



Evaluation methodologies of two use case services: Exoskeleton Service and Workplace Optimization Service

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HUMAN. Concept

HUMAN aims at developing a platform that is contextually aware of both the factory and the human operator, identifying when an intervention is required in order to support the operator in performing their tasks with the desired quality, whilst ensuring their wellbeing.

The preliminary analysis of needs yielded to five so called services:

- Exoskeleton Service
- Knowledge-in-Time Service (KIT)
- Workplace Optimization Service (WOS)
- Social Knowledge Network Service (SKN)
- Shop-floor Intelligence Service (SII)

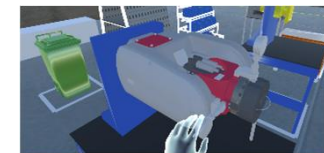
KIT Service



Exoskeleton Service



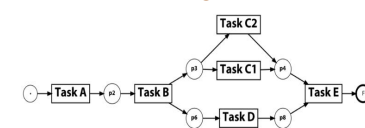
WOS



SKN

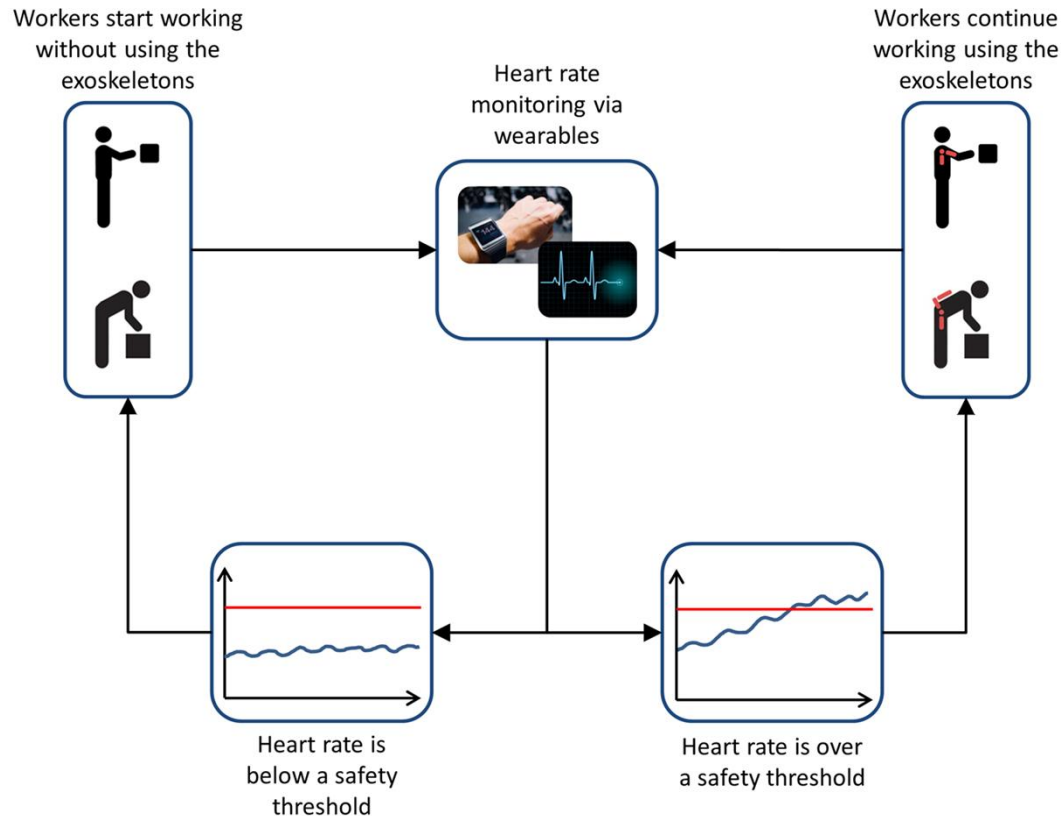


SII



These services are divided into two categories: Short Term Services and Long Term Services.

Exoskeleton. A short term service



Goal

To deliver physical assistance to the operator during repetitive/continuous tasks, providing support to the most critical joints involved in the identified working operations by means of exoskeletons

Technologies

Upper-limb and Pelvic exoskeletons
Wearables for physiological monitoring
Kafka-based and MQTT-based communication

Why?

To deal with working activities that are physically demanding

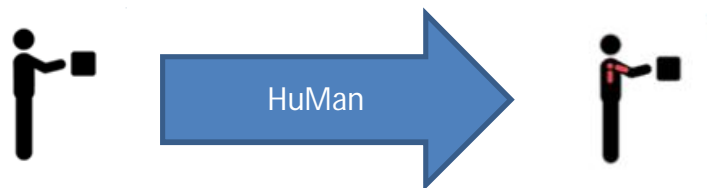
Exoskeleton. HUMAN pilots

- The Exoskeleton Service is evaluated in two different real scenarios:
 - Airbus
 - Royo



Objective: to assist the upper extremities during operations requiring the worker to keep his/her arms elevated for prolonged time per shift

The HuMan solution: upper-limb exoskeleton

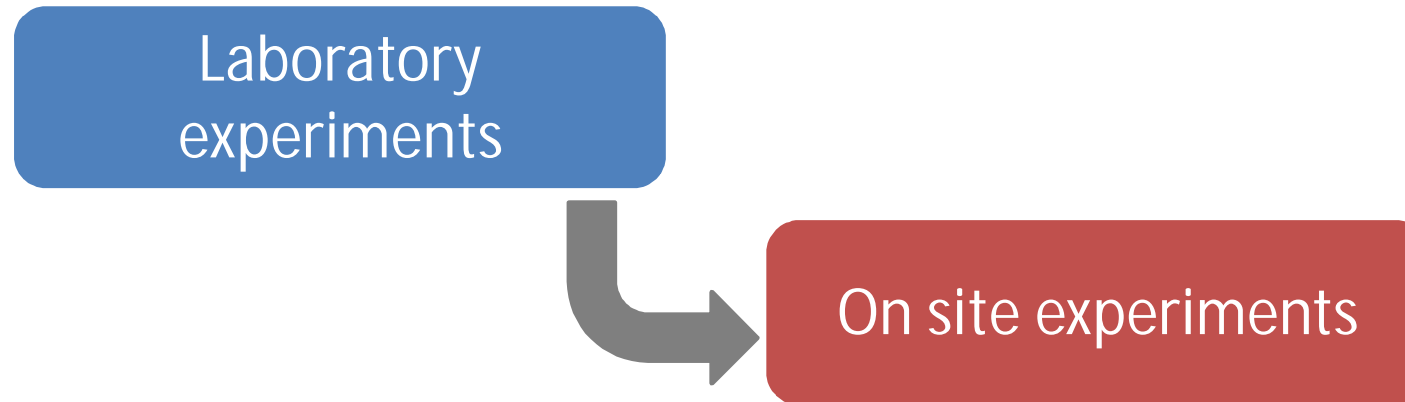


Objective: to assist the low back of operators performing lifting operations (i.e. operations concerned with the lifting and lowering of a load)

The HuMan solution: pelvic exoskeleton



Exoskeleton. Evaluation methodology



Two separate evaluations can be carried out:

- Laboratory experiments under controlled experimental conditions to test the exoskeletons
- Experimentation with real workers in a scenario closer to an ecological one (i.e. real operators performing real operation but not on the production line) to test the whole Exoskeleton Service

Exoskeleton. Laboratory assessments

- Before testing and evaluating the Exoskeleton Service laboratory experiments are necessary to assess the effectiveness of the robotic devices
 - e.g. by measuring the electromyography in different experimental conditions, such as wearing and not wearing the exoskeletons
- Laboratory experiments are currently ongoing to test both the upper-limb and the pelvic exoskeletons
 - results are not published yet and they are still confidential

Exoskeleton. Preliminary tests with real workers

- Preliminary test have been carried out in Airbus (Seville, Spain)



Workers without using the exoskeleton

Upper-limb-Exoskeleton Service

- Aimed at supporting operators who need physical support to perform physically demanding jobs
- Exoskeleton to physically support the worker's arms, which are elevated for long time periods
- Physiological and kinematics data fed to the Short-Term Reasoning Engine
- Change of the assistance level suggested by the Intervention Manager
- Communication between the exoskeleton and HuMan established through MQTT
- Kafka-based software to connect the physical device and the rest of the HuMan system

Workers using the exoskeleton



Exoskeleton. Evaluation questionnaires

- Questionnaires are administered to evaluate the subjective perception both the exoskeletons and the Exoskeleton Service as a whole
 - Standard questionnaires to evaluate the perceived effort (e.g. Borg scale), task load (e.g. NASA test) and usability of the system (e.g. SUS), comparing the results between a condition where the worker is using the exoskeleton with a condition where the exoskeleton is not used
 - ad-hoc designed questionnaires to evaluate the Exoskeleton Service and its module from a merely technical point of view
 - § This evaluation is useful in the developmement phase

WOS. A long term service

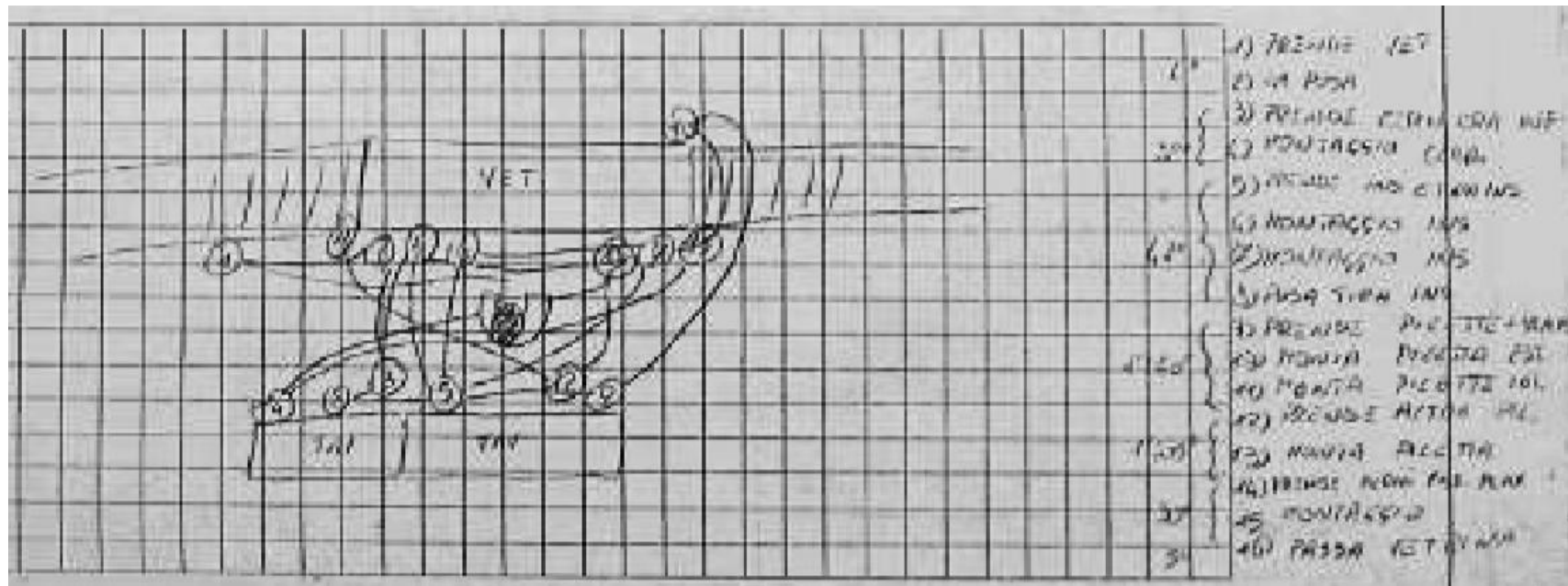
Workplace Optimization Service (WOS)

- à a long term intervention is needed to improve the workplace
- à decision support tool for workplace improvement in human centred way
- à provides the tools to access and redesign a workplace
- à improves the well being of the operators
- à collaboration between different actors
- à utilizes Virtual Reality and Augmented Reality

WOS. Enhanced Spaghetti Diagram

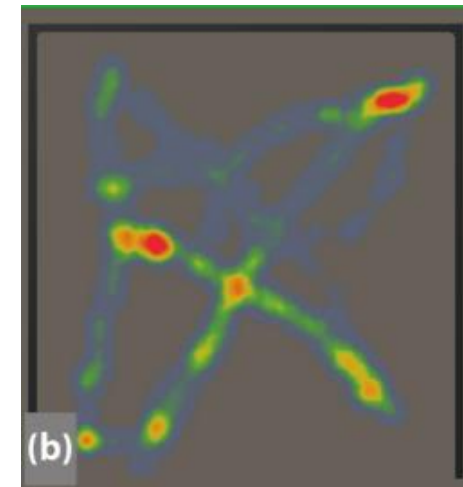
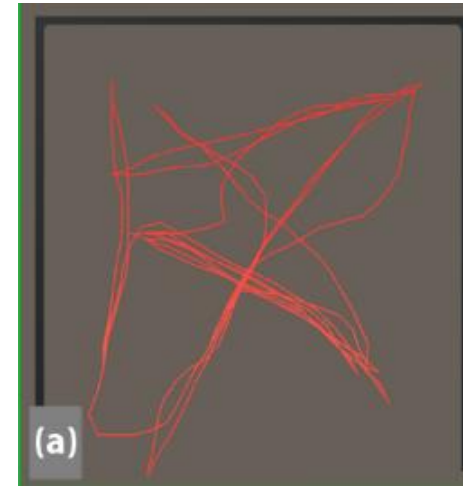
Spaghetti Charts or Spaghetti Diagrams: Simple but efficient lean tool for optimizing handling of materials and movement of workers.

Up until now performed by following operator around, using pen and paper!



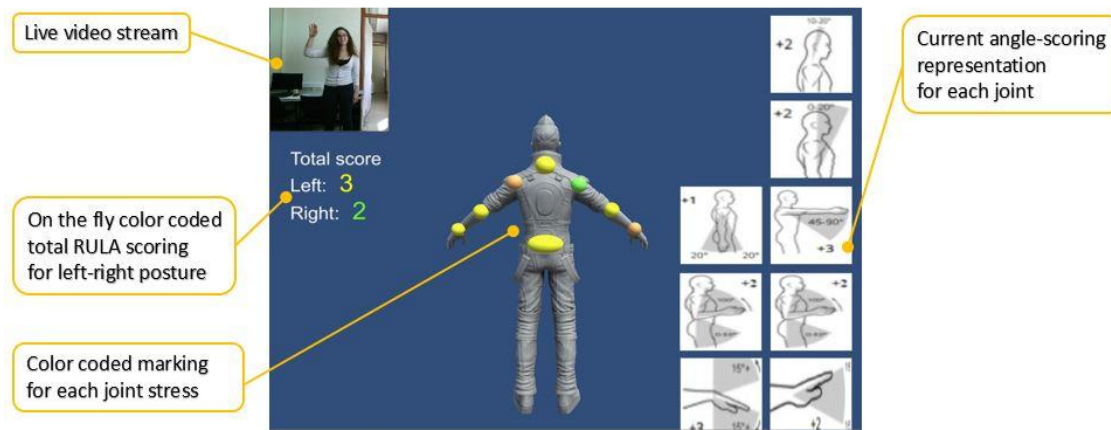
WOS. Enhanced Spaghetti Diagram

- Automatic generation of the Spaghetti Diagram (tracking of the user's movements)
- Heatmap feature to extract time information and detect bottlenecks & time waste



WOS. Ergonomics Assessment

Rapid Upper Limb Assessment -online scoring



- Sensors track operator's body -joint data
- Real time estimation of score for the current posture
- 1 x Kinect for Windows v2

Action level 1

A score of 1 or 2 indicates that posture is acceptable if it is not maintained or repeated for long periods.

Action level 2

A score of 3 or 4 indicates that further investigation is needed and changes may be required.

Action level 3

A score of 5 or 6 indicates that investigation and changes are required soon.

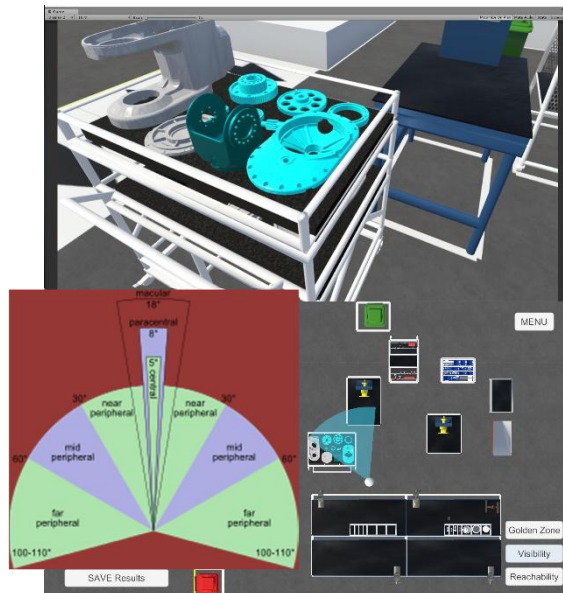
Action level 4

A score of 7+ indicates that investigation and changes are required immediately.

WOS. Visibility - Reachability - Golden Zone

Visibility Assessment

- Near and mid peripheral view
- Highlight visible elements in the immersive environment and the Engineer UI



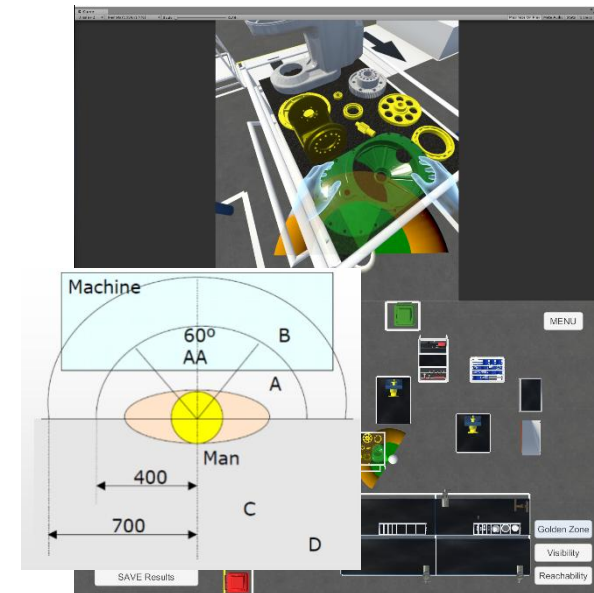
Reachability Assessment

- 50th percentile of American males
- Highlight grabbable elements in the immersive environment and the Engineer UI



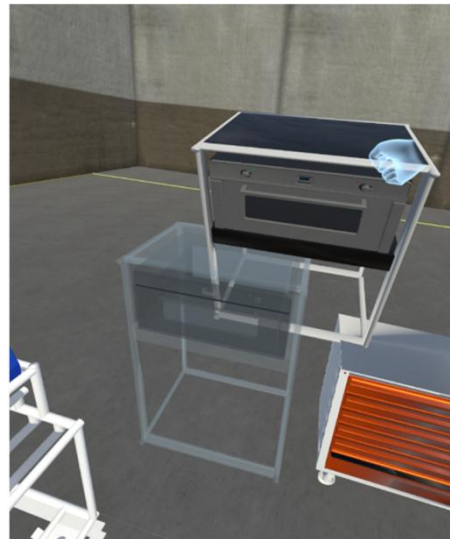
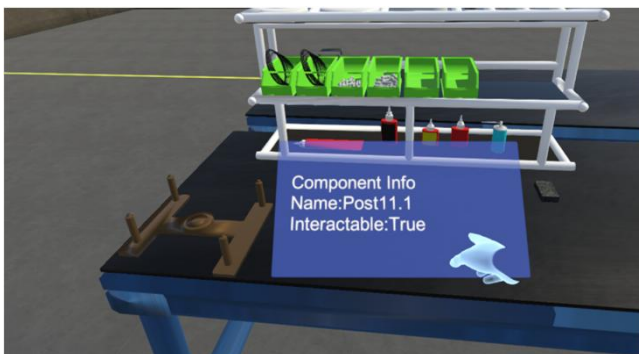
Golden Zone

- To eliminate waste all activities have to remain inside the GZ
- Highlight GZ in the immersive environment and the Engineer UI



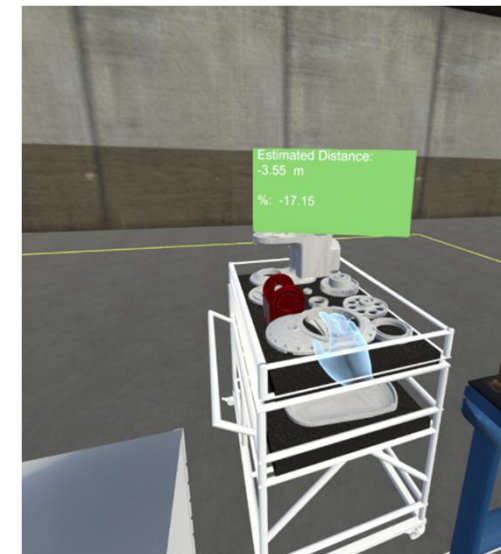
WOS. Layout Redesign

- Pop up information notifications of layout elements
- Information retrieved by the HUMAN system



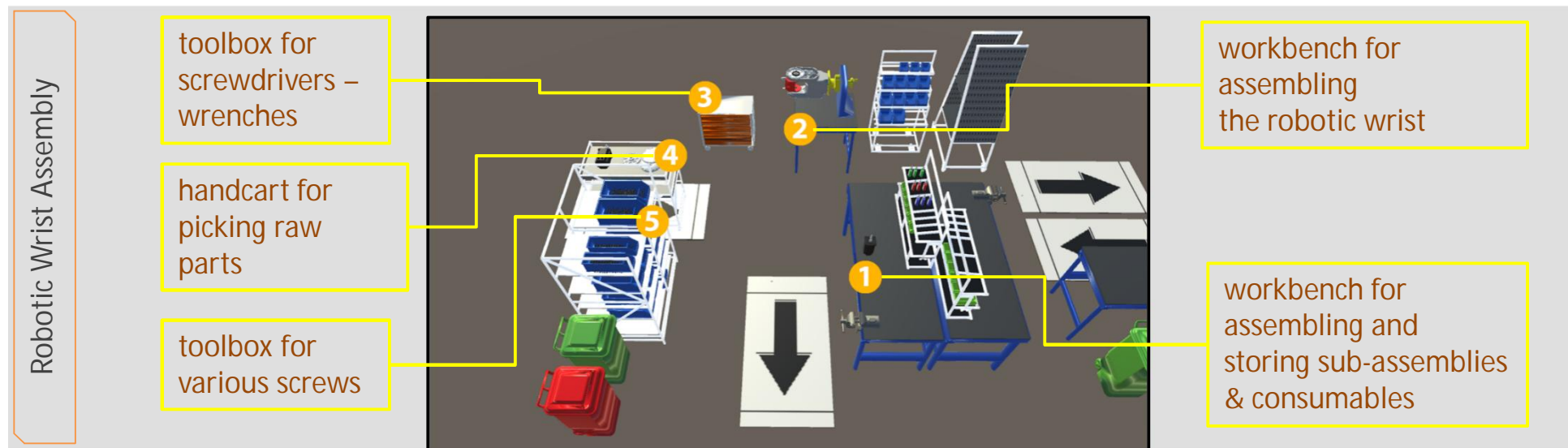
- Modification of the layout from the immersive environment
- Shadow casting when moving a 3D element

- Real time estimation of the impact of the rearrangement workplace
- Use of A* path finding algorithm for distance estimation

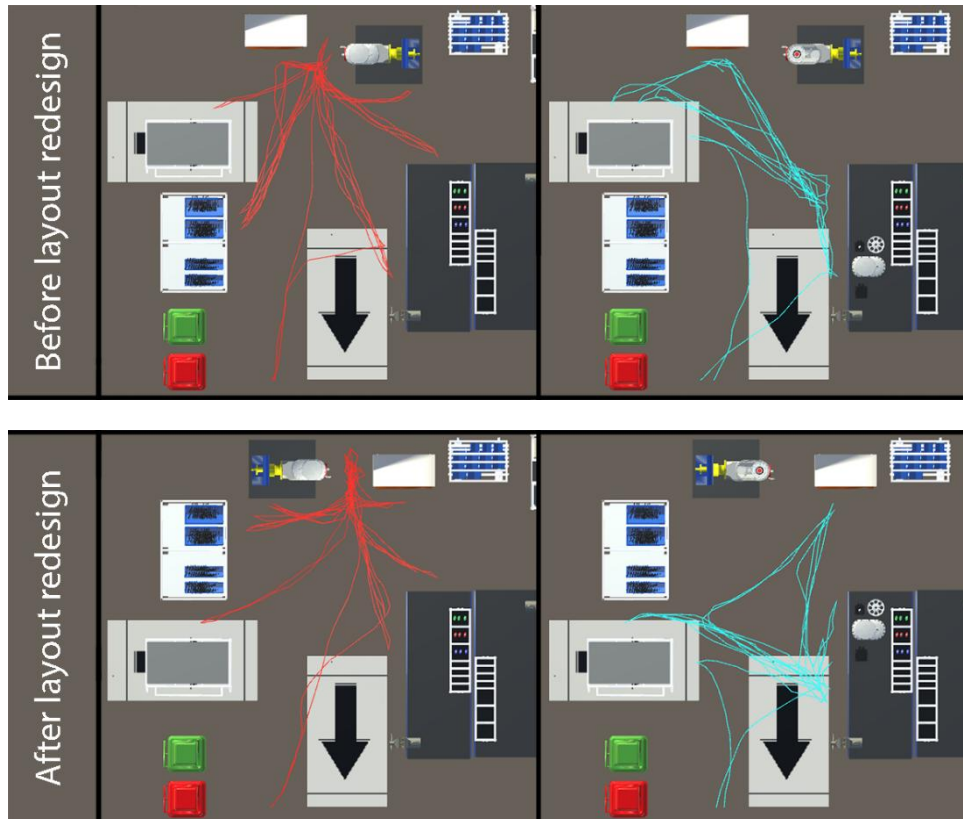


WOS. Reference use case

The Workplace Optimization Service is evaluated in the COMAU use case.



WOS. In house preliminary testing



	Simulation Time	Walked distance
Before layout redesign	7min 42 sec	122m
After layout redesign	7min 13sec	98m

— Worker 1
— Worker 2

WOS. Preliminary tests with real workers

- Preliminary tests have been carried out in COMAU (Turin, Italy)
- The current version of WOS was tested to receive feedback from workers and engineers
- 5 workers and 5 workplace engineers participated in the tests
- Verbal feedback received from the participants, in form of “interviews”
- Questionnaires filled in by the participants
- 2 different questionnaires were used; one for the workers and one for the engineers
- The received feedback will drive the enhancements related to the current version of the tool, in order to improve the acceptance of the users

WOS. Evaluation questionnaires

Worker's questionnaire

1. How long have you been working on this assembly station?
2. What, if any, of these Virtual Reality devices have you heard of?
3. Have you used Virtual Reality equipment before?
4. How easy did you get familiar with the virtual environment – interactions?
5. How realistic did you find the visualization of the Virtual Environment compared to the actual one?
6. How realistic did you find the user interactions with the Virtual Environment?
7. How realistic did you find the assembly procedure using this software?
8. How satisfied are you with this software's ease of use?
9. How satisfied are you with the look and feel of this software?
10. Did you faced any kind of discomfort during the testing session?

WOS. Evaluation questionnaires

Engineer's questionnaire

1. How long have you been working as a workplace engineer?
2. How satisfied are you with this software's ease of use?
3. How satisfied are you with the look and feel of this software?
4. Would you change anything related to the graphical user interface of this software?
5. How satisfied are you with the ability to collaborate with other users on this software?
6. How satisfied are you with the current number of supported assessments?
7. How satisfied are you with the current implementation of the supported assessments?
8. Would you add any kind of new assessments?
9. How possible would it be to use this service instead of the current procedures?

WOS. Evaluation questionnaires

- Questionnaires are administered to evaluate the subjective perception of the workers and the engineers.
 - Standard questionnaires related to the:
 - § Previous experience with this kind of technology
 - § Look and feel of the software
 - § Implementation of the supported assessments
 - § Usability of the developed tool – ease of use
 - § Added value of the developed tool
- A summarized evaluation will be conducted over the following months

Thank you!



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