INDUSTRY IN THE AEROSPACE DOMAIN:
Airbus and Héroux-Devtek Spain use cases
in A4BLUE project

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

This project has received funding from European Union’s Horizon 2020 research and innovation programme under grant agreement n° 723828

AEROTECH EUROPE - Bordeaux 25/09/2019
HÉROUX-DEVTEK SPAIN

- **326 EMPLOYEES**
- **38,500 m² MANUFACTURING SQM (MADRID & SEVILLE)**
- **CUSTOMERS IN 11 COUNTRIES**
- **+150 PROGRAMS**
- **15% R&D of SALES ANNUAL INVESTMENT**
https://vimeo.com/360231253
A4BLUE objectives

- Put together workers and AUTOMATION mechanisms to take advantage of each others strengths
- Put together workers and context-aware ADAPTATIVE ASSISTANCE TOOLS

TO

- Increase worker SATISFACTION and workability
- Increase productivity and overall PERFORMANCE

Long term socio-economic sustainability
A4BLUE involves 4 use case scenarios ...

## INDUSTRIAL PILOTS

<table>
<thead>
<tr>
<th>AIRBUS</th>
<th>TOULOUSE, FRANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCENARIO</strong></td>
<td>Complex, manual hydraulic system assembly</td>
</tr>
<tr>
<td><strong>WHAT</strong></td>
<td>To optimize hydraulic system assembly through the use of smart tools and Virtual/Augmented Reality.</td>
</tr>
<tr>
<td><strong>WHY</strong></td>
<td>To evaluate the impact of an adopted AR HMI in terms of performance and error rate for different skill groups of people and to enable full quality assurance approach and operators performance thanks to traceability.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CESA</th>
<th>MADRID, SPAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCENARIO</strong></td>
<td>Landing gear retraction actuator assembly: Manual deburring operation</td>
</tr>
<tr>
<td><strong>WHAT</strong></td>
<td>To incorporate a robot to assist the worker in the deburring operation</td>
</tr>
<tr>
<td><strong>WHY</strong></td>
<td>To increase the quality, efficiency and ergonomics of the deburring process</td>
</tr>
</tbody>
</table>

## LAB PILOTS

<table>
<thead>
<tr>
<th>IK4-TEKNIKER</th>
<th>EIBAR, SPAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCENARIO</strong></td>
<td>Collaborative assembly in a fenceless environment</td>
</tr>
<tr>
<td><strong>WHAT</strong></td>
<td>To introduce active safety measures supporting Human-Robot collaboration; to support personalized ergonomic adaptation; to provide natural Human-Automation multi-channel interaction; to provide decision support dashboards for quality and maintenance.</td>
</tr>
<tr>
<td><strong>WHY</strong></td>
<td>To evaluate trust, usability and worker satisfaction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RWTH AACHEN UNIVERSITY</th>
<th>AACHEN, GERMANY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCENARIO</strong></td>
<td>Final assembly of electric vehicles</td>
</tr>
<tr>
<td><strong>WHAT</strong></td>
<td>To incorporate AR based guidance based on operator's profile and to provide the tools required for the assembly by means of an automated tool trolley.</td>
</tr>
<tr>
<td><strong>WHY</strong></td>
<td>To improve worker satisfaction, to reduce training time, to improve process efficiency, to improve ergonomics, to validate a tool to determine the optimal degree of automation.</td>
</tr>
</tbody>
</table>
HÉROUX-DEVTEK PRODUCTION NEEDS

- Main characteristics of CESA production (assembly area):
  - Highly manual
  - High expertise of the workers needed
  - Small batches
  - High variability of the products
  - Wide production ratio (from 4 to 140 per year)
  - Highly restrictive quality requirement
  - Some process have a risk for the health of the workers

- CESA assembly use case
  - Retraction actuator of the main landing gear of a single aisle commercial aircraft
  - Around 200 units/per year

DIMENSIONS RETRACTED
1428.8 mm
DIMENSIONS EXTENDED
2092.2 mm
WEIGHT 132.5 Kg
PRESSURE 350 bar
• RETRACTION ACTUATOR ASSEMBLY PROCESS:
  1. Auxiliary operation: human-robot collaborative deburring of a titanium part
  2. Main landing gear guided assembly using AR
**DEBURRING APPLICATION SCENARIO BEFORE A4BLUE**

- **“AS IS” MANUAL DEBurring PROCESS**
  - The raised particles and shavings that appear when metal blanks are machined are referred to as burrs, and the process by which they are removed is known as deburring.
**DEBURRING APPLICATION SCENARIO**

**A4BLUE RESULTS**

**MOTIVATION:**
- Collaborative work

**START PROCESS**
- OPEN DOCUMENTATION
- STEP 1 DEBURRING DRILLS

8 min

3 min

**STEP 2** DEBURRING SHARP-EDGES

10 min

**STEP 3** REMOVING MARKS FROM MACHINING.

60 min

**STEP 4** SMOOTHING AND HOMOGENIZING SURFACES

30 min

**STEP 5** SMOOTHING SOME SURFACES

20 min

**AIR BLOWING**

2 min

**COVER PARTS**

20 min

**END OF PROCESS**

5 min

**138 min**

**100 min**

reduction of manual work
HUMAN-ROBOT COLLABORATIVE DEBURRING OF A TITANIUM EARTH END

https://vimeo.com/334929783
DEBURING APPLICATION SCENARIO
A4BLUE RESULTS

• BENEFITS

  ▪ Improves ergonomic and safety conditions of operators → less exhausting part, avoid breathing metal chips
  ▪ Increases productivity, as operators can use this time in a more effective way → 100 min reduction of manual work
  ▪ Less training needed → level of expertise required is less demanding by reducing dependence on manual work
  ▪ Quality has been maintained at the same good level
  ▪ It adapts to the operators different profiles
  ▪ Flexibility as new parts can be programmed to be deburred by the robot

• Deburring robot is fully implemented in serial production
• 4 male participants completed the usability, and mental workload surveys.

Good/central usability scores

Central Mental Workload: neither overloading nor under-loading
## DEBURRING APPLICATION SCENARIO

### SATISFACTION ASSESSMENT

<table>
<thead>
<tr>
<th>Major Component</th>
<th>Individual Statement</th>
<th>Averaged Scores</th>
<th>Summed Scores</th>
<th>Total Trust Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robots motion and pick-up speed</td>
<td>The way the robot moved made me uncomfortable</td>
<td>4 (0.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The speed at which the gripper picked up and released the components made me uneasy</td>
<td>4.3 (0.5)</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>Safe co-operation</td>
<td>I felt safe interacting with the robot</td>
<td>3.8 (1.5)</td>
<td>15.4</td>
<td>39.8</td>
</tr>
<tr>
<td></td>
<td>The size of the robot did not intimidate me</td>
<td>4.3 (0.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I was comfortable the robot would not hurt me</td>
<td>4.5 (0.58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I trusted that the robot was safe to cooperate with</td>
<td>2.8 (2.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robot and gripper reliability</td>
<td>I felt I could rely on the robot to do what it was supposed to do</td>
<td>3.8 (0.96)</td>
<td></td>
<td>16.1</td>
</tr>
<tr>
<td></td>
<td>I knew the gripper would not drop the components</td>
<td>4 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The robot gripper did not look reliable</td>
<td>4 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The gripper seemed like it could be trusted</td>
<td>4.3 (0.5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Good trust levels (25 to 50).
- Item: “I trusted that the robot was safe to cooperate with” low score, concerning and requires addressing.
**Airbus use case scenario: Overview**

**Scenario:** Towards a more optimized hydraulic system assembly on the A350 Over Wing Panel comprising various sets of operations including a lot of different parts to be installed in constraint positions through Automation and Virtual/Augmented Reality.

<table>
<thead>
<tr>
<th>Actors</th>
<th>α</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly operator</td>
<td>Automation Mechanisms</td>
<td>Smart torque wrench</td>
</tr>
<tr>
<td>Quality supervisor</td>
<td>Interaction devices</td>
<td>Hololens, Smartphone, PC</td>
</tr>
<tr>
<td>Metrology supervisor</td>
<td>Interaction devices</td>
<td>Hololens, PC</td>
</tr>
</tbody>
</table>

**Main motivation:**

1. To evaluate and measure the impact of an adapted AR HMI in term of performance and error rate on the assembly execution for different skilled groups of people.
2. Enable real-time monitoring and synchronize automatically information among different types of resources (H2M, H2H, M2M, M2H).
3. Enable Full Quality Assurance approach and Operators performance thanks to traceability.
From the training .... to the production assembly

... to the quality inspection

https://vimeo.com/337518814
Trials set up

Protocol in two parts done with 7 operators:

**Mockup training**
- Brief explanation and consent
- Explanation of the smartool use
- Explanation of the hololens gestures
- Brief on mockup purpose for learning A4BLUE tooling and pipe assembly as a success criteria
- Mockup trial & survey

**Over Wing Panel assembly**
- Over Wing Panel trial explanation (Qcode, calibration, ...) emphasize on tool and holo connection
- Assembly of, at least, one union of a pipe
- Survey on OWP trial

1 A350 MSN3 Test Aircraft booking
1 lift Toucan licence & booking
7 Operators slot (2h)
Intervention card signed for each day of trial
A4BLUE IT platform set up:
3 laptops, 1 WiFi app, 4 hololens (1 broken)
2 torque wrenches, 2 smartphones, 1 mockup and ~1 kilometer of miscellaneous cables 😊
Operator training, assembly and administrative tasks

**TRAINING**
- Alpha mockup used
- Train on the smartool’use
- Learn the hololens gestures

**OWP ASSEMBLY**
- Automatic synchronization
- Support to feed the Operator’s report

**ADMINISTRATIVE TASKS**
- Real-time monitoring
- Full Quality Assurance and traceability

User
Tool
Job
Some words from operators during the trials

« It is exactly that ! »
Speaking about the torque value set to the torque wrench

« It is great to participate to these trials, it changes from our daily life and it will come to us in a future ! »
Waiting in the elevator when job order was downloaded

« Excellent ! »
When the torque wrench was automatically set to the release point

« Fun & Cool »
Enjoying the use of the smartool and the holo for the mockup and on OWP

« No don’t worry, it's worth spending time waiting, it's really interesting these new technologies, it will improve a lot things even if it is still research but it's good that it comes here
After one hour of technical troubles with network connection, IT troubles, ...
Heartbeat of the SmartTool DynaSam 4.0 from the Airbus metrology bench

10 measurements at 84 Nm

——— : authorized tolerancy on the Aircraft

Use case 1: measure the deviation on a tool to a dedicated torque value in time

Use case 2: detect & alert & block the tool in case of malfunction, test done on fall down detection.
## Airbus use case scenario: Challenges summary success

<table>
<thead>
<tr>
<th>Challenge</th>
<th>A4BLUE Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1.1 - Adapted on the job guidance</td>
<td>Human, process &amp; context variability</td>
</tr>
<tr>
<td>CH1.2 - Adaptation of the tools involved in the assembly process</td>
<td>Process variability</td>
</tr>
<tr>
<td>CH1.3. Decision support</td>
<td>Process variability</td>
</tr>
</tbody>
</table>

+ (2 more regarding metrology)
HÉROUX-DEVTEK AR SCENARIO

• RETRACTION ACTUATOR GUIDED ASSEMBLY USING AR

• MOTIVATION:
  • Reduce the amount of time spent by the operator looking for information
  • Reduce training times
  • Easy way to share tips between workers: Lessons learnt data base
  • Increase confidence, participation, and internal communication among the personnel of the organization
  • Avoid quality scapes
In both business cases good usability scores with a poor comfort scores for both
In Airbus, Mock-up has better usability than the OWP results.
Despite their differences in their jobs & companies, operators’ scores follow the same trends.

Low mental workload scores with high performance scores indicates a level of under-loading potentially due to familiarity with the task.
Airbus & HÉROUX-DEVTEK Share Benefits on A4BLUE

- Easy and **friendly interface** → helpful assembly animations and clear instructions
- **Adaptable** to different experience profiles
- **Training** → extra guidance for less experience workers
- Increases **traceability** → everything can be recorded, reported, including final signature of the tasks

### Improve productivity → reduce time used by the operator to look for information
- Only show information needed by the operator as each precise moment

### Easy way for the operators to share tips and comments

### Automatic synchronization with the torque wrench

### Real-time monitoring
THANK YOU

Laure.parigot@airbus.com
MARIA.OTERO@herouxdevtek.com