Adaptive Automation in Assembly
For BLUE collar workers satisfaction in Evolvable context

A4BLUE

Safe human machine interaction and personalised worker assistance for adaptative workplaces

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Madeira 26 September 2018, Angelo Marguglio (ENGINEERING)

Contents

A4BLUE: Adaptive Automation in Assembly FOR BLUe collar workers in Evolvable context

FOF-04-2016: Continuous adaptation of work environments with changing levels of automation in evolving production systems

Duration: 01/10/2016 – 31/09/2019 **Budget**: 4.179 M€

IK4 TEKNIKER Research Alliance · RWTH AACHEN UNIVERSITY · Cranfield UNIVERSITY · AIRBUS · ENGINEERING · illogic digital creativity lab · CiaoTech · CESA · KOMAT INGENIERÍA Y SERVICIOS DE AUTOMATIZACIÓN Y ROBÓTICA

Project overview: General objective

1. To **develop** and **evaluate** a new generation of **sustainable**, **adaptive workplaces** dealing with **evolving requirements** of manufacturing processes (i.e. short & long term changes);

2. To introduce **automation mechanisms** that are suitable for **flexible** and **efficient task execution** in **interaction** with human workers and by optimising **human variability** through **personalised** and **context aware assistance** capabilities as well as **advanced human-machine interfaces**.

Project overview: Specific objectives

1) **Adaptability:** by providing an **open, secure, configurable, scalable and interoperable adaptation management and assistance system** (A4BLUE adaptive framework) that allows effortless integration of heterogeneous hardware and software components and is able to adjust the behaviour of workplace parts according to changes;

2) **Interaction:** by providing a set of **safe, easy to use, intuitive, personalised and context aware multimodal human-automation interaction mechanisms** ;

3) **Sustainability:** by providing methods and tools **to determine the optimal degree of automation of the new assembly processes** that combine and balance social and economic criteria to **maximize long term worker satisfaction and overall performance.**

New or enhanced automation mechanisms

Plug & Produce Capabilities

A4BLUE adaptive framework including assistance tools

Multichannel interaction mechanisms including AR

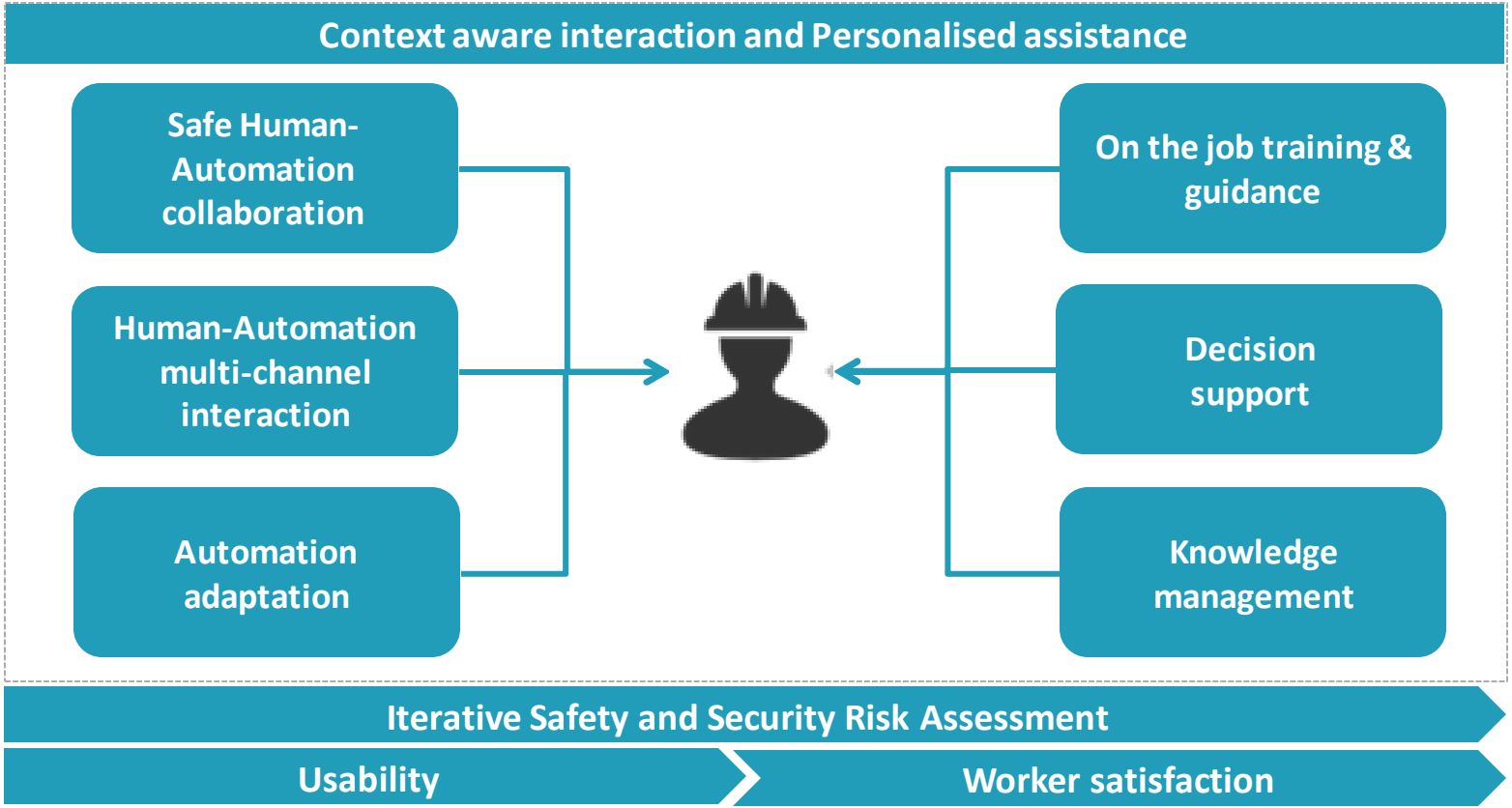
Method & Tool for the definition of the optimal degree of automation

Method & Tool for assessment of worker satisfaction

Usability methodology

Assessment framework

Project overview: A worker centred approach

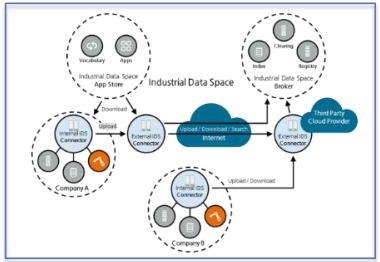


A4BLUE RA: Starting point

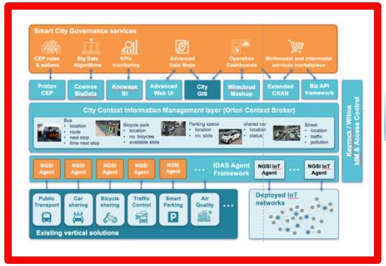
1.- Do not re- invent the wheel

2.- Alignment with the main RAs in Smart Manufacturing

Industrial Data Space Reference Architecture



FIWARE for INDUSTRY Reference Architecture



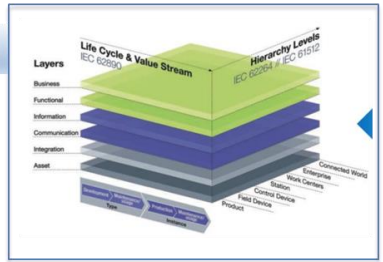
RAMI 4.0

IDS

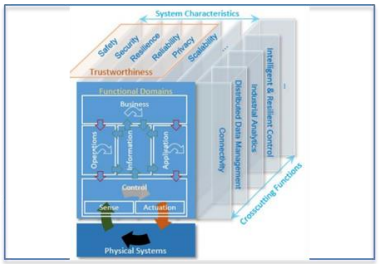
Interope-rability

FIWARE

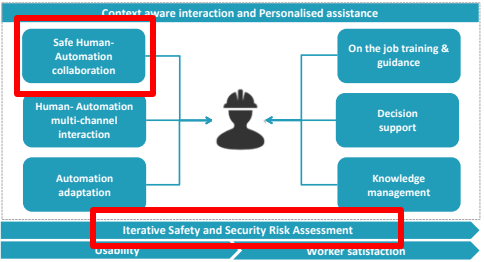
IIRA



Reference Architecture Model Industrie 4.0



Industrial Internet Reference Architecture



Safe Human-Automation collaboration

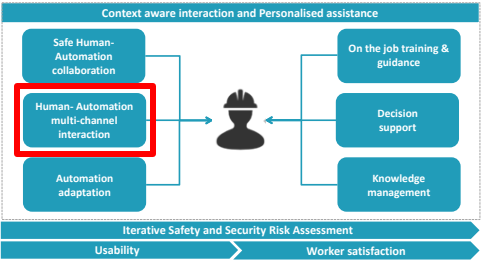
Safety

Introducing **automation** mechanisms in collaboration with humans creates new challenges

Security and Privacy

Enabling adaptation to workers characteristics and context involves the processing of **personal data**

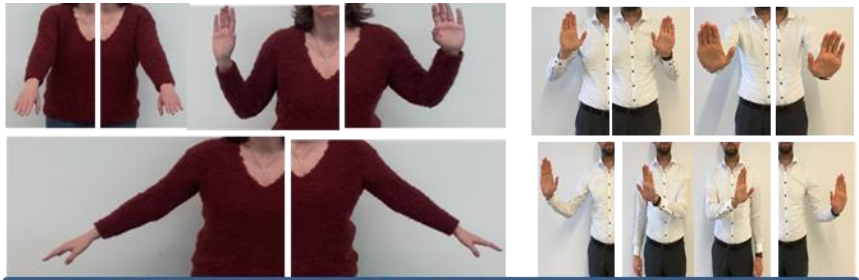
A4BLUE introduced in the design phase both **privacy/security by design** and **safety by design concepts** supported by an **iterative risk management process** to identify potential risks and countermeasures, considering most common regulation and standards.



Human-Automation multi-channel interaction

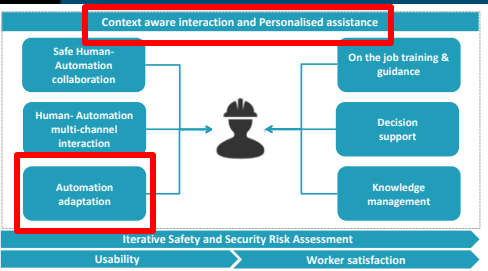
- Verbal and non- verbal interaction to communicate the appropriate commands (H2M).
- Visual and auditory mechanisms to provide feedback (M2H).

Gestures and natural speaking interaction: START, RESUME, STOP operation



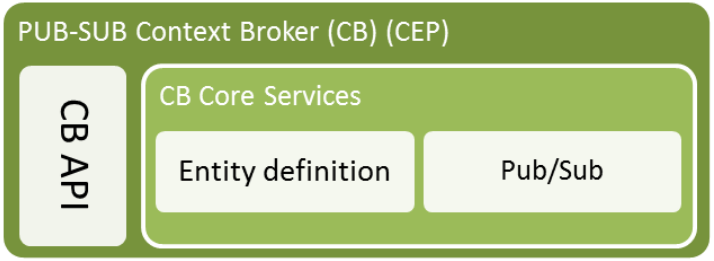
Natural interaction: left-handed and right-handed workers

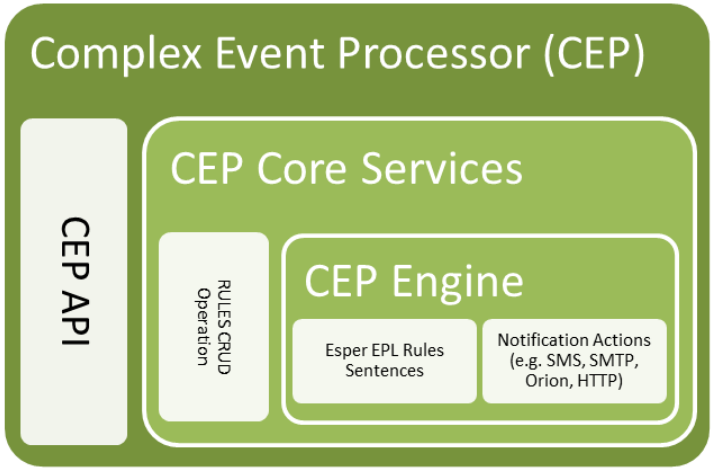
Gestures : COME CLOSER, MOVE APART, MOVE RIGHT, MOVE LEFT, START/ STOP



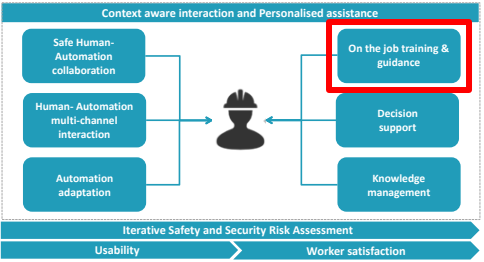
Context aware interaction and Personalised assistance

- Based on FIWARE OCB and part of **FIWARE for Industry** ecosystem
- **Publish-Subscribe broker** supports context information exchange among all the A4BLUE components
- Entity definition based on the **A4BLUE Events Taxonomy**
- CEP **analyses context** and trigger appropriate adaptive reactions, **adapting the A4BLUE overall behaviour** to the recognized person/product/process





FIWARE

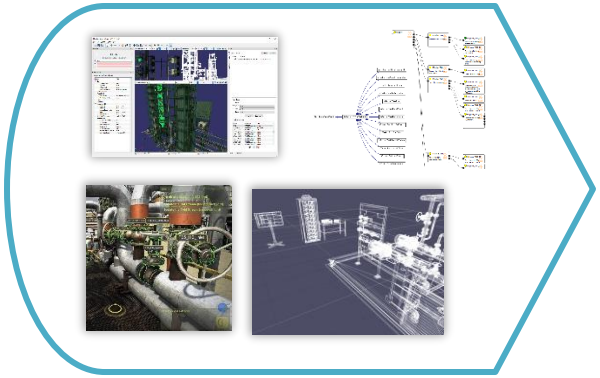


On the job training & guidance

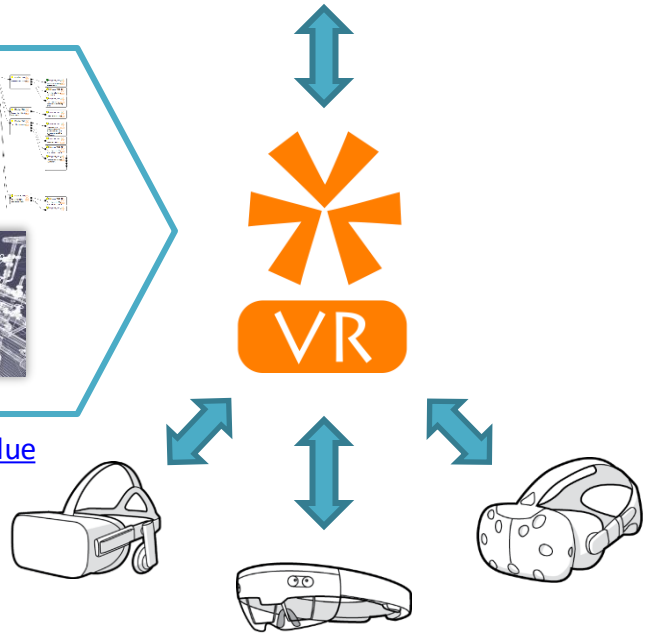
A4BLUE

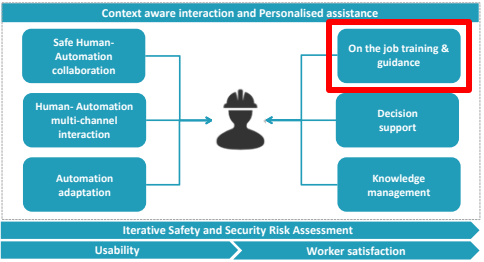
VRStar provides immersive VR/AR simulation.

- **AR and VR Clients**: Front-end applications able to render a 3D scene and collect user inputs
- **Instructor Station**: A graphic control panel for the master node
- **Scene Editor**: A graphic editor of the context maps, their actors and properties
- **Third party Manager**: Bidirectional communication channel with external and remote components

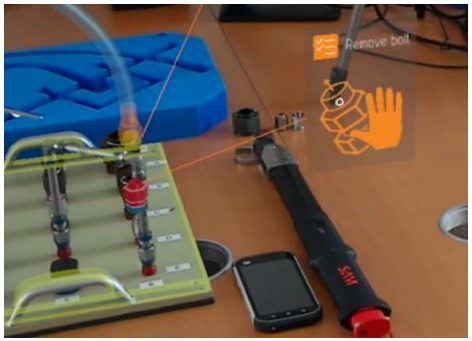


https://vimeo.com/a4blue



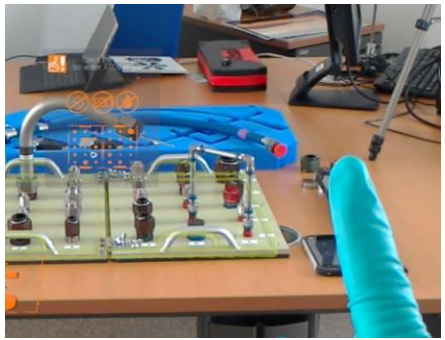


On the job training & guidance

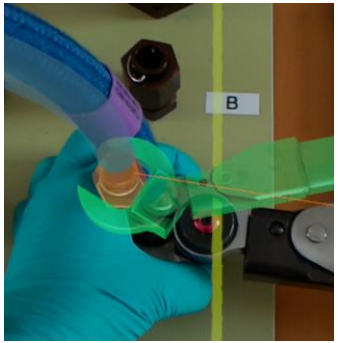


Each step of the guidance is represented and showed to the operator in the form of a **2D floating holographic panel**

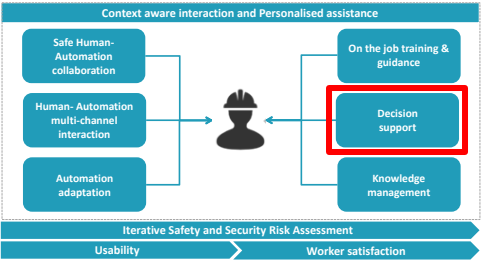
The actions and physical movements to perform on-field for a given procedure are shown by **virtual animations** using holograms



Voice commands and **gestures** represent the main input source for an AR application



Thanks to Spatial Mapping system and the Room alignment procedure, the AR elements are constantly **tied** with the **real world** in **real time**



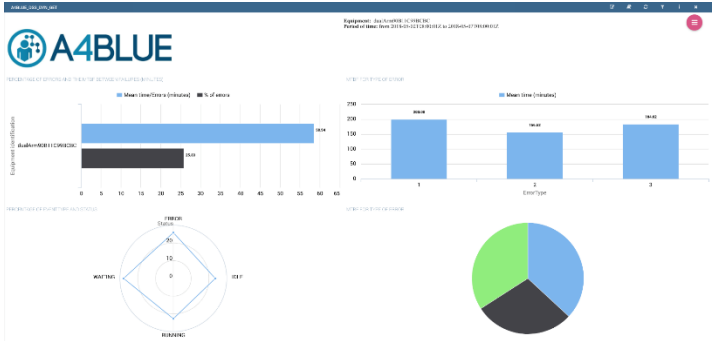
Decision support

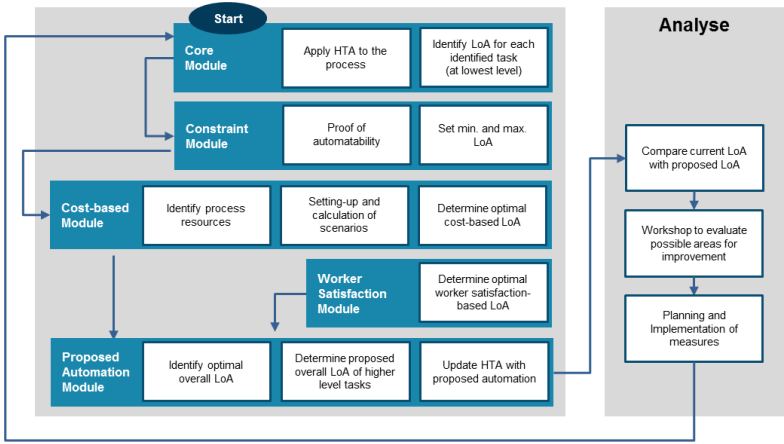
Methodology and web tool to define the Optimal Level of Automation (LoA)

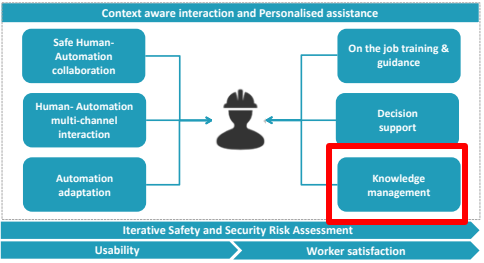
- **Core Module:** Analysing and structuring of the process
- **Constraint Module:** Finding and setting of limits of the automation
- **Cost-based Module:** Determination of the optimal LoA, regarding costs
- **Worker Satisfaction Module: O**ptimal LoA, considering worker satisfaction
- **Proposed Automation Module:** Suggest an LoA for the determined process, taking cost and satisfaction into account
- **Analyse:** Plan, prepare and implement measures to get to the suggested LoA

Intervention requests and DSS

- ***Intervention requests*** (e.g. collaboration, maintenance, inspection)
- Decision support **dashboards**.

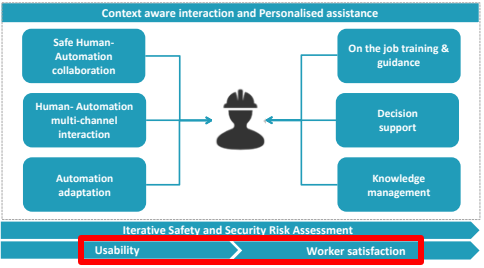






Knowledge management

- Fostering the cooperation and the **human-oriented management of information**
- Providing social networking tools and services, enabling formal and informal support (e.g. tips, best practices, …) and **training services** (e.g. lesson learned, certification, …)
- **Full integration** with A4BLUE RA (CAM, EM, AR, DSS, …)
- Supporting various challenges identified in **industrial scenario** (i.e. CESA and AIRBUS)



Usability and Worker satisfaction

Development of evolvable user-centred automated work systems to promote worker satisfaction within A4BLUE:

- Usability design methodology and assessment
- Operator satisfaction model integration
- Personalised adaptive automation analysis
- Psychometric tool for the assessment of worker satisfaction

Other experiences from partners:

- Task analysis and decomposition
- Mental workload impact analysis
- Worker acceptance and training needs analysis
- Procedural vs tacit knowledge / skill analysis
- Comparison of mental workload and usability across different devices

Physical Ergonomics

- Postural analysis
- Musculoskeletal risk prediction
- Inertial motion capture
- CAD modelling

Cognitive Ergonomics

- Eye tracking
- Task analysis / decomposition
- Tacit knowledge elicitation
- Codification of functions
- Performance and error analysis

Human-Robot collaboration

- Risk analysis
- Implementation strategy
- Trust and acceptance
- Standards
- Ethics

Adaptive Automation in Assembly
For BLUE collar workers satisfaction in Evolvable context

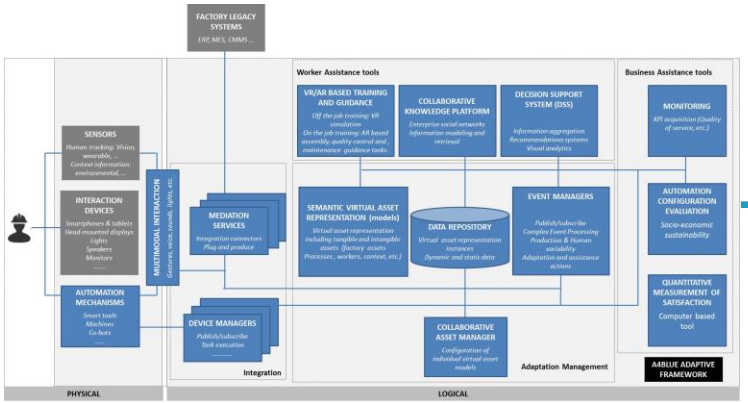
A4BLUE

USE CASES

A4BLUE use case scenario overview

Adaptive framework including Plug & Produce capabilities, assistance tools and multichannel interaction

Reference Architecture + Reference implementation → 4 Use case applications (HW & SW components)



AIRBUS

CESA COMPAÑÍA ESPAÑOLA DE SISTEMAS AERONÁUTICOS S.A.

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RWTH AACHEN UNIVERSITY

Methods for the introduction of adaptive automation and worker satisfaction

Method for the definition of the optimal degree of automation	Method for assessment of worker satisfaction	Usability methodology

Use case application: AIRBUS UC scenario

Scenario: **complex hydraulic system assembly**, quite manual and comprising various sets of operations including a lot of different parts to be installed in constraint positions.

Objective: a more optimized hydraulic system assembly through automation and Virtual/Augmented Reality.

Actors	Automation Mechanisms
Assembly operator Quality supervisor	Smart Torque Wrench

Main motivation: to evaluate the impact of an adapted **AR HMI** in terms of performance and error rate for different skilled groups of people and to enable full quality assurance approach and operators performance thanks to traceability.

Use case application: AIRBUS UC alpha results

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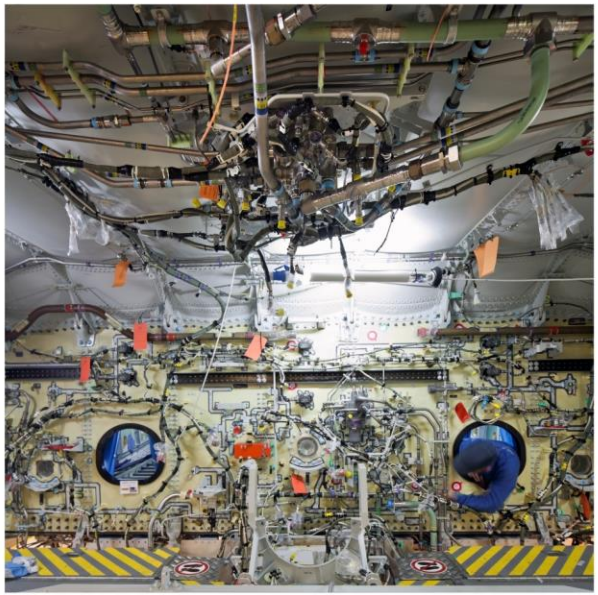

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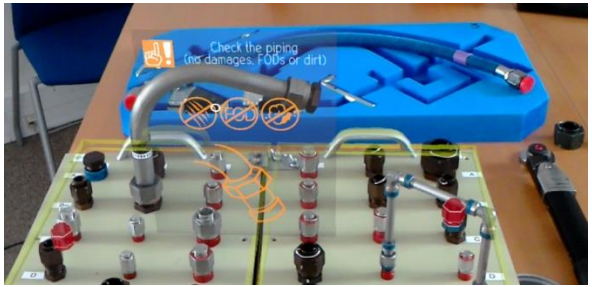
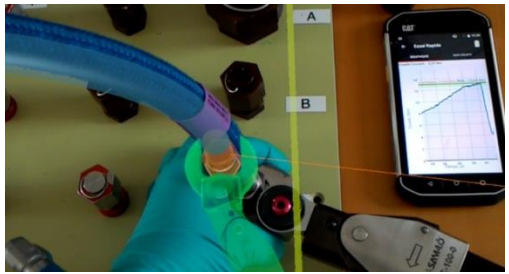


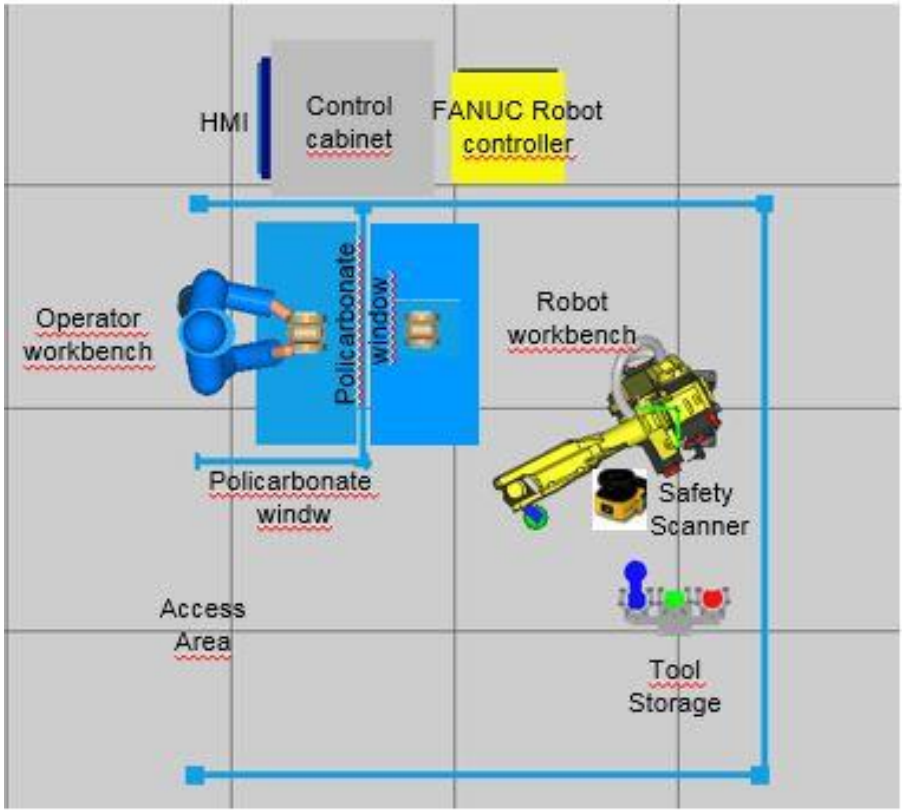


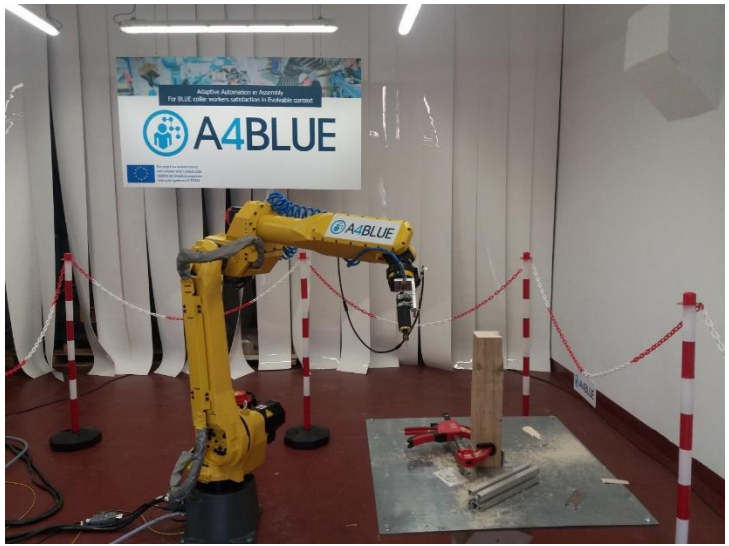
A4BLUE AIRBUS UC alpha scenario:
http://a4blue.eu/watch-the-video-of-our-airbus-use-case-scenario/

Use case application: CESA UC scenario

UC1 Auxiliary process	**Scenario**: deburring operation (completely manual in the AS IS situation) **Objective:** to incorporate a **robot to assist the worker** in the deburring operation **Motivation:** to increase the quality and efficiency of the process as well as the **ergonomic conditions** of the worker by reducing the most exhausting manual work (100 min less)
UC2 Assembly	**Scenario**: main landing gear retraction actuator assembly process which is fully manual and it is supported by a large amount of technical instructions in PDF. Furthermore the **training process** is time consuming and must be performed on periodic basis as the certification expires. **Objective:** to incorporate **AR based guidance** providing the right information to the worker at the right moment based on operator's profile as well as collaborative knowledge management tools supporting knowledge sharing between workers. **Motivation:** to reduce operators training time, to reduce the time spent by the operator reviewing documentation and to increase confidence, participation, and internal communication among the personnel.
Actors	Deburring operator; Maintenance operator; Assembly operator; Workshop supervisor; Quality supervisor
Automation Mechanisms	Collaborative deburring robot

Use case application: CESA UC alpha results





Use case application: IK4.TEKNIKER UC scenario

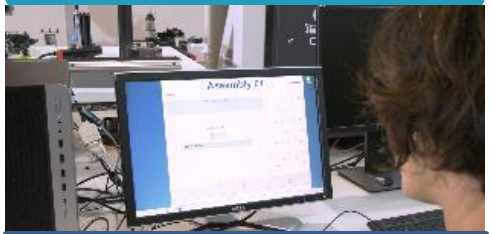
Scenario: **Collaborative assembly of a latch valve in a fenceless environment**, including the preparation activities, final inspection and transport of the finalised part to the warehouse as well as maintenance activities.

Actors	Automation Mechanisms
Assembly operator Quality supervisor Maintenance operator	Industrial dual arm robot Mobile logistic robot

Main motivation: Evaluate trust, usability and worker satisfaction (in terms of safety, interaction, ergonomics, assistance, etc.).

Use case application: IK4.TEKNIKER UC alpha results

Context-awareness



Integration with legacy system (MES)

Automation adaptation

Automatic execution

Personalised ergonomic adaptation

Safe H-A collaboration

Safe coexistente in a fenceless environment

H-A multi-channel interaction

Multimodal interaction - Natural speaking and gestures: START, RESUME, STOP task

Decision support

Intervention request: collaboration, maintenance, inspection – Decision Dashboard

A4BLUE IK4-TEKNIKER UC alpha scenario: http://a4blue.eu/video-ik4-tekniker/

Use case application: RWTH UC scenario

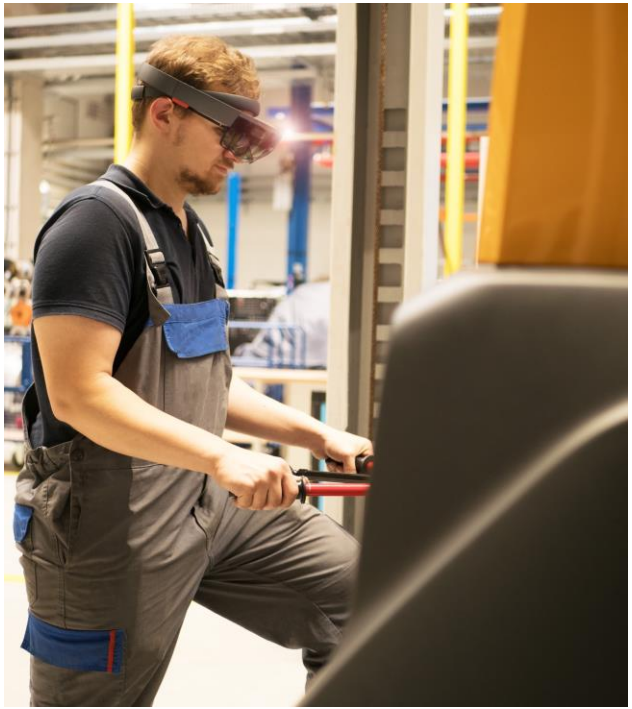
Scenario: final assembly of electric vehicles, focusing on handling, adjusting and joining as well as on the auxiliary processes of picking, documentation and information provision. Furthermore, it involves the provision of the required tools by means of an automated tool trolley (TT).

Objective to incorporate AR based guidance right information to the worker at the right moment based on operator's profile and to provide the tools required for the assembly by means of an automated tool trolley.

Actors	Automation Mechanisms
Assembly operator Maintenance operator Production supervisor Production planner	Automated tool trolley

Main motivation: improving worker satisfaction, reducing training time, improving process efficiency by reducing errors in the picking activity; improving ergonomics, reducing non-added value working time and validating a tool to determine the optimal degree of automation.

Use case application: RWTH UC alpha results



Tool-Trolley Features:

- Free navigation
- M2M-Communication via OPC UA
- Long-range steering via voice commands
- Gesture steering for short-range

A4BLUE RWTH UC alpha scenario:
http://a4blue.eu/the-video-on-rwth-scenario-is-out/

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