A4BLUE PROJECT- Adaptive Automation in Assembly
For BLUE collar workers satisfaction in Evolvable context

Enjoy reading the A4BLUE newsletter!

A4BLUE - Adaptive Automation in Assembly for BLUE collar workers satisfaction in Evolvable context

A4BLUE, funded in the framework of the Horizon 2020 TOPIC FOF-04-2016, aims to develop and evaluate a new generation of sustainable and adaptive workplaces that can deal with evolving requirements of manufacturing processes and human variability. For this purpose, A4BLUE is working to introduce adaptive automation mechanisms to help workers execute their tasks in a more efficient and secure way, as well as to provide them with personalized worker assistance systems - including Virtual and Augmented Reality and knowledge management systems - to help them in assembly and training related activities. Furthermore, A4BLUE will provide methods and tools to determine the optimal balance between automation and workers presence in new assembly processes with the main scope of maximizing the long-term workers satisfaction, as well as the overall process performance.

The three-year project is being carried out by a first-class international consortium led by IK4-TEKNIKER (Spain) and involving prestigious universities such as RWTH Aachen University (Germany) and Cranfield University (UK) and companies such as Airbus Operation SAS (France), Compañía Española de Sistemas Arenonauticos – CESA, a division of Heroux-Devtek Inc. (Spain), Engineering-Ingegneria Informatica SPA (Italy), Illogic Società a Responsabilità Limitata (Italy), Ingeniería de Automatización y Robótica KOMAT SL (Spain) and CiaoTech srl (Italy).

A4BLUE's project progress

Welcome to the fifth newsletter of the A4BLUE project which illustrates the progress in shaping that has been achieved in the framework of our activities. Only 5 months left to end of the project, and we are very satisfied with our work to shape the workplaces of the future!

We are indeed committed to make blue collar workers' lives easier and enhance their work satisfaction via new adaptive workplaces that change and respond to their individual profiles and to the evolving manufacturing environments. For us, automation and robots are not conceived to replace workers, but as an opportunity for increasing their wellness, satisfaction and professional growth, as well as productivity.

A4BLUE is currently working on the implementation of 4 demonstrators for the validation of the envisioned concept, which focuses on three aspects of these new workplaces:

- Sustainability, providing optimal degree of automation for new assembly processes that combine and

balance social and economic criteria to maximise long-term worker satisfaction and overall performance
- Adaptability, providing a management and assistance system (A4BLUE adaptive framework) able to adjust the behaviour of technical workplaces parts (i.e. robots) to work with the needs of social parts (blue collar workers) by means of integrated hardware and software components
- Automation Mechanism for improved interaction and collaboration between workers and robots which can be adapted to the individual operator and make the assembly task easier for them.
The A4BLUE solutions are being tested and validated in four use case scenarios. They consist of two real industrial scenarios: at Airbus in France and CESA in Spain, and two laboratory-based scenarios, at IK4-TEKNIKER in Spain and RWTH Aachen University in Germany. In this newsletter, we would like to share and show to you our remarkable results and the major benefits that our efforts will bring to the workers and production of the factories of the future. In addition, you can see with your eyes our technologies in the videos showing the 4 uses cases described below. The videos are available at the following link: https://vimeo.com/a4blue. Enjoy them!

AIRBUS use case scenario

Airbus, the leading aerospace company in Europe, is an international pioneer in the aerospace industry. Airbus designs, manufactures and delivers industry-leading commercial aircraft, spacecraft and helicopters. One of the final assembly lines is based in Toulouse, France, where A4BLUE is testing and validating its technologies in a real industrial scenario.

Over the past few months, some of its operators in Toulouse have been taking advantage of Augmented Reality (AR) solutions using Head Mounted Display AR devices and DynaSAM 4.0 Smart Tools which adapt themselves to their worker profile.

Final use case scenario

François, 40 years old, is an assembly operator with 20 years' work experience. He is also certified in hydraulic assembly. While Nicolas is only 22 years old and has just started working on this process. They are now working together in the hydraulic assembly of the Over Wing Panel section.

This hydraulic assembly involves the installation of several pipes with different torqueing values into each side of the aircraft. To perform this task, operators should fully comply with the Standard Operating Instruction and assemble the correct pipe in the right position. Ensuring the right torque is applied to each side of the involved pipes ensures full quality compliance and a safe testing phase.

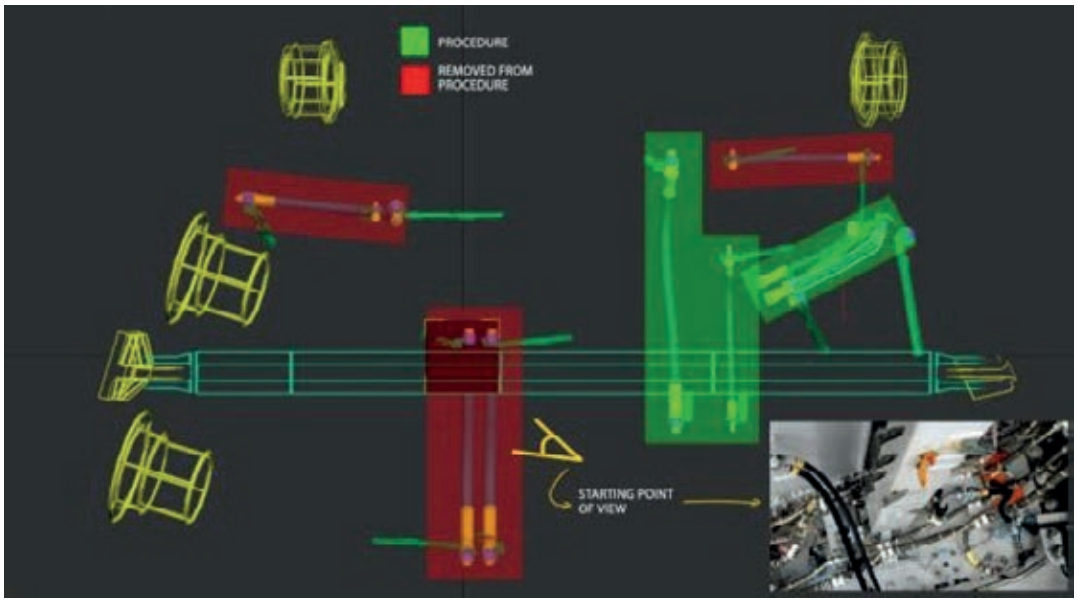

Figure 1: Green pipes selected for the purpose of this scenario

Thanks to the introduction of the A4BLUE innovations, they can now use Augmented Reality technology to guide them with on-the-job operating instructions. These instructions adapt to each operators' own profile and experience as the assembly process progresses. This tooling: Augmented Reality and Smart Tool supports them to successfully complete the hydraulic assembly of the over wing panel in an easy and intuitive way without losing considerable time going through a huge amount of paper-based information displayed on a tablet, as shown in the following picture.

Figure 2: Example of paper based SOI information

During the assembly process, François and Nicolas wear a Head Mounted Display AR device which displays operation instructions based on their expertise and the stage of the process they are at.
As previously mentioned, Nicolas has no expertise in hydraulic assembly. Therefore, he received some initial training using the hydraulic assembly mockup (i.e. the same materials environment used for instructional or experimental purposes) and the A4BLUE Off-the-Job Training Module for the double tightening operation he will perform in the hydraulic assembly process. After this initial training, he will be assigned to the hydraulic assembly of the Over Wing Panel (OWP) section.

Figure 3: Hydraulic assembly mock-up with superimposed Augmented Reality on the left

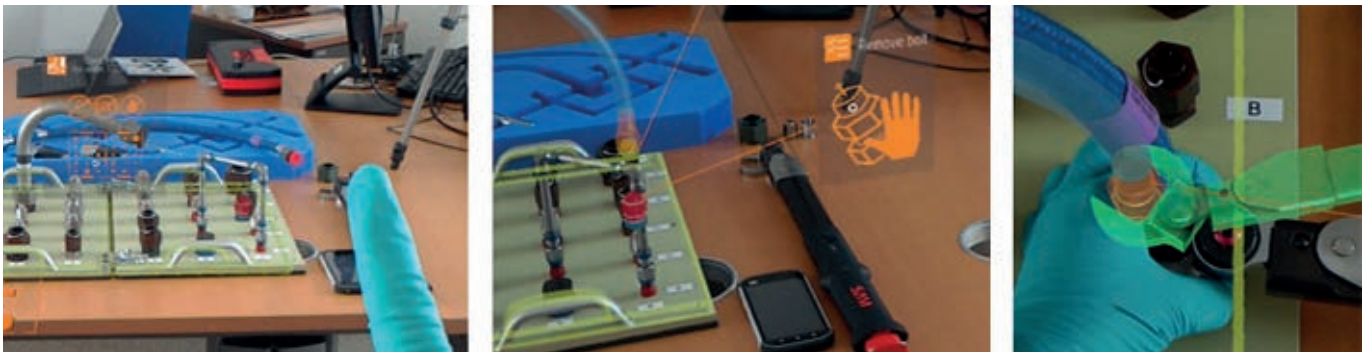

Figure 4: AR based off-the-job training

François' and Nicolas's shift has started, and they are now ready to work. The first thing they do is identify themselves on the A4BLUE system by scanning the QR Code printed on their badge. Then, they identify the relevant SOI to execute and the specific smart torque wrench they are using. Scanning the QR Code is very easy as they can do it directly using the Head Mounted Display they are wearing.

A4BLUE supports standard based (i.e. OPC UA based) automation discovery and operation, so once a smart torque wrench is switched on, data like torque values, status and malfunctions can be monitored and remote commands like torque value configuration can be executed.

During the execution of the instruction, the AR device shows all the information required to perform the assembly (e.g. torque wrench value, validation of the localisation and progress of the instruction, next steps to perform, etc.).

As Nicolas still has less experience in hydraulic assembly, he needs more guidance than François and the system is able to provide him with suitable information. For example, in addition to the general information, he receives extra guidelines like an audio notification when he reaches the targeted value, he has access to tips, advice, pictures showing how to successfully progress through tricky steps, and a big picture of the overall status of the instructions. Thanks to this new on-the-job guidance, he has been able to reduce the duration of his off-the-job training process and start "learning by doing" in real conditions. Furthermore, due to Nicolas' limited expertise, Roméo (47 years old), the quality engineer, needs to oversee his work. A4BLUE involves a read only version of the AR based module, so Romeo is able to see the same information as Nicolas while Nicolas is performing the activity.

When Nicolas or François need to perform a torqueing operation, the A4BLUE system detects it and automatically sends the appropriate torque value to the specific smart torque wrench they are using based on the instruction specification. This new feature aims to reduce potential errors when applying the torque.

Furthermore, the smart torque wrench pushes the real torque value being applied to A4BLUE to support full traceability and displays a notification of the value displayed in the AR device. Thanks to the automatic configuration and notification processes, François has further increased his execution speed and he is now confident that he torqued to the correct value in all cases; even if there are some variations between two aircraft.

Once Nicolas or François finish a specific operation, they report it through the Head Mounted Display AR. Thanks to this, Roméo, is aware at any time of the status of the operations involved in each step of the instruction through the "Instructions Follow-up" dashboard available on the A4BLUE system. This tool allows him to better plan all of the quality supervision activities.

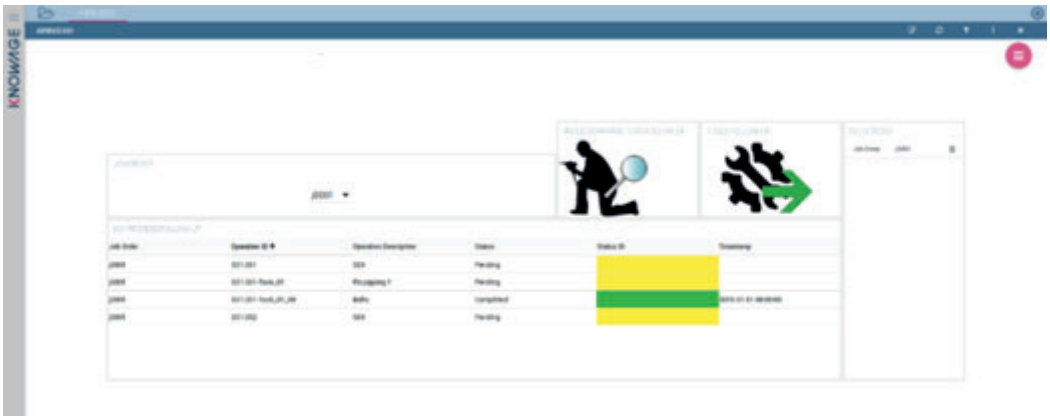

Figure 5: Instructions Follow-Up dashboard screenshot

Before the introduction of the A4BLUE technologies, François was obliged to fill in a report to describe and track his activity and provide relevant information for quality supervision activities. He used to spend a lot of time preparing this report because he had to provide the real torque values and he sometimes made mistakes when filling it in. Now, thanks to the A4BLUE solutions, he does not need to complete this report anymore because it is automatically generated using the information collected from both the AR based instructions and the smart torque wrench. Thus, Roméo is able to access the accurate information through the Parameters Follow-up dashboard.

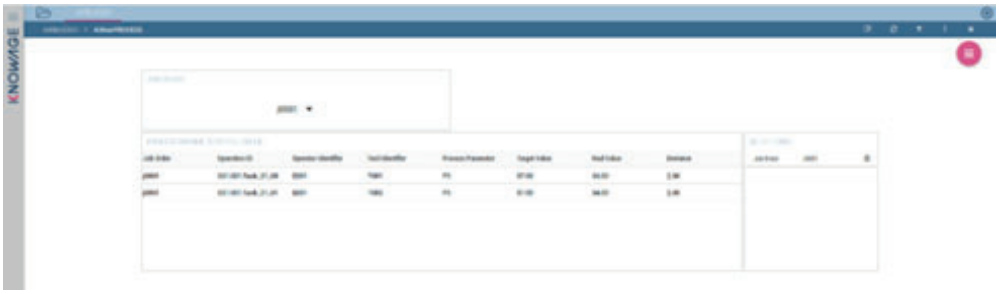

Figure 6: Parameters Follow-up dashboard screenshot

Furthermore, this level of detail of the operations enables Stéphane (33 years old), the Process planner, to easily re-schedule the remaining tasks that need to be performed, with knowledge of potential issues and thus optimise the entire assembly process, including non-standard operations.
Apart from the real torque, the smart torque wrench can send real time information on its internal status (malfunction, fall detection, out of range torqueing ...). As this information needs to be passed on to the Metrology department, a new feature will shortly be released as part of the A4BLUE project to notify him of potential malfunctions, and provide decision support information through the Tool Follow-up dashboard.

Figure 7: Tool Follow-up dashboard mock up

CESA use case scenario

Compañía Española de Sistemas Aeronáuticos (CESA), a division of Heroux-Devtek Inc., is a Spanish industrial company, European leader in the manufacturing of fluid and electromechanical systems for the aeronautic sector. The second industrial A4BLUE use case scenario resides within their facilities, and their scenario will introduce the first automation in co-existence with humans in the company. This introduction will reduce the high dependency on manual work and allow workers to better use their time and will be less exhausting for them. In addition, an AR device will also be implemented to provide a new friendlier and easier way of presenting information to the workers as a complete source of guidance, preventing fragmented information.

Thus, the CESA use case scenario focuses on the assembly process of the Retraction Actuator of the main landing gear of a single aisle commercial aircraft, which is one of CESA's most representative products, and is currently built manually. The scenario also includes one of the auxiliary operations required to guarantee a smooth assembly process: the deburring of the titanium Earth End. The process has already reached a good level of maturity because, with 5 months left until the end of the project, workers are ready to start testing the A4BLUE technologies!

Final use case scenario

It is 14:40 and Carmen (51 years, deburring operator with more than 30 years of work experience) has just arrived at the work centre: 31C, to start his workday. Today the production control's instructions have been to deburr a batch of Titanium Earth End parts before they are assembled to form Retraction Actuators that are to be completed during the week. Carmen knows the process very well, she has been doing this task, manually, for several years, before the A4BLUE human-robot co-existing cell was implemented a few months ago.
The process starts with the operator logging into the MES-Manufacturing Execution System from the PC available in the deburring area and entering the order number and operation associated with the deburring process of the Earth End. As a result, the start time for the deburring process is logged and will be monitored.

Now, she is ready to start working on the first part of the batch. Firstly, Carmen manually deburrs all the small sections that are not accessible to the robot tools. Then, she installs the Earth End in the fixture and starts the robot programme.

Figure 6: Parameters Follow-up dashboard screenshot

While the robot completes its work, Carmen prepares the other parts of the batch and finishes off parts from the previous batch. In the meantime, she receives an alert indicating that the robot has stopped because one of the tools requires replacement due to wear. Once she has replaced it, she starts the robot and it continues with its work.

Figure 9 Screenshot of the Notifier app

When the robot finishes its operation, the operator checks the quality of the surface. Today she discovers an area with greater roughness than expected. As it is a big area, she decides to reprogram the robot so that it can complete the process again. Carmen does this by easily selecting the rework zone in the robot interface installed in the cell PC.

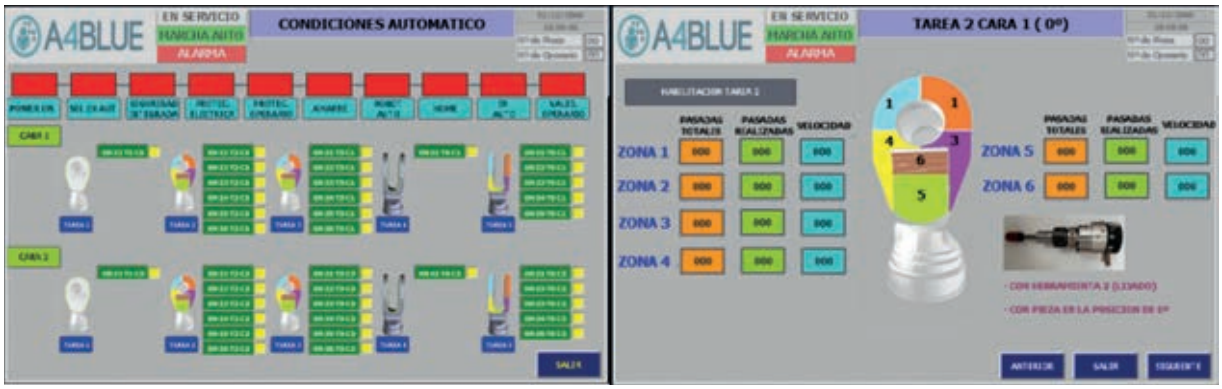

Figure 10 Screenshot of the different areas that can be deburred separately

However, most of the time, any rework needed is so small that he can do it by himself.
During his work, Carmen has an easy access to the Knowledge Management App installed in the PC of the deburring area. There. she can access the best practices shared by his colleagues and other specific comments about the status of the work order.

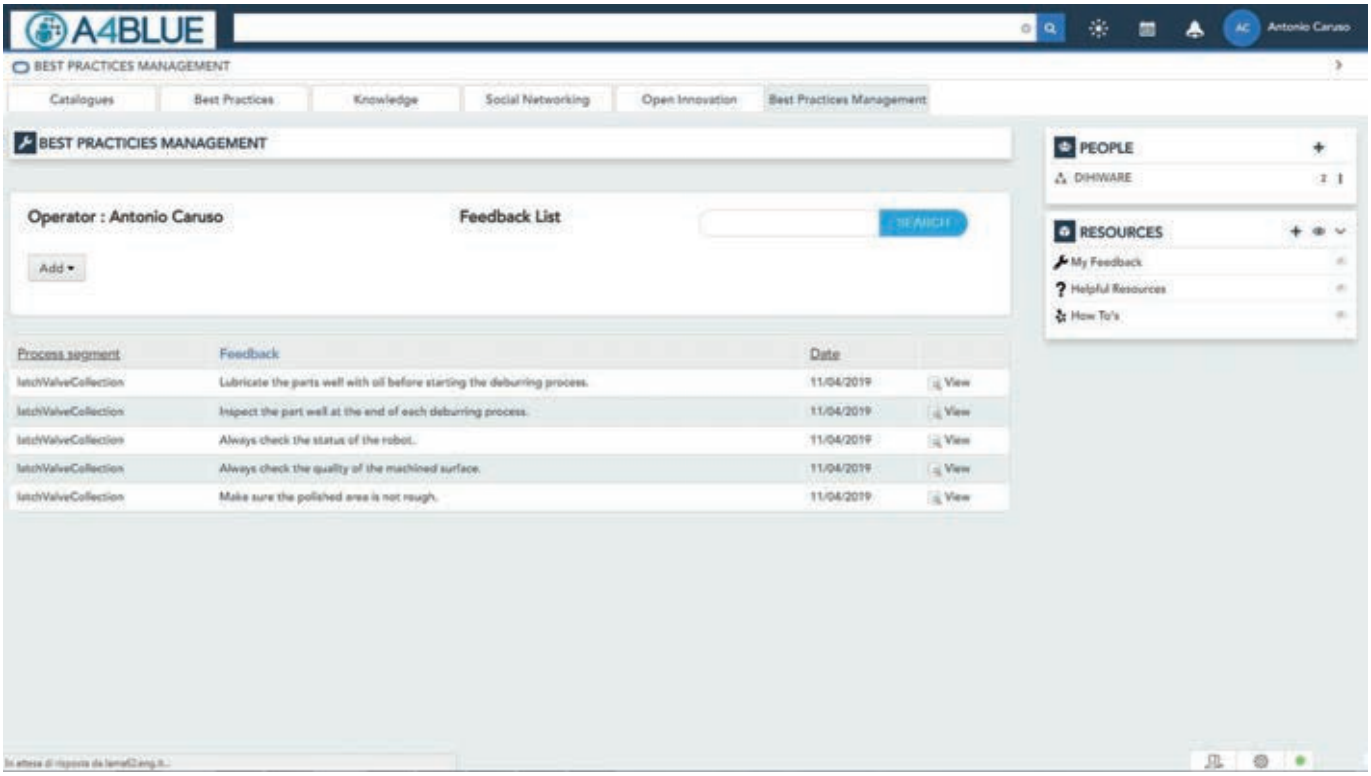

Figure 11 Screenshot of the knowledge management application

Finally, when the part is finished, the operator applies air to remove the remaining metal chips in the part, wraps it with antioxidant paper and leaves it at the shelves ready for logistics to take it to the next workstation.

Carmen repeats the process for all parts in the batch. While she is installing the next part into the fixture, Jose (55 years, maintenance responsible, 27 years of experience in CESA), he receives an email alert with a warning of malfunction in the robot.

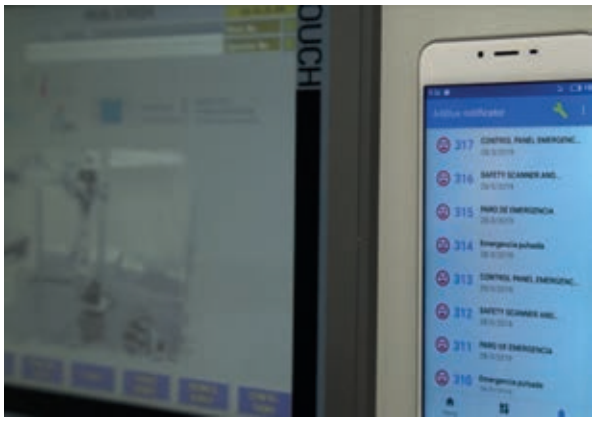

Figure 12 Malfunction notifications

Once Carmen has finished all of the parts in the batch, she is ready to go back to the computer and sign the operation to close it.

In a nearby area of CESA premises, it is 07:40 and Pedro (37 years, assembly operator) has just arrived to "Module 4" to start his workday. Pedro is an experienced assembly worker with almost 20 years of experience at CESA. Today he is being instructed by the production control on how to assemble a Retraction Actuator that needs to be delivered to the customer by the end of the week. He already knows the process very well, as the Retraction Actuator is not a new product to him, and he was certified to do this assembly some years ago. However, now he uses the AR Head Mounted Display device which guides him through the assembly process helping to avoid mistakes and makes him aware of any changes in the assembly (e.g. if a new part/number or process has been modified).

To start, Pedro first needs to identify himself, so that the time he spends working on the Retraction Actuator assembly be monitored. For that, he scans the QR Code from his identification batch using his AR Head Mounted Display.

Then, he scans the QR code of the work order and the AR device starts showing him the first step of the process he needs to perform.

Figure 13 Operator scanning workorder QR code

Suddenly, Pedro receives a notification alert. He selects the alert to open the message and discovers that the previous operator has had a problem with a tool, so he needs a new one. Pedro follows the instructions and goes to the area workhouse to get the new tool.

Now, he is ready to start the assembly. Pedro proceeds task by task through the text instructions, animations and 3D models that are shown through the AR glasses. When he needs more information, he can access to drawings or the complete work order. After an operation is completed, he can indicate the new status via the info panel using his fingers and skip to the next tasks.

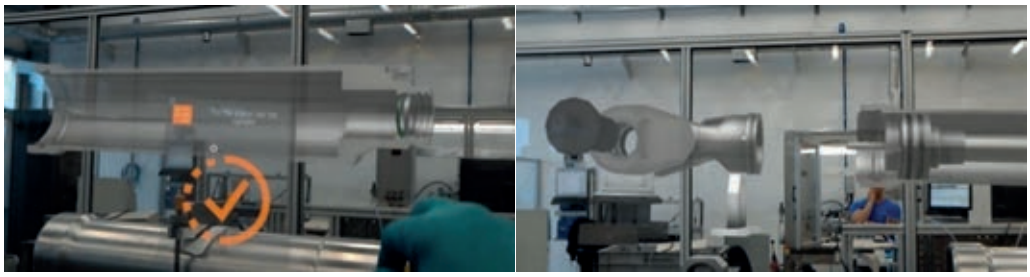

Figure 14 Example of the work instructions shown to the operator through the AR glasses.

Figure 15 First test of AR prototype at CESA: operator is cleaning the seals before assembling them into the cylinder

While preparing the seals for the assembly, Pedro notices that they are dirty. After lubricating them with SKYDROL, he decides to clean them using a cloth. It is not the first time Pedro has found dirty seals, so he decides to record a tip for other workers to warn them about this. He records a voice message through the Head Mounted Display to recommend other operators clean the seals with a cloth after lubricating them.

The next step is to equip the piston head with a gasket. To do that, he needs to use a tool and hit it with a hammer. When he is about to proceed with this operation he receives and alert that recommends using a cloth to avoid SKYDROL lubricant splashes.

Pedro finished the last operation, now the Retraction Actuator is completely assembled. He closes the last info panel and logs out from the A4BLUE Head Mounted Display system.

Figure 16 First test of AR prototype at CESA: Operator closing one operation to progress to the next one

Carlos (5 years of experience in CESA) is the operator in charge of assembling the next Retraction Actuator the following day. Pedro is not available as he needs to complete the acceptance tests. It is the third time Carlos assembles this type of actuator, so he needs more guidance than Pedro. The AR Head Mounted Display makes him feel more confident facing the usual assembly tasks.

The process is exactly the same as that performed by Pedro, but the Head Mounted Display can show Carlos more detailed text instructions, animations and 3D models.

IK4-TEKNIKER use case scenario

The third use case scenario is deployed in the manufacturing shop floor lab at IK4-TEKNIKER, a technological research centre located in Spain that aims at the development and transfer of technology to improve the competitiveness of industry.

The introduction of the new A4BLUE solution has increased process re-configurability and flexibility by easing the integration of new hardware components (e.g. logistic robot) through the use of a standard based (i.e. OPC UA based) plug and produce approach which supports both automation discovery and operation. Furthermore, it has improved the working conditions and workers' satisfaction.

During these last few years, the work of the assembly operators has evolved a lot. To start with, they completed different manual assembly processes; now their work has evolved into overseeing several different assembly work cells, involving manual assembly in co-existence with industrial assembly robots in fenceless environments. Furthermore, now they have new responsibilities that include supervision, final inspection and some basic maintenance activities.

Final use case scenario

Marian is 30 years old; she is an assembly operator with more than 3 years of work experience. Every morning, when she starts her shift, she logs into the Manufacturing Execution System and initiates the scheduled job order in each of the work cells under her supervision. As shop floor operators can be involved in more than one work cell, the Manufacturing Execution System (MES) is made available on an industrial PC located in a convenient location nearby (MES corner). Today, the work assigned to the "Assembly 01" work cell is the assembly of a latch valve ("LV1 reference"). Most of the assembly process of the "LV1" reference has been automated, but she needs to perform a very specific fastening operation that cannot be automated.

Marian initiates the related job order through the MES Graphical User Interface (GUI), and the first activity is to perform the setup. To do so, she needs to prepare the assembly tray in the workbench just in front of the dual arm robot and once it is ready, she must finalise the setup and start the assembly task itself. Now that the A4BLUE solution is available, Marian can use natural speaking commands to start the assembly operation instead of walking to the MES corner, some meters away, saving a lot of time.

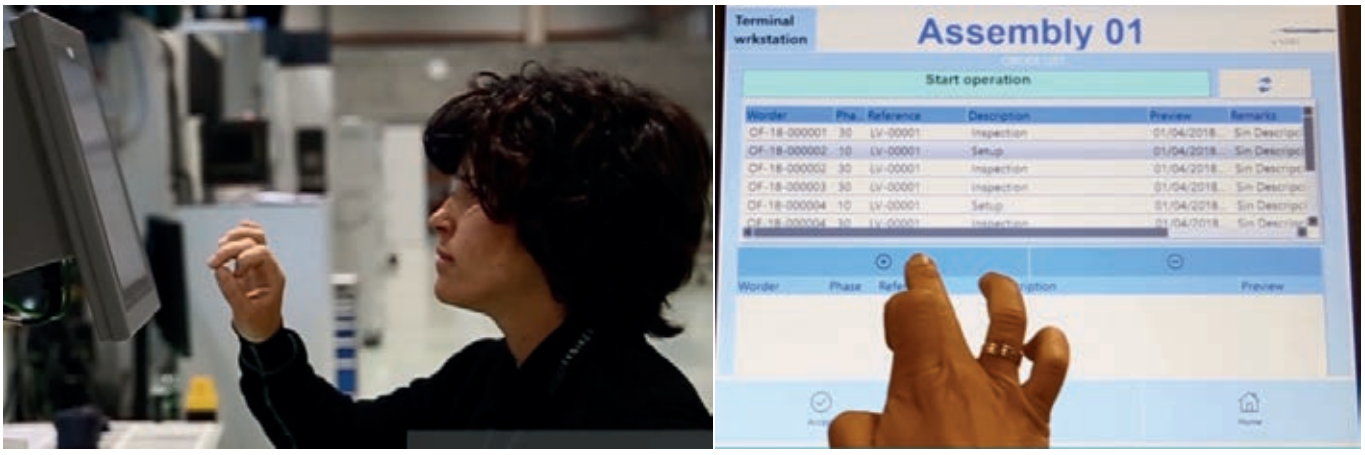

Figure 17 Integration with MES (log in / work order start)

Marian is happy with this natural speaking feature as sometimes she has some problems to remember pre-defined commands. She prefers verbal interactions, but she knows that Alvaro (61 years old, assembly operator with more than 30 years of work experience) uses gestures as he has some language related issues. In any case, she can use, at any time, both gestures and natural speaking commands.

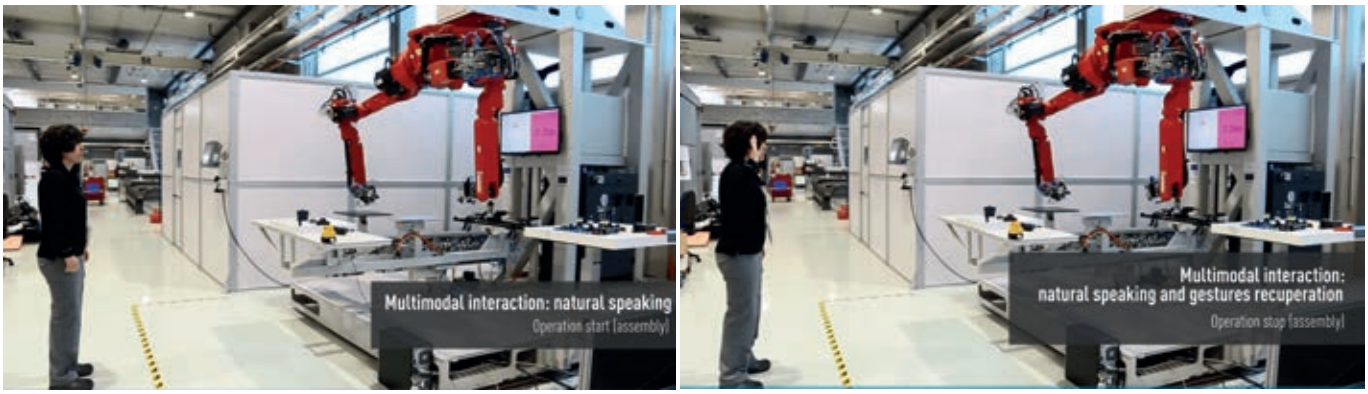

Figure 18 Multimodal interaction

When she gives a command (e.g. to START, RESUME, STOP or END an operation), she receives a visual (through the Notification app installed on her smartphone) and audio feedback (through the ear set she wears) which confirms that her command has been received and whether it is valid or not (e.g. RESUME command is valid only if the operation has been stopped previously).

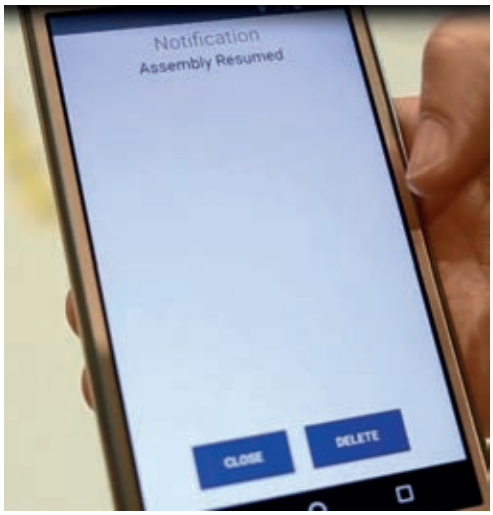

Figure 19 Multimode feedback notification

Once the A4BLUE system receives a valid START command, it automatically initiates the control program associated with the product reference included in the initiated job order (e.g. "LV1"), so the dual arm robot starts assembling the part. In the meantime, Marian can start another job order in any of the other work cells assigned to her or perform some inspection or maintenance activity.

When it is time to perform the fastening operation, Marian receives a push collaboration intervention request to her Smartphone, and she comes back to the "Assembly 01" work cell to do it. When she arrives, the dual arm is holding the part in an ergonomically suitable position adapted to her height. Since the robot adapts the positioning of the part to the anthropometric characteristics of each worker during the collaborative operation, no more days out of work were reported due to musculoskeletal problems.

Figure 20 Adaptive automation

Once the fastening operation has been finalised, Marian uses a natural speaking command to restart (i.e. RESUME command) the automatic assembly process. Now, she can perform some other actives until she receives an "Inspection request notification" to proceed with the final visual inspection.
Furthermore, once the automatic assembly is finished, the A4BLUE system automatically updates the status of the operation in the Manufacturing Execution System, so no longer necessary for Marian to report on the completion of the activity through the MES GUI.
Moreover, Marian is no longer has to carry the completed and inspected parts to the warehouse located at the other end of the shop floor. Now she can use natural speaking to ask an autonomous logistics robot to navigate to the work cell where she is located to collect the completed parts. Once the logistic robot arrives, she has just to load them and give it the instruction to proceed so that the logistic robot autonomously transports the parts to the warehouse stopping point, saving her time.

Marian's trust in co-existing with robots in fenceless environments has increased as the system can distinguish between persons and inanimate obstacles and take into consideration the proximity to the robot and adapt its speed. The system is even able to react in a different way depending on the part of the body entering the safety zone (e.g. adapt the robot's behaviour in a different way whether the foot or the head enters the safety zone). Furthermore, this active safety feature has increased the robot availability and overall productivity as it is able to better control safety related stop times.

Figure 21 Logistic robot

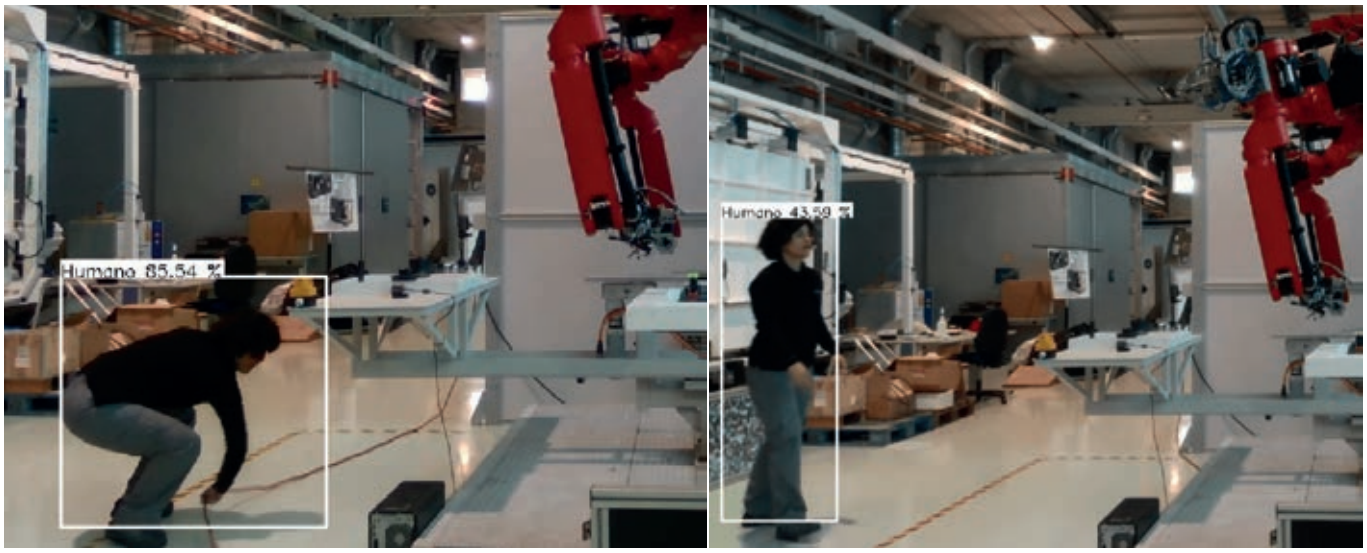

Figure 22 Active safety: Person recognition

If an unexpected downtime occurs during the automatic assembly process the system raises a "Maintenance Intervention Request" notification. If the maintenance protocol related to the specific error involves basic maintenance activities, the notification is sent to Marian or Alvaro (i.e. operator logged in the specific work cell) otherwise it is sent to Juan (49 years, maintenance technician). If there is a problem in the logistic robot the "Maintenance Intervention Request" notification is sent, directly to the maintenance technician who can receive it either by means of a push notification into their smartphone or through an email.

A new feature is being deployed so that when Marian or Alvaro receives a "Maintenance Intervention Request" notification they will be able to use the available AR based guidance module that supports them in performing the basic maintenance activities. During the maintenance activities, they will wear a Head-Mounted display (i.e. Head Mounted Display) providing them with the information they need, adapted to their level of expertise, to perform each specific step of the maintenance protocol and allow them to use their hands for the work. The same system will be used by Juan to perform more complex maintenance interventions.

Furthermore, Juan can access the "Maintenance Decision Support" dashboard at any time to access relevant information about equipment related errors and relevant information to perform maintenance activities.

Figure 23 Maintenance DSS

On a periodic basis, Alvaro, Marian and Juan are asked to fill in questionnaires to assess usability and worker satisfaction to improve the system and boost worker satisfaction. Alvaro and Marian have been told that a new feature will be introduced shortly so they will be automatically asked to provide their feedback to better identify improvement activities.

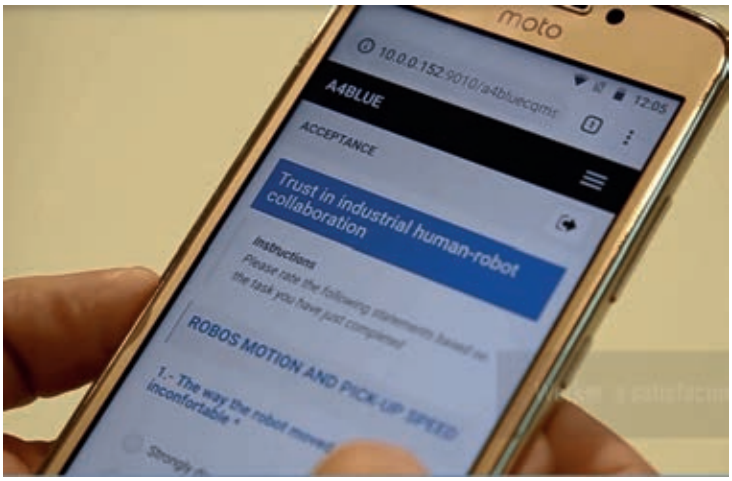

Figure 24 Worker satisfaction Assessment

Mercedes (53 years, Human Resource responsible) can access the results of the satisfaction assessment to identify whether measures need to be put in place to improve working conditions. The collected results will be presented anonymous to comply with privacy issues and to encourage the workers to freely share their true opinions.

RWTH use case scenario

RWTH Aachen University is a research university located in Aachen, North Rhine-Westphalia, Germany. With 260 institutes in nine faculties, RWTH Aachen University is one of Europe's leading institutions for science and research. The work of the research centres of RWTH Aachen is closely oriented towards the current needs of business and industry and their participation in AB4LUE project is an evidence of this vision.

Within the RWTH Aachen University use case, the A4BLUE solutions are applied to enhance the assembly process of electric vehicle prototypes. The assembly of the rear light as well as the break module is performed with the example of the electric vehicle ACM2 eTaxi.

Final use case scenario

The prototyping team is composed of Hans (26 years old), temporary worker, and Friedrich (57 years old), worker with medium experience and reduced physical capacity.

Hans and Friedrich's shift starts at 6 am. Since the timetable for the completion of the electric prototype vehicles is very tight, Hans is temporarily supporting to finish the vehicles on time. He usually works in other facilities; thus, he does not have any experience with this product or process. Because of his tight timetable, Friedrich, the experienced worker, is very stressed and not able to support Hans by training him in the processes. Additionally, the prototyping environment challenges both workers with a set of highly variable and changing tasks.
Arriving at their workplace, the workers wear an Augmented Reality device.

To set up the assembly process, Hans and Friedrich need to ensure that the required tools are available at the workplace. The tools are used in many different locations throughout the facility and may not be at the workplace at all time. This usually leads to physical stress and inefficiencies resulting from searching efforts. In order to physically relieve both workers, A4BLUE developed in the RWTH use case an intelligent and autonomous tool trolley (see Figure 26 and Figure 27). The tool trolley reacts to human gestures and follows the workers on command.

If the tool trolley is not at the required workplace, a long-range steering via voice control is available to request it. Receiving the request, the tool trolley autonomously moves from any place in the factory to the desired spot by using intelligent and adaptive routing. Sensors for localization and surround scanning ensure safe routing, even with several obstacles are on the planned route. Once the tool trolley arrives and the tools are available at the workplace, Hans and Friedrich are ready to start with the assembling of the vehicle.
For cognitive relief, both are wearing the smart glasses which provide them with personalized and process-relevant information. The smart glasses enable hands-free information provision within the operators' field of vision. Thanks to this device Hans and Friedrich can operate on full physical strength.

The experience level of Hans is retrieved from the A4BLUE system as "Novice". Thus, starting with the assembly process, Hans is provided with very detailed process instructions. On the other hand, Friedrich is only provided with minimal process information - since he is qualified as "Expert" and does not need as much detail - as well as possible data about changes. Both start the process by picking up the necessary components for the process. The former paper-based picking lists were replaced by visual marking of the component containers through the smart glasses, as well as information on the items to be picked (Figure 26). The position of the parts may change from day to day because components are replaced, or the workplace is slightly reorganized for different reasons. Therefore, the picking information are the same for Hans and Friedrich. Supported by Augmented Reality, they are able to quickly find and pick the needed components, without losing time searching for them throughout the prototyping environment.

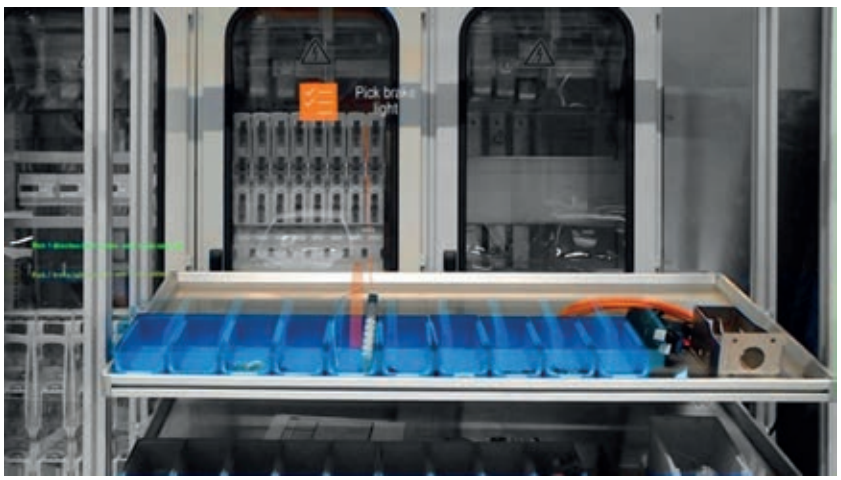

Figure 25: Picking process supported by Augmented Reality

Hans and Friedrich place the components on the top of the tool trolley which positioned itself directly at the shelf via the long-range steering. To move the tool trolley within the workplace area, Hans and Friedrich use gesture control (Figure 26). They use hand gestures to turn the tool trolley around or to move it to a specific position.

To cross the preassembly of brake module, which is carried out at the other side of the assembly station, they activate the "follow-me" function: the tool trolley follows them around the workplace. When the tool trolley is no longer needed, or if it is obstructing walk - or workways, the mid-range steering is used (Figure 27). The tool trolley is moved by positioning a virtual model of the trolley at the desired position via the Augmented Reality device and then, it moves to the specified place.

Figure 26: Gesture steering of the tool trolley for short range steering

Figure 27: Visual steering of the tool trolley for mid-range steering

Afterwards, Hans and Friedrich start the actual assembly processes that mainly consists of the setup of tools as well as of joining operations. Even if Hans does not have enough experience to execute the process on his own, he is able to perform the task without Friedrich's support thanks to the necessary information provision about the operations shown via Augmented Reality. Hans is supported - directly in his field of vision - with the detailed assembly instructions composed of text and virtual models (Figure 29). Thus, they can independently execute the assembly which raises efficiency since no training time is needed and errors are significantly reduced.

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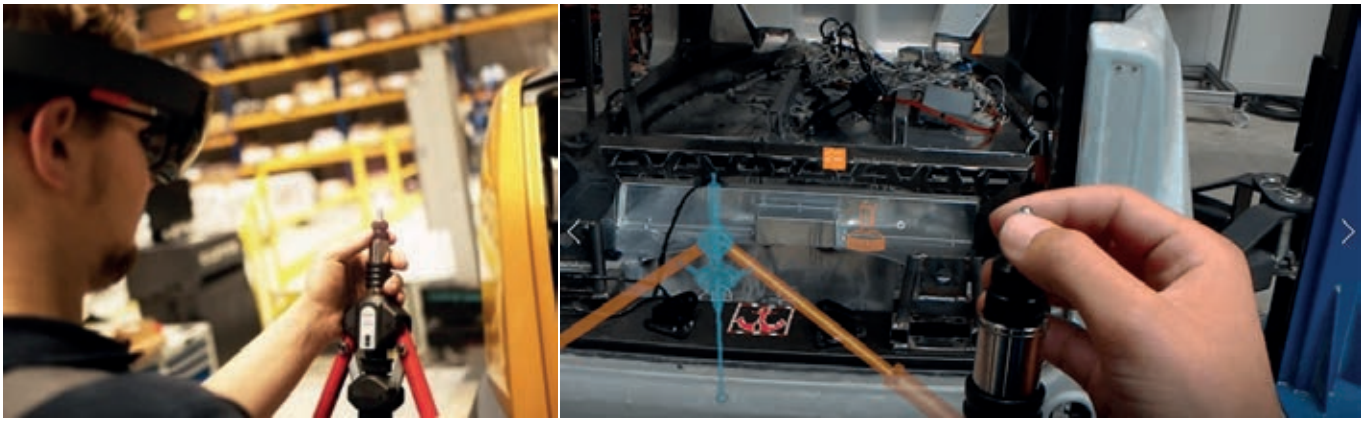

Figure 28: Rear light assembly operation

To ensure and measure Hans and Friedrich satisfaction with their new smart tools, they are asked to fill in questionnaires on a regular basis using the Worker Satisfaction Tool of the A4BLUE Adaptive Framework. If the satisfaction of the worker decreases, production supervisor Werner (43 years old) is ready to envisage a workplace and conduct a process reconfiguration.

Werner is responsible for the planning and the optimization of processes and workplace, as well as for intervention or support in case of quality issues. He works in an office located outside of the assembly area. Therefore, his activities need high quality data to have a comprehensive picture of the real process. In order to support Werner in the RWTH use case, two main modules of the A4BLUE Adaptive Framework are used: The Automation Configuration Evaluation Tool and the Decision Support System Dashboard.

Werner starts his working day at 8 am. First of all, he takes a look at the Decision Support System Dashboard (DSS Dashboard) in order to check process-relevant key performance indicators collected by the Augmented Reality devices in real-time. This way, he is aware of anything unusual happening before his arrival. The DSS Dashboard provides Werner with graphically processed information of the key performance indicators. He is able to spot trends, positive or negative, as well as irregularities such as quality problems, current or imminent. Based on this data, he is able to decide whether it is necessary to observe the problematic process personally and/or talk in person to Hans and Friedrich who may have already identified the root cause of the issue.

Figure 29: DSS Dashboard current state of development for the RWTH use case

In order to improve economic efficiency and Hans' and Friedrich's satisfaction, Werner uses the Automation Configuration Evaluation Tool (ACE Tool) which calculates the optimal degree of automation, balancing economic aspects and worker satisfaction.

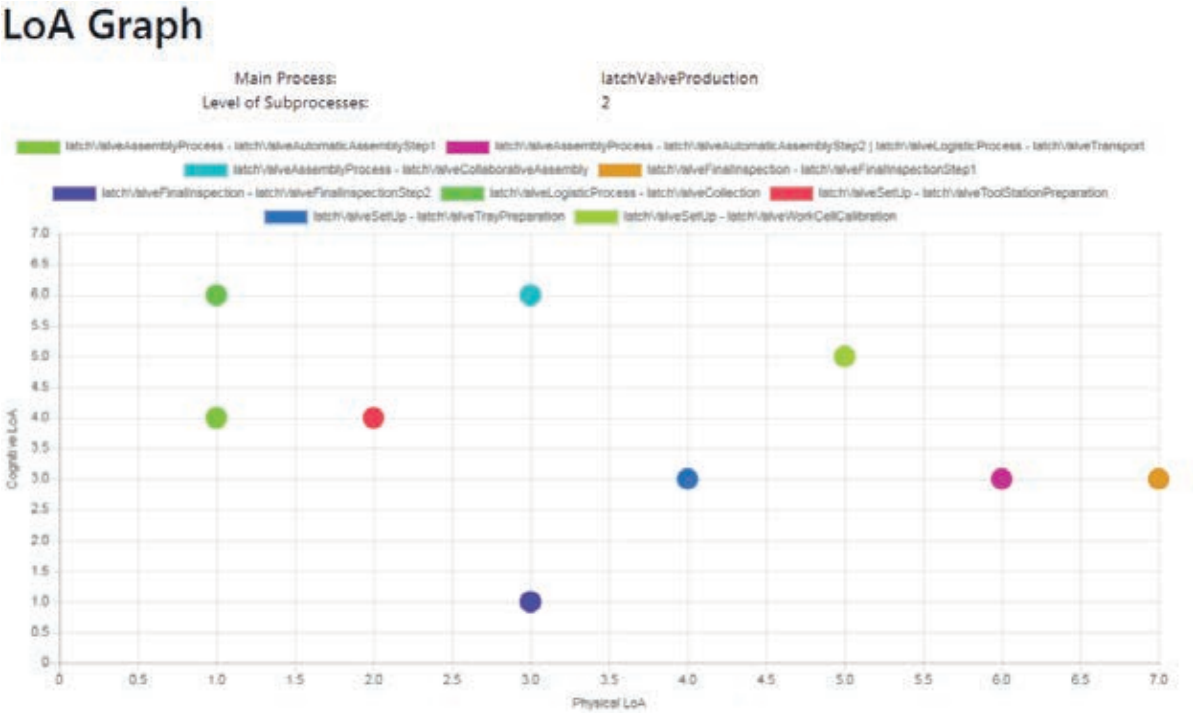

Figure 30: Level of Automation graph of the ACE Tool in current stage of development

If Werner needs to plan a new workplace or process, he calculates the optimal automation configuration by using estimations for process times and worker satisfaction. From time to time, after process implementation, he recalculates the automation configuration with the actual data arising from the implemented process in order to identify the potential for further optimization. This supports an optimal process able to adapt to changing requirements and individual preferences, as well as the growing level of Hans' experience.

Dissemination & Communication activities

We are continuously engaged in dissemination and communication activities in order to increase the visibility of A4BLUE, as well as to highlight why we are working so hard in this project: develop the workplaces of the future where workers and automation systems can safely and efficiently interact by improving workers satisfaction and productivity in evolving manufacturing processes. Automation is not a threat for workers but rather an opportunity for them to participate in the changing work environment by taking part in designing the new workplaces, and at the same time increasing their work satisfaction and upgrading their skills.

For example, Illogic and CiaoTech presented the A4BLUE solutions during the A&T 2019, the trade fair dedicated to Industry 4.0, testing and measurements, robotics, and innovative technologies (in Turin, Italy) on 14th February 2019. Illogic also provided a live demonstration of the AR applications used in the A4BLUE project on all of the 3 exhibition days at the Illogic booth. During the demonstrations, visitors were able to wear the Head Mounted Display and see with their own eyes how AR instructions and guidance for the operators work to help and assist workers in performing their assembly tasks.

In order to improve economic efficiency and Hans' and Friedrich's satisfaction, Werner uses the Automation Configuration Evaluation Tool (ACE Tool) which calculates the optimal degree of automation, balancing economic aspects and worker satisfaction.

Figure 31: A4BLUE @A&T 2019

On the 18th of April, CiaoTech presented A4BLUE at SAVE Milano, the Exhibition Conference dedicated to the Industrial Automation and Tools. The impressive results achieved in the four use cases were presented to the audience that joined the session dedicated to the Smart instruments.

Figure 32: A4BLUE @ SAVE MILANO 2019

A4BLUE partners are planning participation at other events in the coming months. For example, Cranfield University will join the Competitive Advantage in the Digital Economy Forum (CADE 2019), organized by the University of Warrick from 20th to 22nd of May 2019 in Venice, Italy, to present the work performed on the development of the worker satisfaction model. Finally, RWTH will present a paper during the 10th International Conference on Applied Human Factors and Ergonomics (AHFE 2019) in Washington D.C., U.S., (27th July 2019) - Paper title: "Enabling Smart Workplaces by Implementing an Adaptive Software Framework".

ACE-Factories Cluster Event – 23 May 2019, Brussels

A4BLUE and the ACE Factories Cluster members are glad to invite you to the **Human-Centred Factories Event** that will take place on the **23rd of May 2019** in the framework of the Factories of the Future Community Days-Connected Factories Event, organised by the European Factories of the Future Research Association (EFFRA). The event will take place in Brussels, Belgium, at the Thon Hotel (75 Rue de la Loi).

The event consists of two different sessions. During the morning session (10 am- 1pm), the 5 projects composing the ACE Factories Cluster (**A4BLUE**, **Factory2Fit**, **HUMAN**, **INCLUSIVE**, and **MANUWORK**) will present the latest Human-Centred industrial innovations and the results obtained in the framework of their activities, focusing on the experience of the industrial partners involved in the relative consortia. In the afternoon session Human-Centred Factories Exhibition (2 pm - 4 pm) will allow you to take part in interactive exhibitions and demo sessions, where the ACE Factory Cluster's tools and solutions for the Factories of the Future will be showcased.

Participation in these two events is free, but registration is required at the following links:
- Morning session (through the EFFRA Community Days – Connected Factories Event): https://www.eventbrite.com/e/fof-community-day-connectedfactories-event-tickets-57585346321
- Human-Centred Factories Exhibition (afternoon session): https://www.eventbrite.com/e/human-centred-factories-exhibition-registration-59101561361

Visit this **link** to learn more and join us in Brussels!

A4BLUE Consortium

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For more info about the project visit the A4BLUE website at: www.a4blue.eu

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