AUTOWARE

Wireless Autonomous, Reliable and Resilient Production Operation Architecture for Cognitive Manufacturing

D5.1b Pilot site set up and data collection

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Dissemination level	PU	**Dissemination nature**	OTHER
Date	11. Feb. 2019	**Version**	1.0

European Commission

Version History

No.	Date	Author (Organization)	Description
0.1	04/12/2018	SFKL	Deliverable structure and ToC
0.2	08/12/2018	SFKL	Included JSI inputs Included imec inputs Included SMC inputs
0.3	20/12/2018	SFKL	Included SFKL inputs
0.4	06/02/2019	SFKL	Added Tekniker inputs
0.5	07/02/2019	TTT	Review comments
1.0	11/02/2019	SFKL	Finalized

Project partners

Software Quality Systems	SQS
Asociación de Empresas Tecnológicas Innovalia	INNO
Technologie-Initiative SmartFactoryKL e.V.	SFKL
Jozef Stefan Institute	JSI
TTTech Computertechnik AG	TTT
Consiglio Nazionale Delle Ricerche	CNR
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Robovision	Robovision
Universidad Miguel Hernández	UMH
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	FhG
Blue Ocean Robotics	BOR
Fundación Tekniker	Tekniker
SMC Deutschland GmbH	SMC

Executive Summary

Task of Deliverable D5.1b is to report the preparation and the lessons learned in each pilot. This deliverable is in charge of preparing the pilot sites. Included in this task is identifying the data, human resources, manufacturing processes and IT assets needed to perform the different pilot implementations. This task will also compile the lessons learned in each pilot, the data gathered for the KPIs defined in WP1 and prepare some sectorial recommendations and observations.

The industrial use cases for the AUTOWARE project have been designed to fulfill two main objectives. On one side, the use cases are intended to extend and enhance "neutral" experimentation infrastructures that are available to SMEs and industry for the investigation of industry 4.0 approaches and solutions. The extension objective is to empower such experimentation sites with the latest reference architectures, development and design methodologies and platforms to allow the development of autonomous processes in the context of the cognitive factory. Thus, the experimentation sites are natural physical extensions of the digital business ecosystems, where cognitive automation approaches and solutions can be validated. AUTOWARE considers the expansion of 3 key "neutral" experimentation infrastructures that will respond to the experimentation needs of collaborative robotics (TEKNIKER), automation processes (SmartFactory KL) and reconfigurable work-cells (Josef Stefan Institute). On the other hand, the AUTOWARE industrial use cases are also designed to meet the requirements of industrial deployment both from large industry and smaller businesses. It is important that the AUTOWARE framework is acknowledged by both large companies and SMEs so that the business ecosystem is sound and global. AUTOWARE considers furthermore an automation process use case for cognitive automation represented by STORA ENSO and a use case focused on the collaborative and cognitive assembly of components represented by SMC Deutschland GmbH.

Keywords

Business process modelling, Challenges, KPIs, Manufacturing, Methodology, Requirements, Use case scenarios.

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Acronyms

KPI	Key Performance Index
CPS	Cyber Physical System
OPC-UA	Open Platform Communications Unified Architecture
RFID	Radio-frequency identification
CNC	Computer numerical control
MQTT	Message Queuing Telemetry Transport
QR code	Quick Response Code
RESTFUL	Representational State Transfer
AMQP	Advanced Message Queuing Protocol
ROS	Robot Operating System

QA	Quality assessment
CAD	Computer Aided Design
PLM	Product Lifecycle Management
ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
PMI	Production Manufacturing Information

1. Introduction

1.1 Purpose and scope

Deliverable D5.1 is in charge of preparing the pilot sites and identifying the data, human resources, manufacturing processes and IT assets needs to perform the different pilot implementations. This task will also compile the lessons learned in each pilot, the data gathered for the KPIs defined in WP1 and prepare some sectorial recommendations and observations.

AUTOWARE is organized in two waves of iterative research and innovation. The first cycle is intended to build a solid IT infrastructure foundation, align multi-sided stakeholders views and innovative concepts for cognitive manufacturing and neutral industrial experimentation and build the technical and business confidence on the potential behind the cognitive approach that underpins the AUTOWARE digital business ecosystem and reference architecture.

This phase is completed with the first presentation of the AUTOWARE ecosystem approach to general industry (both manufacturing-ICT) as part of the communication process and evidence gathering.

2. Mapping with Requirement analysis and KPIs

WP5 will follow the way to map all components developed by the AUTOWARE work packages (WP2-WP4) into each neutral facility. In this version of the deliverable, the setup and data collection is described in hindsight to the KPIs defined in WP1. AUTOWARE is developing 10 components that are shown in the table above (see Table 1), which will be deployed in the pilot facility of five sites of SFKL, JSI, TEKNIKER, STORA and SMC.

Table 1. Mapping table from pilot plants and components

	JSI	SFKL	SMC	STORA	TEKNIKER
OpenFog					
TSN config					
Aug Reality					
CloudFlow					

FIWARE					
Industrial connection					
Distributed data mgmt.					
Robotics Interface					
Cognitive Vision					
Program. By Demo.					

3. Neutral industrial Pilot: SmartFactoryKL

The SmartFactory infrastructure can be used as a neutral experimentation infrastructure to integrate, customize, test, validate and demonstrate AUTOWARE innovations, prior to the end-user implementation and market launch. Experiments can be performed, among others, in the area of:

1. Active Digital Object Memories (ADOMe), which extends the usage of classic Auto-ID technology by additional memory and processing capabilities and maintain comprehensive information on their own production.
2. Decentralized control factory based on autonomous and cognitive CPS. Cloud-based data analytics
   (a) to optimize the planning and utilization of production resources through smart decision support for the reconfiguration of the production process;
   (b) to enable a product tracking if the current products state in the production line also fulfills the intended state in the digital twin, to support an early recognition of abnormalities.

2.1 Manufacturing resource

Figure 1 Pilot plant site of SmartFactory KL

a. Production module – FESTO module

Description	This projection module engraves the bottom parts of business card holder with an end mill module. FESTO, which is a SmartFactoryKL consortium member, built this production module in order to show the concept of Modular system with own products. Main components: OPC-UA servers, Gantry robot with gripper and an engraving system of end-mill tool and spindle, 2 flexible conveyor belts, RFID system to detect the products and other production modules. 
Function	The module BOTTOM ENGRAVING by FESTO initializes the digital product memory to a specific production order via RFID. The production order is loaded from a Web Server of the superordinate Enterprise Resource Planning system (ERP) via http-protocol by means of a specially developed Web Client.
Data	OPC-UA server message: Owner, Contact Person, Short Description, Extended Description, Source System(s), Main Data Entities, Format, Access Protocol, Volume, Type, Related Use Cases, Confidentiality / License, Sample, Utility / Potential Use Smart sensor message: Temperature, vibration, current

b. Infrastructure Box

Description	The infrastructure nodes of SmartFactoryKL are separate supply modules for the power supply, compressed air and for the network communication of one or more production modules. The aim is, to provide a separate supply station that acts as central energy supply and communication node for all affiliated modules and module groups. The infrastructure node provides a network switch for a TSN-based dataflow. 
Function	The infrastructure node provides a defined interface for electromechanical connection that contains connectors for voltage, pneumatic and ethernet. The components of the node itself gets the power supply also by use of this interface.  The usage of an infrastructure node allows the combination with edge devices to provide sensor and actor data as OPC-UA-interface to the server, which are based on TSN.
Data	Network dispatch of OPC-UA server messages.

c. Manual working station

Description	A MANUAL WORKSTATION is also connected to the process via the robot platform, a system created by MiniTec. Internet and communication systems provide optional support to the worker for various assembly tasks from an ergonomically perfect workstation. Thanks to the Augmented Reality systems developed at SFKL, an individual process step or even an entire production process can occur completely manually. Augmented Reality - the connection of real-time pictures with recommendations for actions – offers many advantages, especially for training processes and assembly with many variants. Through an integrated RFID reading and writing device, the employee can read out the current production progress of the product as well as the client specific

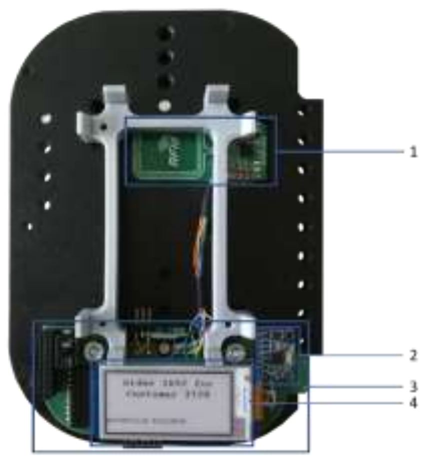
	information. Augmented Reality Technologies support him with the implementation of the variable tasks. Mobile devices like tablets, smartphones, smartwatches, and smart glasses are useful in providing an appropriate mobile support to the worker. 
Function	Main function of this machine is to assemble a business card holder manually by providing individual instruction. The instruction is launched by detecting the RFID tag attached in the bottom parts of the work-in-process. Each step of the assembly sequence is represented by 2 monitors in front of the operator and a project highlighting a specific area on the desk in according to the hand gesture observed by a side camera and a top dual camera. It is possible to synchronize with the digital data with both production system.
Data	Semantic data base of manual working steps Product identification information

d. Product and process

Product	Machine	Process	Parts
Business card holder 	PILZ module	PLATTING STORAGE MODULE	Pallet
	FESTO module	BOTTOM ENGRAVING	Active RFID tag Bottom
	REXROTH module	CLIP MOUNTING	Card clip,
	HARTING module	FORCE FITTING	Cover
	PHOENIX CONTACT	LASER MARKING	Complete product
	METTLER TOLEDO module	WEIGHING MODULE	
	Lapp Kabel	QUALITY CONTROL	

Figure 2 Sequence of assembly processes

The Product is actualized with active components and sensors that are in the workpiece carrier which communicates with the product memory, which is saved on an RFID chip. During the whole production process the product and workpiece carrier are connected and form a unit.

Workpiece carrier	Part number	Component description
	1	RFID Reader / Writer
	2	Accelerometer / Gyroscope
	3	Single-board computer
	4	E-Ink Display

2.2 IT assets

Asset name	Roles	Input	Output	Deployment plan	Source
IBM Integration Bus	Collect and Publish messages	OPC-UA message	MQTT, WebService	Done	Commercial
FIWARE DyVisual	Visualize 3D factory	Machine event msg.	Web 3D model	Done	FIWARE AUTOWARE

Hololens Smart Operator App	Interacts with human operator	3D model events	Camera stream	Done	AUTOWARE
Object detection algorithm	Detect parts and human existence	Camera stream	Detected humans and parts	Done	AUTOWARE
RedBorder	Cyber Security	Traffic data of each ports	Traffic analysis	In progress ~ April 2019	AUTOWARE
ADOMe	Intelligent product and logistics	Operation Order ID Time stamp Machine ID	Operation Order ID Time stamp Machine ID	Done	AUTOWARE
5G AP / Router	20GMps Wireless comm,	Camera images	Optical Quality Control	Done	SFKL consortium
OpenFOG	Managing Virtual machines providing local cloud services	Service requests	Service output	In progress ~March 2019	AUTOWARE
TSN config	Optimize the priority of various networking	Traffic data	Priority control command	In progress ~April 2019	AUTOWARE
CPLEX algorithm	Optimize Production Schedule	Incoming Orders, Process times	Tags for product rescheduling	Done	AUTOWARE

2.3 Data

The input data is the order coming from the customer who asks for a specific product module characterized by color types and QR code image printed over the cover. The

ERP system sends the order data into the first production module storage that is the initial point of the whole production system. The order data comes from customers through the ERP system. Color types are the product types.

Table 2. Product message contents

	Dataset Product
Owner	SFKL
Contact Person	Jens Popper / William Motsch
Short Description	Dataset which has product information
Extended Description	This dataset keeps product-specific, production-sequence and tracking information in the production line.
Source System(s)	Product
Main Data Entities	Product ID, priority flag for production sequence, product defect flag, distance between modules
Format	Binary
Access Protocol	RFID / OPC-UA
Volume	One for each product
Type	Dynamic
Related Use Cases	UC#2 DEPLOYMENT OF THE AUTONOMOUS MODULE IN DIFFERENT ENVIRONMENTS UC#3 IN-LINE MONITORING AND IN-LINE INFORMATION REQUESTS UC#4 OPERATOR IN-LINE DECISION SUPPORT UC#5 SMART ASSEMBLY LINE SEQUENCING UC#9 OPTICAL QUALITY CONTROL UC#10 PRODUCT TRACKING IN AND BETWEEN PRODUCTION LINE MODULES UC#11 OPTIMIZATION OF PRODUCTION LINE SEQUENCE (BY USING CPLEX ALGORITHM) AND COMMUNICATION TO THE PRODUCT MEMORY
Confidentiality / License	Approval from the company
Sample	
Utility / Potential Use	Research and experimentation

The cameras inside the factory are intended to support the quality control processes. By using the cameras of the augmented reality device MS HoloLens, the scope is to support the factories worker tasks with object (and state) detection. The camera streaming data is collected by an edge computing server locating nearby production modules, where human operators handles machine and assembly parts. Furthermore, a camera is installed on the autonomous logistics robot ("Robotino") in the SmartFactoryKL, which uses the 5G connection to transfer pictures of the transported goods to a cloud where an optical quality inspection is made by using the object detection algorithm. This way, the human worker at the manual assembly station can be notified whenever a faulty part is transported and if further inspections are needed.

The data flow circulates through three areas, that are machine, factory and cloud. Machine area data consist of production modules, publishing messages from an OPC-UA server. The message consists of the criteria which is shown in the following table.

Table 3. Dataset of production module

Dataset - Production Module	
Owner	SFKL
Contact Person	Jens Popper / William Motsch
Short Description	Provides information on the production modules
Extended Description	This dataset provides data related to individual production modules such as their power consumption, their status, operating mode (maintenance, active, etc.)
Source System(s)	Module
Main Data Entities	All module production related info: Module ID, module description, production status, conveyor status, operating status, error status, uptime information, power consumption, order number, process time etc.
Format	OPC-UA or JSON over MQTT
Access Protocol	OPC-UA or MQTT
Volume	Number of modules in the production line
Type	Static
Confidentiality / License	Approval from the company Anonymization Reduction of datasets
Sample	-

Factory layers and cloud layers produce their own second messages based on OPC-UA data. In the factory layer, OPC-UA servers are implemented on both the PLCs as well as on the edge devices implemented in the production modules. In addition, the edge server collects the camera streaming data through wireless communication. These OPC

UA messages are streamed to the IBM integration bus of SmartFactoryKL, which produces new messages represented as MQTT and sent to the cloud layer. This is shown in Figure 3.

In the AUTOWARE project, FIWARE components are used as cloud services.

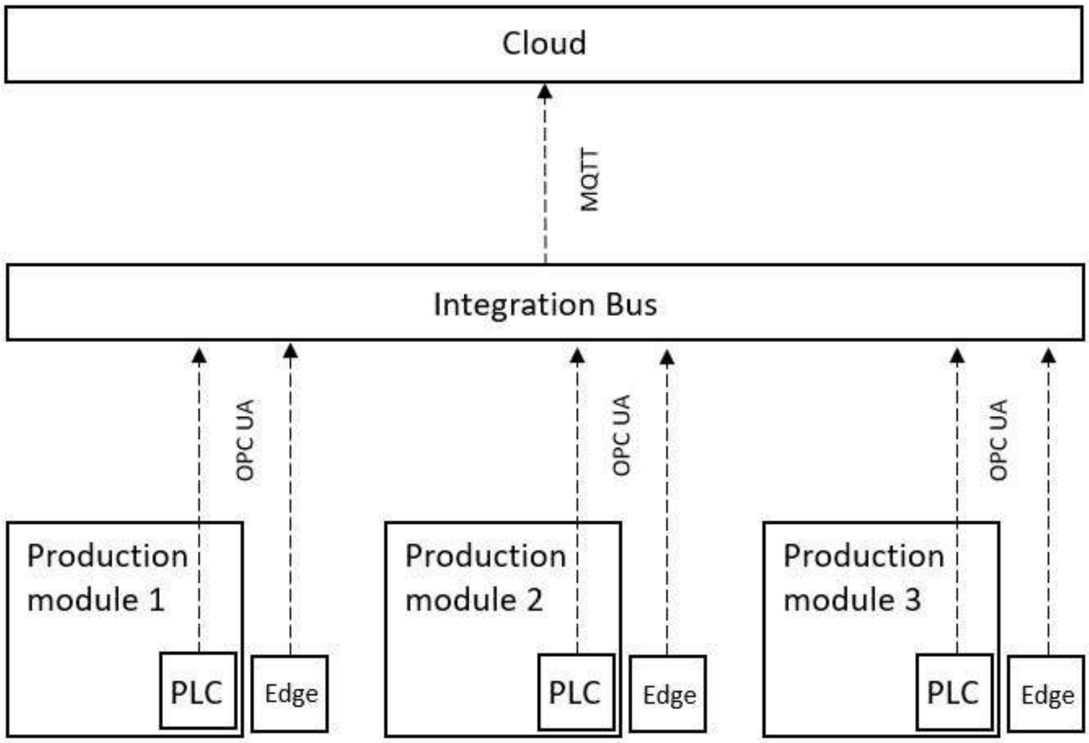


Figure 3 SmartFactory communication schematic

Main output messages are generated, based on the OPC-UA message which is described by using the criteria showing in table 2. FIWARE visualizer and Digital twin of the factory are shown in an separate front end, which is shown in Figure 4.

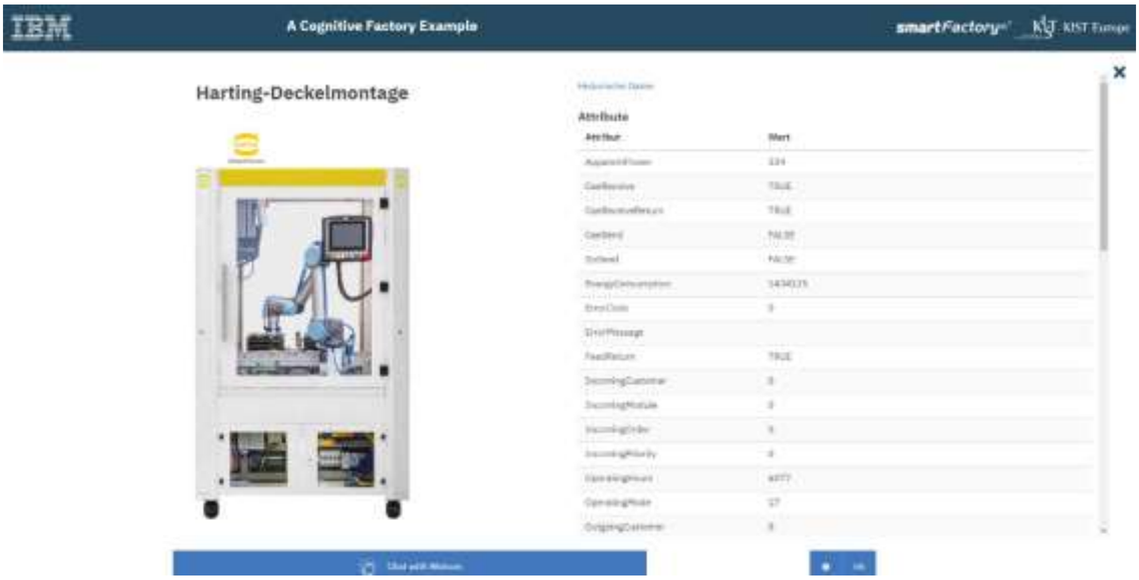


Figure 4 Examplary site of the dashboard

2.4 Human resource

The skills required to finalize the demonstrators based on the setup described here include understanding network and cloud communication protocols; creating, animating, and managing 3D model representations; and creating training data for object recognition and object detection. A basic understanding of production processes is also required for modeling production processes as well as the architecture of asset administration shells. Knowledge from ongoing and completed EU research projects is also needed to build on the results obtained in these projects. Further knowledge includes programming skills in handling Augmented Reality (AR) tools like the MS HoloLens and Unity3D. In the field of object recognition, the creation of pipelines for machine learning must be understood as well as the handling of related libraries such as Tensorflow, Keras and OpenCV.

In the SmartFactory this project is carried out by the contact persons and content editors Jens POPPER and William MOTSCH as scientific staff members of the association SmartFactoryKL. Federico Diez CANSECO is also part of the team Construction and Development for the practical implementation and design of the network communication between and to the production modules.

2.5 Pilot set-up schedule

	M1-14	M15-20	M20-26	M27-M35	M-M36
OpenFog				X	
CloudFlow (with CloudiFacturing)				X	

3. Neutral industrial Pilot: Jozef Stefan Institute

The described reconfigurable robot workcell can be used to integrate, customize, test, validate and demonstrate AUTOWARE innovations, prior to the end-user implementation and market launch, in the context of robotics and automation. Experiments can be performed in the area of human robot collaboration, since the proposed workcell includes robots that are safe for collaboration with humans. The aim is to show that robots can be used to augment the capabilities of human workers, freeing them to do what humans are good at; dexterity and flexibility rather than repeatability and high precision.

Figure 5 reconfigurable robot workcell where new AUTOWARE technologies will be demonstrated at JSI

3.1 Manufacturing resource

The main purpose of this component is to make available the data about the production process / processes that are currently executed in a reconfigurable robotic workcell. Two major types of data have been identified:

- Data needed to improve the functionalities of the workcell using machine learning technologies (deep learning, big data). These data include information about robot movements and sensory data (the arising forces and torques, images, image sequences, etc.).
- KPIs and data related to the operation of the workcell (execution times, success of task execution, quality measurements, etc.).

The main purpose of the first type of data is to improve the functionality of the workcell using external machine learning services that implement various technologies that typically rely on high computational power (HPC) and big data, which are difficult to provide locally. The second type of data provide information for higher-level systems like MES, ERP, and business assessment. In the previous version of the deliverable, we identified the technology enablers for improving workcell functionalities and enablers for gathering KPIs, which will be used for benchmarking of benefits of AUTOWARE approaches and technologies. Benchmarks and workcell functionalities relevant for AUTOWARE were identified in D1.2. In this version of the deliverable, we justify the selection and describe the implementation of these enablers in the neutral industrial pilot "Reconfigurable workcell", which applies robot technologies.

3.2 IT assets

Asset name	Roles	Input	Output	Deploy-ment plan	Source
Workcell control software based on ROS (Robot Operating System)	Workcell control	Programs implementing robot control, machine learning, pose localization and visual quality control algorithms	Hardware actions (robots, grippers, fixtures, tool changers, cameras, force-torque sensors, etc.)	Already Deployed	Recon-Cell
Workcell hardware (2 UR-10 robots, various grippers, 2 Basler cameras 2 ATI force-torque sensors, 2 Destaco tool	Production task execution	Programs	Hardware actions	Already Deployed	Recon-Cell

changers, 6 reconfigurable fixtures, 2 industrial PC, 3 workstations, 3D printer)					
"Nova skupna gruča" (NSC)	Nordugrid ARC High-Performance Computing Cluster	Training Data, Model, Training Algorithm	Trained Model	Already Deployed (first workcell integration by April 30th, 2018)	JSI AUTO-WARE
MQTT, and OPC UA	Communication with outside computing resources	Assembly process data	KPIs	First workcell integration accomp-lished	AUTO-WARE FIWARE

3.3 Data

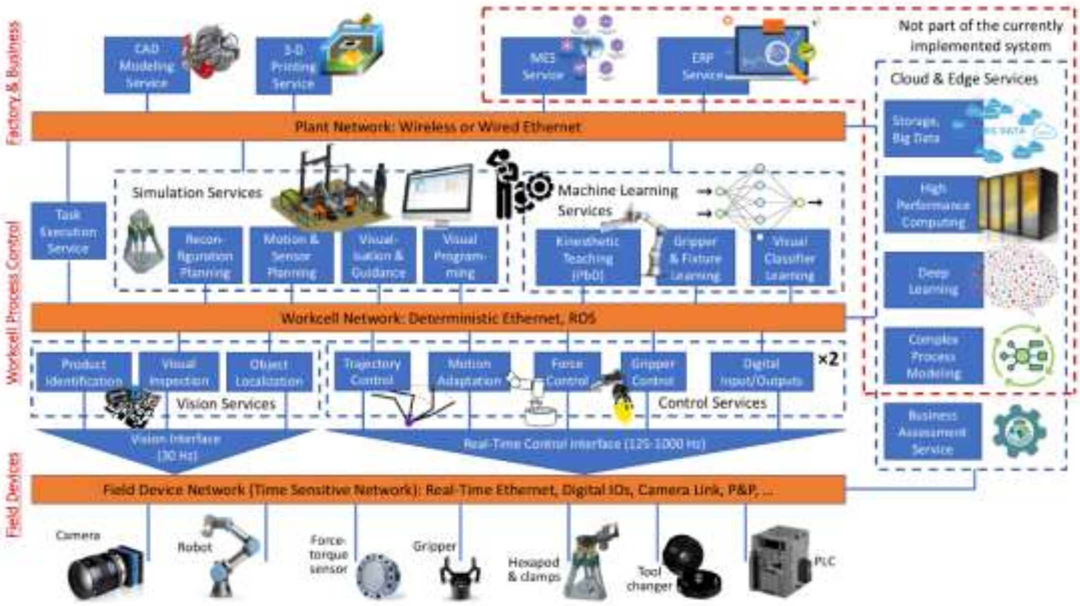


Figure 6 Data exchange in a reconfigurable workcell

Training of visual classifiers for visual quality control in a reconfigurable robot workcell

The input data would comprise of datasets in the order of hundreds to thousands of images, depending on the learning task to be accomplished. These images would either be grayscale or RGB images, or perhaps even RGB-D images or 3D point clouds, depending on the acquisition devices involved, e.g. 2D or 3D camera systems.

The desired machine learning model and training algorithm would also form part of the input data to the cluster.

The NSC grid computing cluster operates using the Nordugrid Advanced Resource Connector (ARC) grid middleware that requires that jobs be predefined in terms of their data, algorithmic and computational requirements before being submitted to the cluster grid for computation where it is placed in a queue. Once the job has reached the top of the queue, the grid allocates computational resources for the job, runs the computation and returns the results.

These jobs would be evaluated on the cluster in terms of their performance on the particular learning task at hand. For example, if the task were to train an image classifier for improving visual quality control in a product assembly line where certain parts must be matched to a template within certain tolerance ranges, the classifier might report a binary decision of whether or not the part was successfully matched to a template. The performance indicator in such a case might be the overall visual classifier accuracy or an ROC curve measurement. This would be evaluated as part of the training procedure during training on the cluster, as well as on test datasets at the production facility once the trained model has been returned.

Data publishing interfaces for service based functionalities: implementation, tests and evaluations

The purpose of the specific implementation/experiment is to upgrade a neutral industrial pilot located at JSI, the reconfigurable robot work cell, with standard interfaces for external data exchange and processing.

In the present stage, the robot cell generates processes and uses all process data mostly internally; that is by software modules developed specifically by and for the various work cell developer subjects. Service – based solution are confined to ROS services. This is a good solution for in-cell tasks. However, in the present stage they are inappropriate to locate and extend data processing to outer users or computing components, for example to ones running in the cloud.

One of main points of the presented task is to extend this neutral experimentation infrastructure with a specific data interface that would implement a solution following the AUTOWARE's software-as-a-service architectural principle. We are specifically interested in a process-level data, generated by and for physical devices as robots, sensor and actuators, which often pose higher real-time, latency and related requirements.

For gathering and evaluation of the proposed KPIs (identified in D2.1), we evaluated IIT protocols identified in D5.1a. Due to the generally low quantity of data, Message Queuing Telemetry Transport (MQTT) was found appropriate. In order to measure KPI TPI01 "Cycle time of assembly process" and TPI02 "Time needed to set up a new assembly process" it was necessary to update the ROS master program on Neutral Industrial Pilot: Reconfigurable robotic workcell, as depicted in Figure 7. For this, we created custom ROS messages, which consist of the time tag and operation identification code (for the start and end of assembly, start and end of reconfiguration start, error code, etc.). All these custom messages are immediately published to the MQTT client, which gathers the data and passes them to KPI evaluator. Additionally, all custom messages are saved into the ROS bag and can be retrieved latter upon the request from the MQTT client. This scheme is also capable of capturing error states. Based on this statement, we propose to extend the list of KPIs form D2.1 with an additional KPI "Mean time between errors".

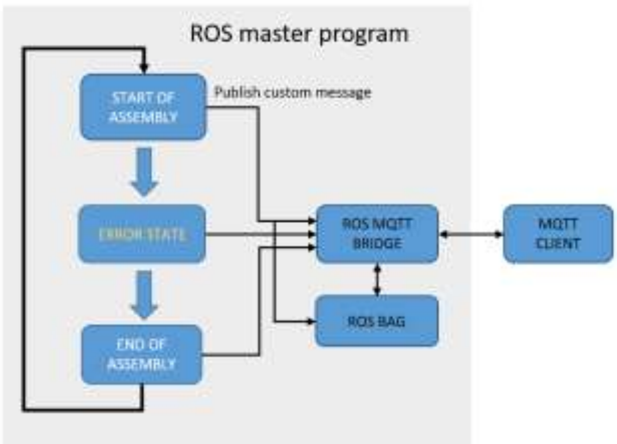


Figure 7 Modifications in ROS master program required to gather KPIs

3.4 Human resource

Training of visual classifiers for visual quality control in a reconfigurable robot workcell

In order to design the algorithms involved in, for example, the image template matching task mentioned above, general expertise in machine learning would be required, as well as specific expertise in deep learning algorithms for computer vision. In the specific production scenarios envisaged for AUTOWARE, the software knowledge requirements would largely center around Python and the various deep learning software libraries associated with it, e.g. Keras, TensorFlow, PyTorch, etc. These expert requirements would vary to greater or lesser degrees depending on the specific learning task involved.

In order to encode jobs for computation on the NSC cluster computing grid, further expertise would be required in order to work with the Nordugrid ARC middleware software. This would involve the ability to define the computational requirements for a job and the ability to deploy it to the cluster. This deployment process may end up being semi-automated via various scripting technologies, e.g. bash shell scripting and Python scripting.

Contact people:

- Barry Ridge, JSI – deep learning algorithm expert, cluster job deployment.

Data publishing interfaces for service based functionalities: implementation, tests and evaluations

Contact people:

- Anton Ružić, JSI – expert on smart production environment interfaces

4. Neutral industrial Pilot: IK4-TEKNIKER

The collaborative robotic workspace infrastructure can be used as a Neutral experimentation infrastructure to integrate, customize, test, validate and demonstrate AUTOWARE innovations, prior to the end-user implementation and market launch. The solutions developed using AUTOWARE infrastructure in automation and robotics have the following potential advantages: 1) Interoperability: the ability of cyber-physical systems (i.e. workpiece carriers, assembly stations and products), humans and Smart Factories to connect and communicate with each other via the Internet of Things and the Internet of Services. 2) Big Data: access to updated libraries of images, maps, and object/product data, 3) Cloud Computing: access to enablers for statistical analysis, learning, and motion planning, 4) Contextual adaptation: systems sharing information and adapt based on the contextual information.

4.1 Manufacturing resource

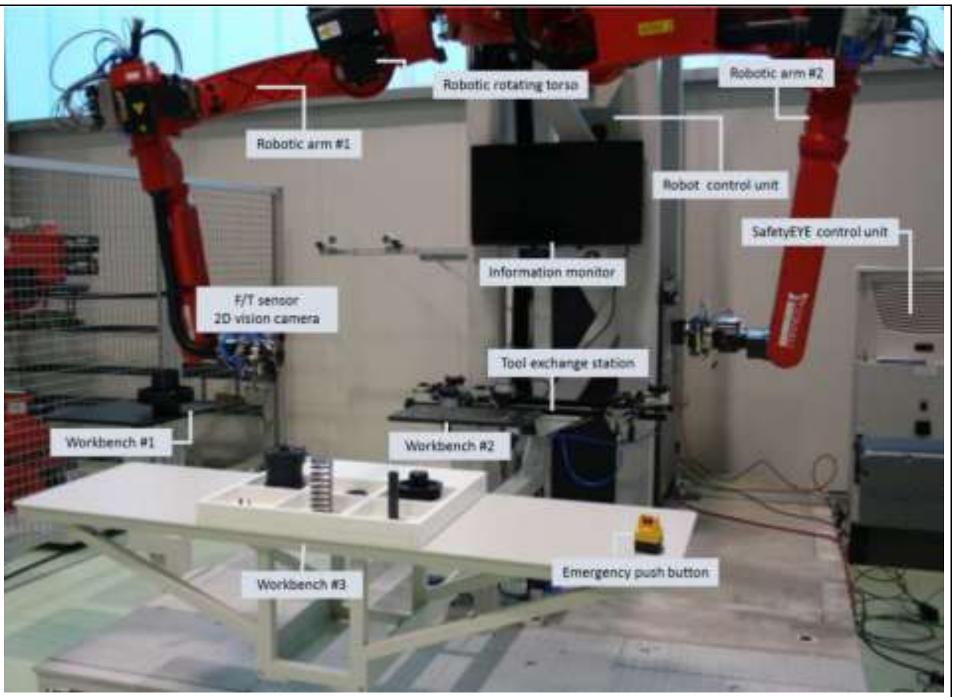
Figure 8 Robots the neutral facility

The neutral facility involves two robots with their workplaces shown in Figure 8; a dual arm robot interacting with the worker in close co-operation during the assembly and a mobile robot performing logistics related operations. The main contributions provided by this experimentation infrastructure are:

- The integration of enabling mechanisms for communication and integration at higher level between the work cell elements (bi-manipulator, safety elements, mobile platform, etc.).
- High re-configurability and flexibility of the solution based on the concept of robot-robot collaboration and human-robot collaboration.

a. Dual arm workcell

Description	The current lab scenario is a standalone workcell (i.e. not integrated with any factory control systems or ICT infrastructure) composed of a dual-arm robot and multiple sensors. Based on this dual-arm robot concept, a generic purpose layout has been designed with three different workbenches and a tool exchange station. This tool exchange station allows using different tools that can be exchanged automatically in real time, adding flexibility to the assembly cell. Additionally, the robot has been enhanced with different sensors like 2D and RGB-D cameras and a force/torque sensor



Function	Assembly of a latch valve in a fenceless environment. The proposed scenario is aligned with the need of incorporating robots able to safely and adaptatively co-operate with humans.
Data	The work cell is a standalone system, with a high integration with all the elements inside the work cell but low standardization and flexibility for integration of new components. The execution control is performed on an external PC, with direct link to the robot control through PDL2 program or through the C5G Open control. Both connections ensure the ability to operate the robot in a high level (ex. execute movements, routines…) or in hard real time with a complete control in low level (ex. implement impedance control, force/torque control for insertions…). Addition of sensors to the cell are controlled by the PC to enhance the robot programs, offering the possibility to modify the execution of the program based on the information received from the sensors.

b. Mobile platform

Description	Segway® Flex OMNI High-payload material transport machine. Holonomic mobile robot platform, for use in an environment with limited space that requires precise mobility and handling.

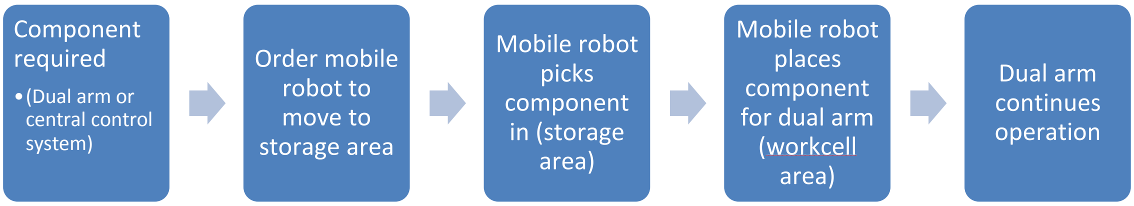
	
Function	Driverless Transportation Systems internal logistics. Transport parts from storage area to assembly area (dual arm workcell)
Data	OPC-UA communication about robot status

c. Internal logistic process

The process to be Implemented using AUTOWARE technologies is an internal logistics workflow between the dual arm workcell and the mobile platform. The workflow is represented in the figure where the process starts when the control system of the bi-manipulator asks to the mobile robot for a component. The mobile robot acts as a component supplier for the dual arm. The objective is to demonstrate:

Flexible adaptation to production demands.

Coordination of different production resources (bi-manipulator and mobile robot) and providing Interoperability among the elements of the cell.



4.2 IT assets

Asset name	Roles	Input	Output	Deployment plan	Source
WorkCell control server	Control all the assembly processes	Program execution Sensor data	Robot actions	Already Deployed	TEKNIKER
Safety Eye	Safe Access to the area	Vision sensor	Safety incidence	Already Deployed	TEKNIKER
COMAU dual arm control	Control all the robot movements	Program execution Workcell control server	Robot actions	Already Deployed	TEKNIKER
Mobile robot	Supply parts	Program execution Sensor data	Mobile Robot status	Already Deployed	TEKNIKER
Secondary lightweight data distribution layer	Achieve high fault tolerance	Data from first data distribution layer		To be deployed by the end 2018	CNR

4.3 Data

The data exchange among the different assets is represented in Figure 9:

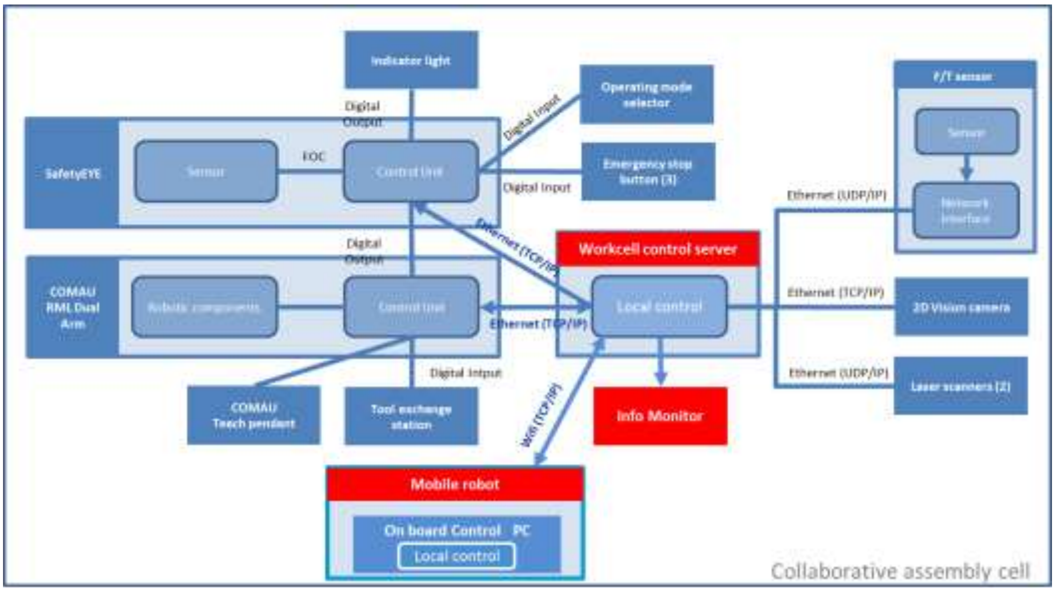
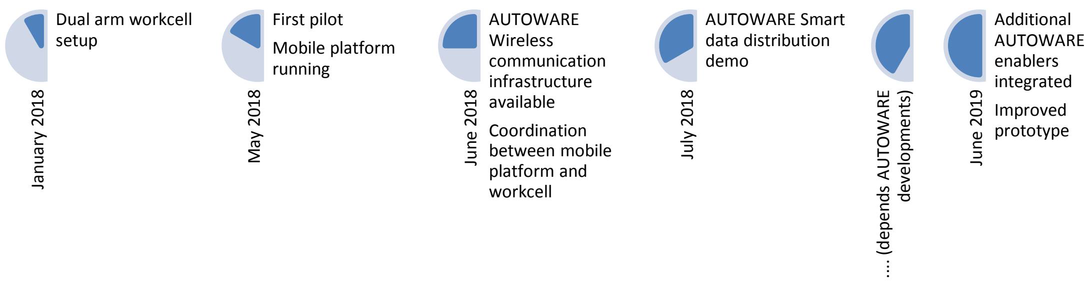


Figure 9 Data flow of Tekniker pilot plant

4.4 Human resource

Coordinator	Loreto Susperregi	loreto.susperregi@tekniker.es
Workcell programmer	Miguel Angel Perez	miguelangel.perez@tekniker.es
Mobile platform programmer	Ander Ansuategi	ander.ansuategi@tekniker.es

4.5 Pilot set-up schedule



5. Industrial Cognitive Automation: STORA ENSO

STORA ENSO's business opportunity will be focused on the demonstration of a sensor-fusion component to monitor and optimize product line efficiency and switchovers, aiming for performance and flexibility improvement through real-time Big Data processing and model based control strategies. Robovision's focus will be on the vision control system which includes an AI learning framework component that reduces the learning times for vision-controlled robots and Cloud-based AI delivery architecture that orchestrates the execution of real-time AI algorithms on a series of GPU-dedicated machines to achieve real-time video sensor processing of multiple cameras. This is implemented in the Stora Enso plant site as shown in Figure 10.

Figure 10 Stora Enso plant site

5.1 Manufacturing resource

a. Conveyor belt

Description	Infinite conveyor belt to transport paper and cardboard waste
Function	Transports the paper and cardboard stream to separators
Data	Wireless interface to receive velocity commands

b. Robot arm (FRANKA/UR3)

Description	Collaborative robot arms with 0.5 to 1m reach equipped with grippers
Function	Sorting of paper from cardboard
Data	Telecommand and telemetry

c. Camera system

Description	Machine vision cameras (brand TBD)
Function	High dynamic range object classification and clustering
Data	Image (RAW, JPEG formats)

d. Air separator

Description	Uses pulses of compressed air to split objects on conveyor belt to two separate lines
Function	Separates paper from cardboard based on visual inputs
Data	Decision by simple camera system

e. Pin separators

Description	Uses pins to split objects on conveyor belt to two separate lines
Function	Separates paper from cardboard based on texture
Data	No data, purely mechanical

f. Fall-through separator

Description	Uses a screen/sieve split objects on conveyor belt to two separate lines
Function	Separates large cardboard from smaller pieces
Data	No data, purely mechanical

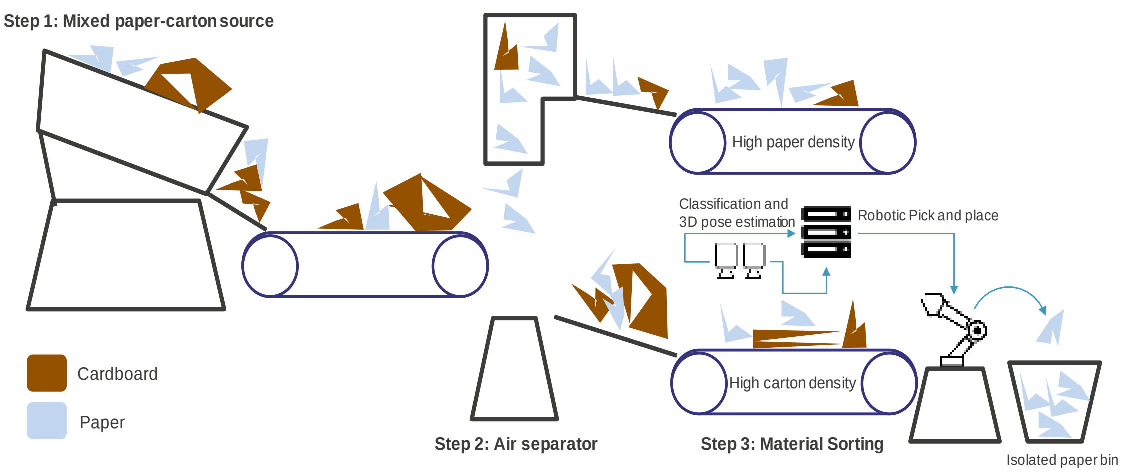


Figure 11 Recycling process of Stora Enso

5.2 IT assets

Asset name	Roles	Input	Output	Deployment plan	Source
GPFlowOpt	MLaaS, Fast reconfiguration vision system, machine learning framework	Camera input stream, Deep learning vision system	Rapid reconfiguration of vision system	First version ready, work ongoing	AUTOWARE development, Open Source
Nvidia DGX-1	Deep learning application server	Camera input stream, machine learning software	Computation, decision making	Ready to deploy on site	Proprietary
Keras	Neural network library	Tensors	Object recognition	In development for use case	Open source (google)
Robovision DL vision pipeline	Deep learning processing pipeline	Camera input	Start-to-end efficient processing	To be tailored to use-case	Proprietary Robovision

5.3 Data

The input data is a constant stream of images taken from a (rapidly moving) conveyor belt on which cardboard, paper and undesirables (e.g. plastics) are moved. The camera system constantly screens the items on the conveyor belt and converts these images into tensor objects which are used as input for the deep learning vision system. This system, constructed using historical data, makes a real time decision to remove certain items from the belt using a gripper or an air separator. Different datasets can be constructed using different mixes of products on the belt.

5.4 Human resource

joeri.ruyssinck@imec.be, Keshav.Chintamani@imec.be, jonathan.berte@robovision.be, dirk.deschrijver@imec.be : responsible for test use-case set-up (off-site)

rik.pauwels@storaenso.com Project manager paper division, dirk.gillis@storaenso.com Inbound and Outbound manager paper division

5.5 Mapping with Requirement analysis and KPIs

KPI Stora Paper/cardboard separation efficiency

At this moment, experiments are being performed at the offline test site which are not able to obtain the required accuracy to be implemented at the STORA ENSO site. Further efforts are done to increase the accuracy of the vision system.

TPI21 Stora Time needed to adapt to a batch of different quality to be sorted

Work on this KPI has not started as it requires the existence of a fully functional and accurate deep learning vision system. The current planning foresees a working integration by Jan 20, 2019.

6. Industrial cooperative assembly of pneumatic cylinders: SMC Deutschland GmbH

SMC Germany and Fraunhofer IGD will develop a machine module, including a collaborative robot with an installed 3D laser scan head, which will automatically execute the inspection and documentation of quality specifications of SMC pneumatic cylinders. The system will be supported by a human operator, who is handling and mounting cylinder parts and products. For the quality inspection of cylinder parts or after the completion of the assembly, the employee will load the workpiece into the inspection unit. Workpieces will be analyzed automatically according to the quality requirements, specified in the product manufacturing information (PMI) of the 3d model of the product. These PMI will also be used to develop a new assembly guidance system, which will lead the employee through the assembly process.

6.1 Manufacturing resource

1. Quality inspection unit

Description	Universal Robots UR3: Light-weight, flexible and collaborative industrial robot
Function	Carrying and moving of the scanning system
Data	Robot arm trajectories High level (e.g., grid-based) positioning data of target assembly parts on the work table In case safety parameter violation, signals from additional sensors to stop or slow down the robot High level task commands from workflow guidance system

Description	Scanning System: station with a 3D laser scanner, a high-resolution camera and a light weight positioning device consisting of a turntable combined with gimbal arm for the scanner head
Function	Quality assessment, documentation and provision of scan data for recognition and verification of the assembly status within the current workflow. The system acquires desired scanning poses automatically and provides comparable 3D scans and image data for processing and reasoning at the workflow guidance system
Data	Input of target scanning poses (for QA tasks, etc.) annotated in CAD object coordinate system 3D point clouds for recognition and comparison with the CAD data Camera image data for documentation and computer vision purposes

Description	Frame and housing of the unit

Function	Basis of the robot and the scanning system, protecting employees from laser radiation of the scanning system and injury from movement of the robot
Data	Safety SPS integrated and combined control signals

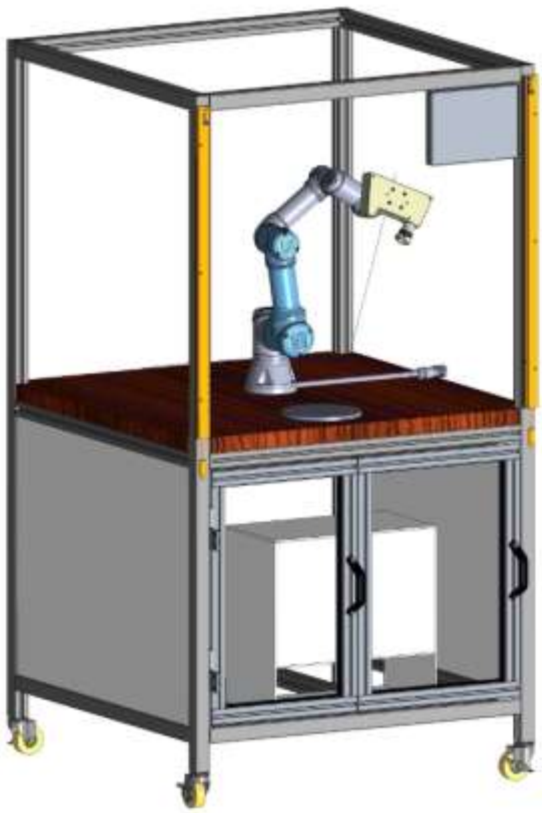


Figure 12 Quality inspection module

2. Product and process

Product	Machine	Process	Parts
	Scanning system	Scanning (lower quality) of quality-related features of the components	Cylinder body, piston-piston rod-assembly
	Human	Assembling of the pneumatic cylinder	Cylinder parts
	Scanning system	Scanning (high quality) and documentation of quality related	Pneumatic cylinder

		features of the cylinder	
	Human	Leakage check of the final cylinder	Pneumatic cylinder

6.2 IT assets

Asset name	Roles	Input	Output	Deployment plan	Source
Object Registra-tion	Registration	Point clouds	Transformation , Registered point clouds	Done	RESOURCE APP
Dual Reality Manage ment	Synchronization between real and virtual environment	2D/3D sensor data, CAD models	Dynamic Virtual environment model	Done	VISTRA
Process Sync. & Planning	Track the progress of the assembly process	Assembly state, Semantic Model	Adapted Assembly Process	Done	VISTRA
Semantic Workflow Modeling	Conversion of production data to semantic model	Product engineerin g and productio n planning data	Semantic Model	Done	VISTRA
Dual Reality Modeling	Provide model to enrich dynamic virtual environments with virtualized physical environments	CAD models	Virtual environment model	Done	VISTRA

6.3 Data

To realize the demonstrator "Industrial cooperative assembly of pneumatic cylinders" the following input data is required:

- CAD models representing the different assembly states with product manufacturing information containing:
  - Greasing annotations, stating which faces need to be greased
  - Dimensionality control annotations, stating the two faces to measure in-between and the desired distance and acceptable derivation
  - Input of target scanning poses annotated in CAD object coordinate system

- CAD model representing the worktable with product manufacturing information containing:
- High level (e.g., grid-based) positioning data of target assembly parts on the work table
  - Collaborative assembly workflow definition
  - Physical assembly parts

- As output, the application will provide:
  - Time to assemble a product
  - Quality assessment results
- Dimension measurements
- Photos

The input data is provided by SMC and is processed in the application. The following diagram shows the data flow between the above-mentioned manufacturing resources and the IT assets.

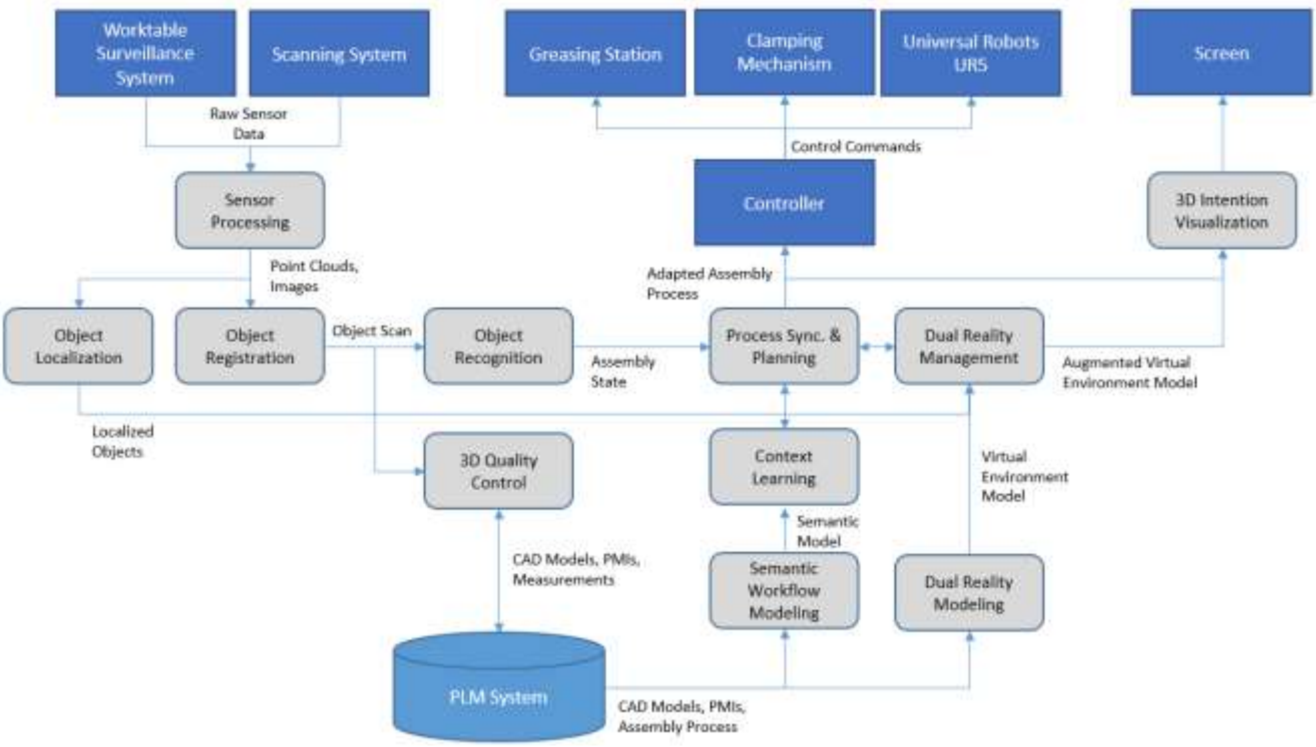


Figure 13 Data flow between manufacturing resources and IT assets

6.4 Human resource

As preparation for the pilot set-up, the following tasks have to be processed:

- Definition of requirements for the quality inspection module(SMC)

- Construction of the machine frame for the quality system (SMC)
- Development of the hardware and software of the 3D laser scan head (Fraunhofer)
- Development of the robot control (Fraunhofer)
- Development of data integration (Fraunhofer)
- Development of assembly guidance system (Fraunhofer)
- Development of assembly state recognition
- Assembly and CE certification of the quality inspection module (external partner Bohnert Systemtechnik GmbH)

Also the development and production of the manufacturing resources is required. This involves all previously mentioned resources in section 7.1.

The demonstrator set-up will be performed in parallel at the facility of Fraunhofer IGD Darmstadt and in the Industrial Application Center at SMC Germany in Egelsbach. Subsequently, Fraunhofer IGD will perform commissioning and calibration of the collaborative working station. For the future, trained employees at SMC will take care of the exploitation and the continuous maintenance of the working station. Fraunhofer IGD will serve as a technical support.

Contact persons:

- Mario Heitmann: SMC Manager Innovation Management
- Reimar Tausch: Fraunhofer Institute for Computer Graphics Research IGD

6.5 Mapping with Requirement analysis and KPIs

KPI	Method	Achieved	Target
Productivity [pcs / head or pcs / h]	Analysis of the needed quality measuring time (manually vs. robot)	No prototype existing yet	11%
Production quality [Not good pcs / produced pcs]	Analysis of the relation of scrapped cylinders to produced cylinders	No prototype existing yet	100%
Training of employees [Implementation 2/2 trainings]	Training of system programmers for preparation of product changes and assembly operator re-	No prototype existing yet	100%

	garding machine module usage		

7. Conclusion

Different partners of the AUTOWARE project provide their facilities for demonstration purposes as well as for testing, implementation, validation and verification of the AUTOWARE technologies. In order to make this process comprehensible for later evaluation, the production equipment, IT assets and personnel used as well as the processes carried out must be listed and explained. These components are prepared on the basis of the progress achieved in work packages WP2, WP3 and WP4. A first enumeration of these components is given in the previous Deliverable D5.1a.

The goal of D5.1b is to enumerate the setup for the pilot sites that will form the basis for the AUTOWARE technology demonstrators in the further course of the project. In particular, the experiences and changes based on the collected data since the first version of the deliverable will be incorporated and the setup will be updated. These pilot sites are divided into 3 neutral facilities and two industrial facilities. The update of the general setup, the IT assets and personnel should ensure that the demonstrators of the AUTOWARE technologies correspond to the technical solutions and KPIs determined in the other WPs and are up-to-date.

The next step of work package 5 is the completion of the technical preparation, implementation, evaluation and demonstration of the AUTOWARE technologies at the above mentioned partners with the listed setup in D5.2b in M36, in which the final results of the implementations will be described.