workers may have the ability to use this platform everywhere, even when they do not have access to a computer. In order to achieve this, mobile equipment or ubiquitous user interfaces can be utilized based on the use case requirements.
Software Requirements	• OS: Microsoft Windows • Web server • Web browser: Google Chrome or Mozilla Firefox • Java Runtime
Hardware Requirements	• CPU: Dual-core, 4GB Ram, 40GB HDD
Input	• Gamification Module (communication via REST services) • Factory2Fit Repository (communication via REST services)
Output	• Augmented Reality Tools (communication via REST services) • Factory2Fit Repository (communication via REST services)

Table 24: Social Media Platform component

3.1.13 Gamification Module

Description	The Gamification Module is responsible for applying gamification in various aspects of Factory2Fit project. Its aim is to motivate workers have a better performance in the domain of every external system (primarily in participating to the knowledge sharing process) and also support them for corrective feedback and positive reinforcement. The input data of this module will derive from the Factory2Fit Repository and the SSN Online measures & monitoring modules.
Software Requirements	• OS: Microsoft Windows • Web server • Web browser: Google Chrome or Mozilla Firefox
Hardware Requirements	• Standard office PC or tablet
Input	• Factory2Fit Repository (communication via REST services)
Output	• Augmented Reality Tools (communication via REST services) • Social Interaction & Cooperation Tools (communication via REST services) • Factory2Fit Repository (communication via REST services)

Table 25: Gamification Module component

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3.1.14 Augmented Reality Tools

Description	Tools for augmenting real world using HoloLens and smart devices.
Software Requirements	• OS: Microsoft Windows 10, Google Android OS (4.0 or newer)
Hardware Requirements	• Microsoft HoloLens (specifications available here: https://developer.microsoft.com/en-us/windows/mixed-reality/hololens_hardware_details) • Smartphone/Tablet: Quad Core 1.4GHz, 2Gb RAM, 8MP camera.
Input	• Factory2Fit Repository (communication via REST services) • Gamification Module (communication via REST services) • Social Media Platform (communication via REST services) • Workplace Adaptation Engine (communication via REST services)
Output	• AR HMI's (communication via REST services) • Factory2Fit Repository (communication via REST services) • Workplace Adaptation Engine (communication via REST services)

Table 26: Augmented Reality Tools component

3.1.15 Factory2Fit Training Application

Description	The Training Application will be responsible for providing on the job adaptive training to the worker in the factory. Training scenarios vary depending on the type of the manufacturing (discrete, continuous, sensitive, highly technological etc.), and the skill set of the workers to be trained. Therefore training scenarios must be customized with consultation of the training manager and participation of the workers. These scenarios will be focused towards the situations where the novice workers face problems. With the consultation of the worker a list of the most problematic scenarios will be created. Video of expert worker will be used for training.
Software Requirements	• OS: Ubuntu 16.04 • Mongo Database
Hardware Requirements	• CPU: i7 Intel or similar, 8GB Ram, > 20GB HDD • Graphics Card Nvidia GTX 1080 or similar • Tablet or smartphone with camera to access the content
Input	• Image captured from smart device
Output	• Workplace

Table 27: Factory2Fit Training Application component

3.2 System requirements summary

In this section consolidated requirements of the Factory2Fit Framework are described based on the component requirements defined in previous section.

Software Requirements	• OS: Ubuntu 16.04 • OS: Windows 10 • Java Runtime

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	• Apache Tomcat • Payara Server • Mongo Database • MySQL Database • Web browser: Google Chrome or Mozilla Firefox
Hardware Requirements	• CPU: i7 Intel or equivalent processor • Memory: 16GB RAM • HDD: 200GB • Samsung Gear Smartwatch • Microsoft HoloLens • Smartphone/Tablet: Quad Core 1.4GHz, 2Gb RAM, 8MP camera. For VC4.0 Simulation Platform standalone PC is required with the requirements defined in section 5.1.11 For Factory2Fit Training Application a standalone PC is required with the requirements defined in section 5.1.15

Table 28: System requirements summary

3.3 Proposed deployment architecture

This section describes the architecture for the deployment of the F2F Framework. The deployment architecture consists of one server containing 7 virtual machines (VM_1..VM_8) and 3 standalone PC's (PC_1..PC_3) to host components that cannot run in an virtual environment.

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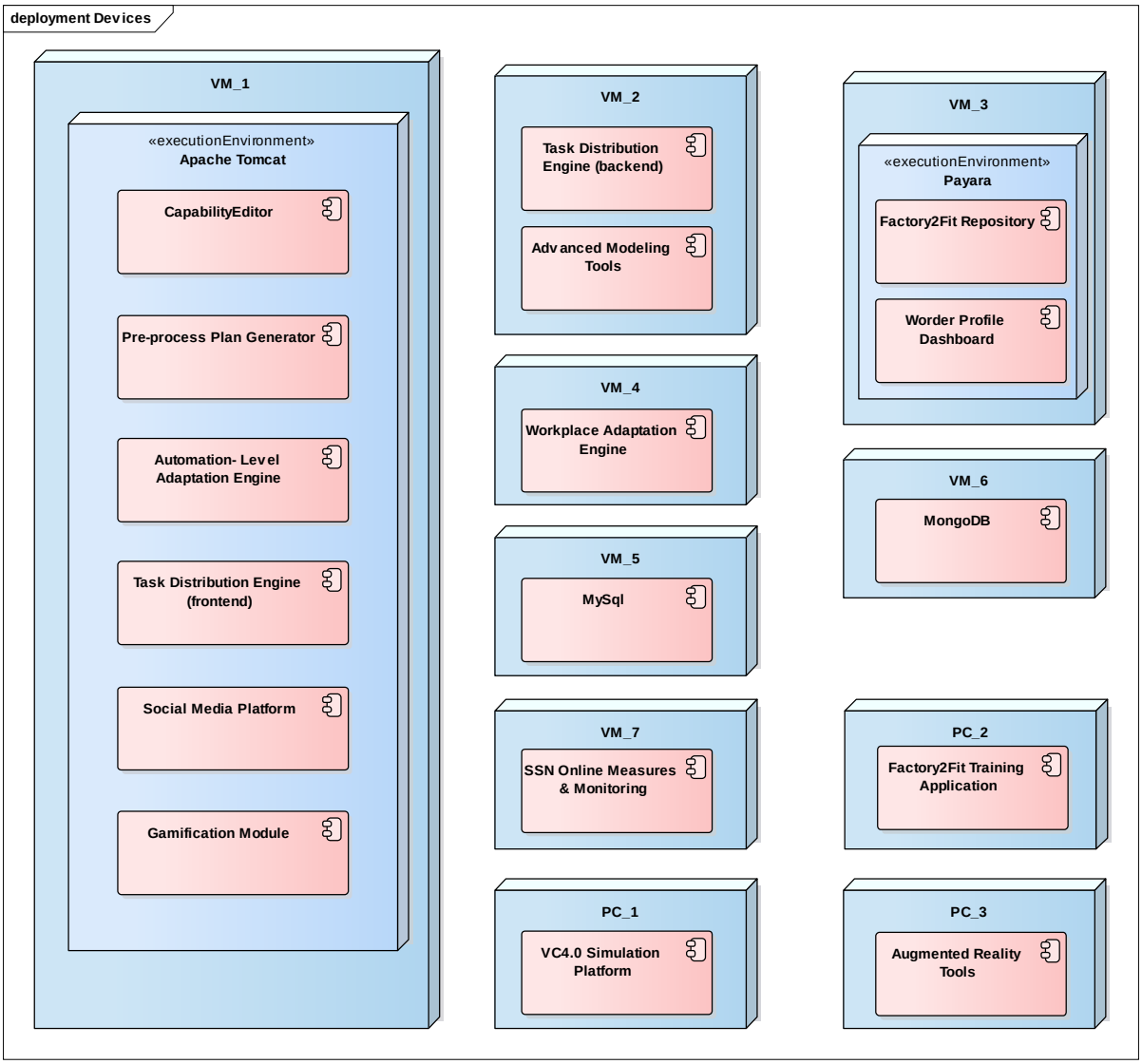

Figure 2: Proposed deployment architecture

3.3.1 VM_1

Description	Adaptation web applications
Software Requirements	• OS: Ubuntu 16.04 • Web server: Apache Tomcat
Hardware Requirements	• CPU 4 Cores, 8GB RAM, 40 GB HDD
Components	• Capability Editor • Pre-process Plan Generator • Automation-Level Adaptation Engine • Task Distribution Engine (Front End) • Social media platform • Gamification module

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Table 29: VM_1 Adaptation web applications virtual machine

3.3.2 VM_2

Description	Task distribution engine back end
Software Requirements	• OS: Windows
Hardware Requirements	• 4 Cores, 8GB RAM, 40GB HDD
Components	• Task Distribution Engine core • Advanced Modelling Tools

Table 30: VM_2 Task distribution engine back end virtual machine

3.3.3 VM_3

Description	Factory2Fit repository
Software Requirements	• OS: Ubuntu 16.04
Hardware Requirements	• 4 Cores, 8GB RAM, 40GB HDD
Components	• F2F repository • Worker Profile Dashboard
Database	• VM_6 – MongoDB

Table 31: VM_3 Factory2Fit repository virtual machine

3.3.4 VM_4

Description	Workplace adaptation engine
Software Requirements	• OS: Ubuntu 16.04
Hardware Requirements	• 2 Cores, 4GB RAM, 20GB HDD
Components	• Workplace Adaptation Engine

Table 32: VM_4 Workplace adaptation engine virtual machine

3.3.5 VM_5

Description	MySQL
Software Requirements	• OS: Ubuntu 16.04
Hardware Requirements	• 2 CPU Cores, 4 GB RAM, 120 GB HDD
Database	• MySQL

Table 33: VM_5 MySQL virtual machine

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3.3.6 VM_6

Description	Mongo DB
Software Requirements	• OS: Ubuntu 16.04
Hardware Requirements	• 2 CPU Cores, 4 GB RAM, 120 GB HDD
Database	• Mongo DB

Table 34: VM_6 Mongo DB virtual machine

3.3.7 VM_7

Description	Smart Sensor Network
Software Requirements	• OS: Ubuntu 16.04
Hardware Requirements	• CPU: 2-3 GHz, 4096 Mb Ram, 10 GB HDD
Components	• VM_6 Mongo DB

Table 35: VM_7 Smart Sensor Network virtual machine

3.3.8 PC_1

Description	VC4.0 Simulation Platform
Software Requirements	• 64-bit operating system of Windows 7 SP1, Windows 8.1, or Windows 10
Hardware Requirements	Separate PC with "Minimum: • CPU of i5 Intel or equivalent processor • RAM of 4GB • HDD with 1GB of available space • Graphics driver (newest generation) with integrated HD440 or similar • Graphics display resolution of at least 1280 x 1024 • Mouse with three buttons (left, middle, right) Recommended: • CPU of i7 Intel or equivalent processor • RAM of 8GB or more • HDD with 2GB of available space • Graphics driver (professional graphics card) equivalent to Nvidia Quadro or AMD - FirePRO with at least 2GB dedicated memory • Graphics display resolution of 1920 x 1080 Full HD or higher • Mouse with three buttons (left, middle, right)"
Components	• VC4.0 Simulation Platform

Table 36: PC_1 VC4.0 Simulation Platform

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3.3.9 PC_2

Description	Training Tool
Software Requirements	• OS: Ubuntu 16.04
Hardware Requirements	• CPU of i7 Intel or similar Cores, • 8GB RAM, • Graphics Card Nvidia GTX or similar
Components	• Training tool
Database	• VM_6 – MongoDB

Table 37: PC_2 Training Tool

3.3.10 PC_3

Description	Augmented Reality Tools
Software Requirements	• OS: Windows
Hardware Requirements	• 2 CPU Cores, 4 GB RAM, 120 GB HDD • Graphic card
Components	• Augmented Reality Tools

Table 38: PC_3 Augmented Reality Tools

3.3.11 Cloud services

Description	Cloud service
Cloud service provider	• Microsoft Azure
Components	• Worker Feedback Dashboard

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4 F2F Framework test scenarios

4.1 Task execution in Virtual Factory

The Virtual Factory should request a task created by the Task Distribution Engine via the Workplace Adaptation Engine. Afterwards the task should be executed, and the associated state changes of the task should be notified to the F2F repository

Description	Expected result
VF requests new task name from TDE by changing the setting the associated variable in the Virtual Factory information model	- Change of the request variable in the VF model triggers a request sent over the WAE to the F2F repository - Task name updated in VF
VF starts execution of task	Task status updated in F2F Repository
VF finishes execution of task	Task status updated in F2F Repository

Table 39: Task execution in Virtual Factory test scenario

4.2 Calculating of worker wellbeing from worker health parameters

The simulated worker parameters of the Virtual Factory like heart rate, step count and sleep quality should be processed in the Advanced Modelling Tools (AMT) and used for estimating and updating the corresponding variables of the Worker Model for each worker. The Task Distribution Engine should be able to consider the updated variables when an assignment decision must be made, resulting in a re-adapted work schedule.

Description	Expected result
VF updates health parameters (heart rate, step count, sleep quality)	Raw parameters are collected with the WAE and forwarded to AMT
AMT calculates corresponding worker data	Worker data is update in F2F repository
TDE recalculates the work schedule	Task list is re-adapted
Display data on Worker feedback dashboard	Updated well-being data is shown on the Worker feedback dashboard

Table 40: Calculating of worker wellbeing from worker health parameters test scenario

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4.3 DSS Digital Adaptation flow

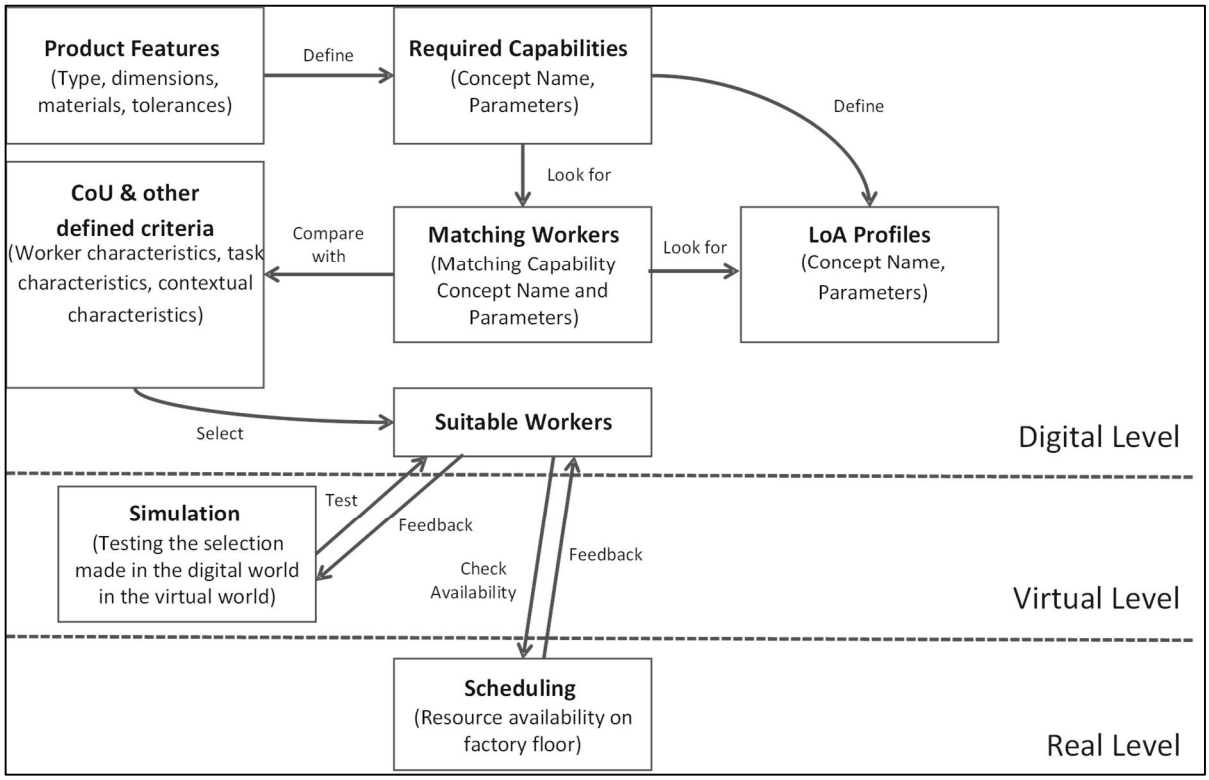

Figure 3: Factory2Fit proposed adaptation process flow (as presented in D3.1).

Referencing the Factory2Fit proposed adaptation flow shown in Figure 3, this test scenario will simulate the process of generating product features and requirements through the Pre-process Plan Generator (PPG), creating a Resource Ontology via the Capability Editor (CE), proceed to coarse capability-based matching of resources to pre-process plan tasks using the Automation Level Adaptation Engine (ALAE) and real level task scheduling through the Task Distribution Engine (TDE). The resulting schedule will be stored in the Factory2Fit Repository, along with the outputs of the Events & Data Storage Layer components tested in this simulation flow.

Description	Expected result
Resource Ontology is created in CE	Resource ontology data and capability data JSON files generated and stored in F2F Repository.
Pre-process Plan is created using PPG	PPG retrieves capability JSON file from F2F Repository. Pre-process plan data JSON file generated and stored in F2F Repository.
Capability-based matching of resources to tasks.	ALAE retrieves resource ontology, capability and pre-process plan JSON files from F2F Repository through the WAE.

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	ALAE generates intermediate CSV data files containing pairs *TaskID-ResourceID*, *TaskID-TaskDescription* and *RecourceID-RecourceName*
Matching results sent to TDE via web services interface	CSV data files created in the ALAE are retrieved through POST request by the TDE.
Task scheduling and assignment	Task Distribution Engine inserts the new task in the work schedule and assigns it to the most appropriate resources, based on requirements (workers, machines). The work schedule is re-adapted accordingly.
Work schedule stored in F2F Repository	The changes in tasks are finally stored to the F2F Repository by the Task Distribution Engine, through WAE.

Table 41: DSS Digital Adaptation flow test scenario

4.4 Worker Profile Dashboard -> F2F Repository

This test scenario will check the data exchange procedure between the Worker Profile Dashboard and the F2F Repository. The Worker Profile Dashboard allows workers to insert or edit personal information, such as preferences, into the system. After successful login, the worker profile dashboard retrieves current information from the Repository using the appropriate web services and displays it to the worker. The updated information provided by the worker is received from the Worker Profile Dashboard and then sent to the Repository.

4.5 SSN -> WAE -> F2F Repository

The Smart Sensor Network component manages the devices equipped with various sensors (e.g. smartwatches) and publishes the events containing the data to the Workplace Adaptation Engine. Subsequently, the Workplace Adaptation Engine sends the events to the F2F Repository in the appropriate JSON format by performing POST requests.

4.6 Engaging in Knowledge Sharing

This test scenario will investigate how knowledge sharing tools interface with the Factory2Fit Repository, how content is created and stored, how it is distributed to various output devices (PCs, smart devices, HoloLens) and how gamification is applied to worker profiles for completing exemplar knowledge sharing tasks.

Description	Expected result
Gamification Module is used to create a new gamified task and generate a list of achievements for workers to earn.	Achievement information and gamified task rules are stored into the Gamification Module database.
Social Media Platform Login	A user (e.g. worker, supervisor) successfully logs on to the Social Media Platform.
Social Media Platform is used to search content for problem solving	A worker enters a keyword related to a problem to search for information. The Social Media Platform returns relative content found

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	in the database (videos, images, text) in a user friendly format.
Social Media Platform is used to make and answer questions.	A worker can use the online forum to ask a question regarding his/her work or to reply to a question of a colleague and give feedback (upvote/downvote). The changes are stored to the Social Media Platform database.
Social Media Platform is used to exchange ideas	A supervisor uses the idea collection section, and creates a new post for participatory design, containing the necessary attachments. A worker can post his/her opinion.
Social Media Platform is used to present information about gamified tasks to the worker	The Social Media Platform communicates with the Gamification module using web services and presents collected points and leader boards to the worker through a web browser.
AR Tools are used to access video data (Smartphone/Tablet)	AR Tools obtain information from Factory2Fit Repository stored data on videos through the WAE.
AR Tools are used to access video data (HoloLens)	AR Tools obtain information from Factory2Fit Repository stored data on videos through the WAE.
Achievement tracker in AR Tools notifies Gamification Module that an achievement has been earned	AR Tools interface with Gamification Module to update worker gamification profile in F2F Repository. New profile indicates specific achievement has been unlocked, and profile score is increased by the designated amount.

Table 42: Engaging in Knowledge Sharing test scenario

4.7 Sensor data acquisition

Description	Expected result
The next task is being displayed	The next task, that needs to be done, is being displayed on the smartwatch of the worker. The worker is being informed immediately and can select or dismiss the task.
Assessing parameters through questionnaires.	Short questionnaires and single questions are presented on the smartwatch. The worker can fill out the questionnaires and information about the status of the worker can be derived.
Assessing parameters through sensors.	Through sensor data (mainly heart rate and movement sensors), parameters, for instance activity and physical stress can be determined in order to adapt the process.
(Localization of the worker)	(Localizing the worker enables the possibility for selecting optimized task distribution based on the current position of the workers)

Table 43: Sensor data acquisition test scenario

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4.8 Training tool

A typical usage scenario involves worker looking for a training video about how to assemble/use some components. A worker launches the training app with a smart device (tablet). The worker needs information about the use of a specific component in the factory. An image of the specific part is taken from the smart device camera. The image is submitted for the image-based search and transferred to the server using HTML5. A machine learning and computer vision algorithm is used to identify the part in the picture and the relevant video containing that part are retrieved. The videos with the specific part are transferred to smart device and displayed on the smart device. The worker can view the video on the smart device.

Description	Expected result
Launch the training application	Graphical interface appear on the smart device
Launch search option	The camera of the device is activated
Upload image for search	The image is transferred to server for video search
Perform search/display results	The relevant video are shown on the smart device

Table 44: Training tool test scenario

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5 Conclusions

In this deliverable, a detailed definition of the Factory2Fit framework is given. This framework will be tested in a lab test environment at TU Chemnitz in this Task 5.1. In the following steps in WP5 this tested framework is used to implement the pilots that will be later defined in the deliverable D5.2 and D5.3 in WP5.

First there is an overview of user requirements that define the Factory2Fit framework. These requirements are derived from the deliverables D1.2 (Industrial requirements) and D1.4 (Adaptation architecture). Based on the Adaptation Architecture the requirements of the architecture-components of are summarized to generate at the end the test cases, to verify the functionality of the Factory2Fit framework. The requirements overview is categorized based on the requirements summary of Delivery D1.2 (Industrial requirements) – Worker modelling and system adaptation, Knowledge Sharing, Training, Participatory design of manufacturing operation, Virtual factory, Work satisfaction.

Next, the Factory2Fit framework is specified. A summarized overview of the architecture components based on the deliverable D1.4 (Adaptation architecture) is given with a brief description of each component with its software and hardware requirements and also input and output of the components.

Afterwards these software- and hardware requirements are summarized. Based on this summary a physical deployment architecture for the test lab environment is derived. This deployment will be done in Task 5.1 physically on Virtual Machines in the Test Lab at TU Chemnitz. A detailed description of each virtual machine with its technical requirements defines the technical aspect of the Test lab environment.

As a final step there are derived Factory2Fit framework test scenarios based on the requirements in chapter 4. These test scenarios are later used in Task 5.1 to verify the functionality of the F2F framework in the Test lab environment.

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