LMS
Laboratory for Manufacturing Systems & Automation

MARI4YARD
MARI4ALLIANCE

Training on High-payload robots in shared space with humans

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LMS - Laboratory for Manufacturing Systems and Automation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006798

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LMS Introduction

The Laboratory for Manufacturing Systems & Automation (LMS) is oriented on research and development in cutting edge scientific and technological fields. LMS is involved in a number of research projects funded by the CEU and European industrial partners. Particular emphasis is given to the co-operation with the European industry as well as with a number of "hi-tech" firms. LMS employs approximately 120 researchers.

LMS

Laboratory for Manufacturing Systems & Automation

LMS is organized in Three Different Groups

- Manufacturing Processes
- Manufacturing Systems
- Manufacturing Automation, Robots & Virtual Reality Applications

Manufacturing Automation, Robots & Virtual Reality Applications

- Collaborative Robots in MFG Environments
- Human-Robot Collaboration in MFG
- Process Control & Automation
- Virtual Prototyping
- Digital Human Simulation
- Process Simulation
- Virtual Collaborative Environments

For More Information:

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Publication of more than 600 Scientific articles

Organization of more than 12 International conferences.

Participation in more than 200 R&D Projects

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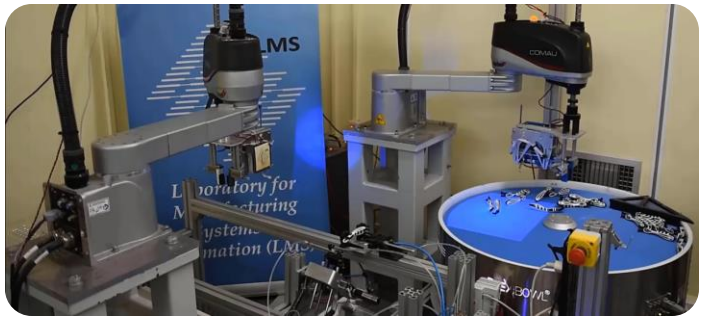
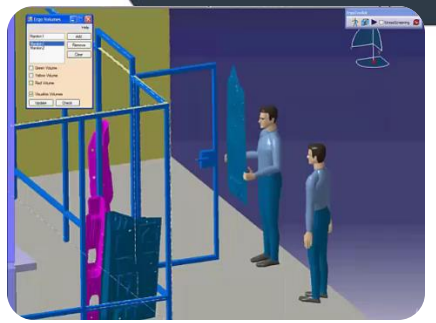
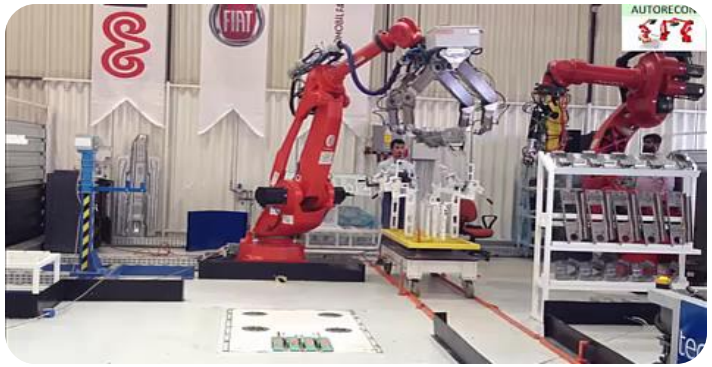
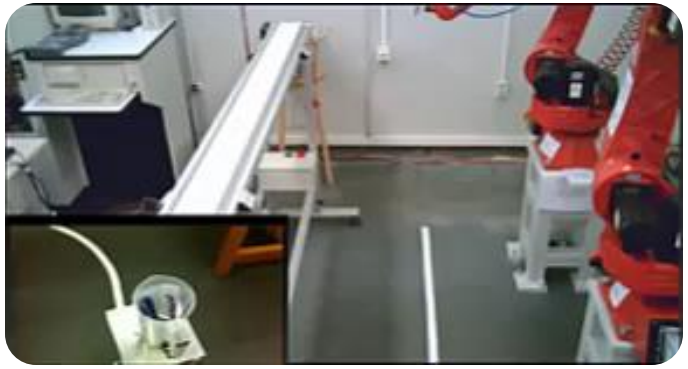
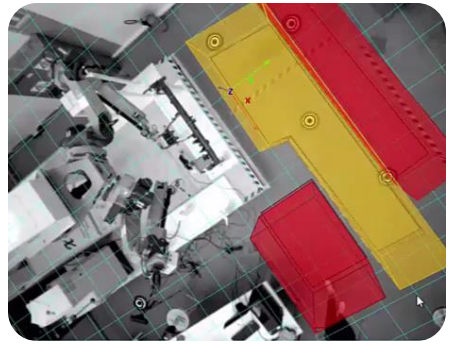
LMS Introduction

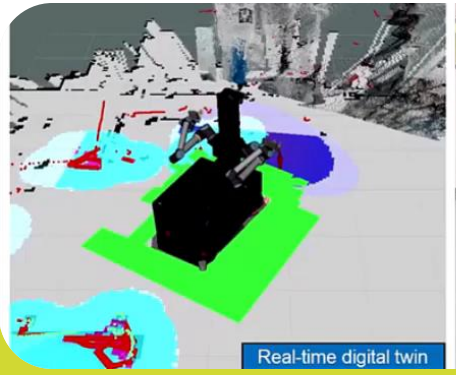












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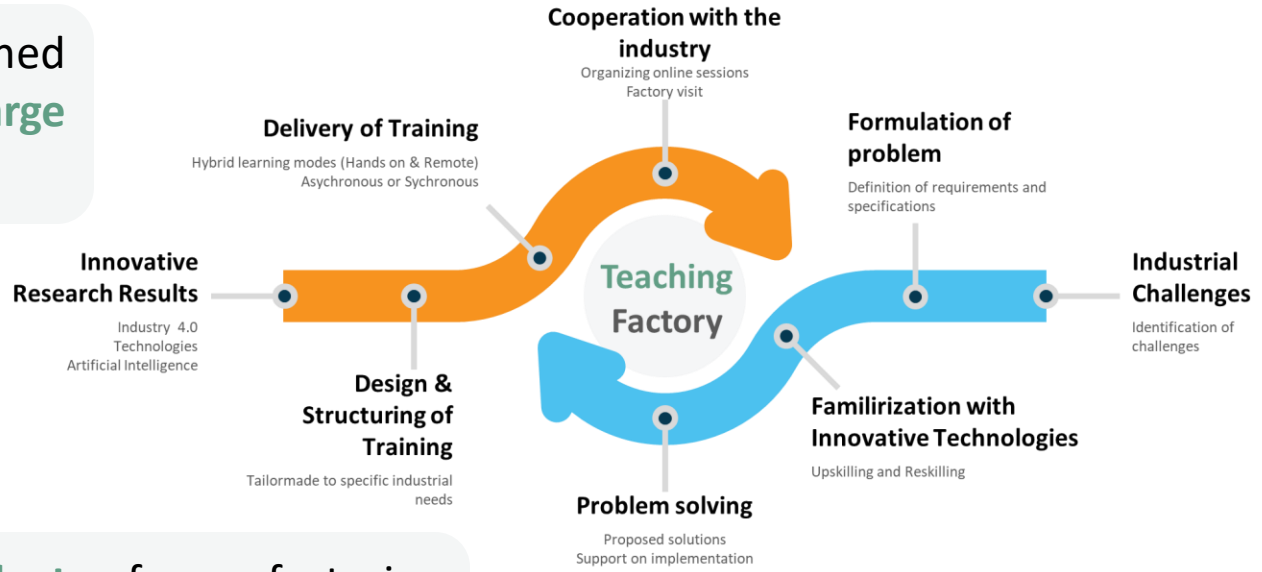
Teaching Factory Competence Center

The Teaching Factory Competence Center has been established through the collaboration of the **LMS** and **a number of large industrial companies and SMEs** established in Greece.



Mission

Create added value for the services and products of manufacturing companies, **through innovative technologies and research activities** performed by academia.

Goals

- **Enable the knowledge sharing** among the academia and the national industry.
- **Integrate innovative Industry 4.0 technologies in manufacturing.**
- **Exploit Research Results** towards **Industrial Applicability in pilots**.

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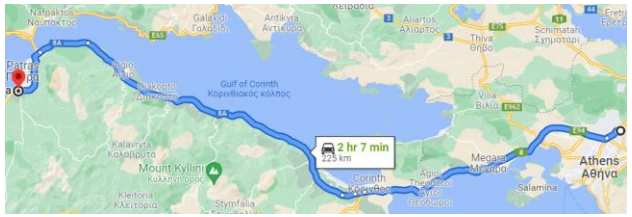
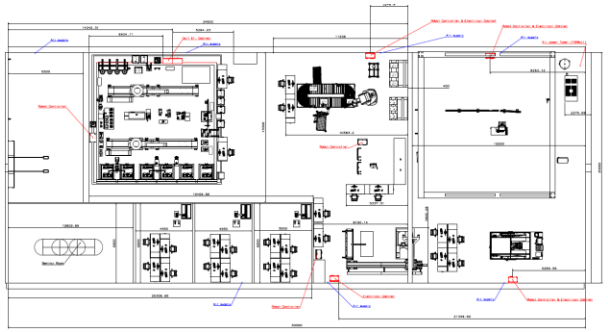
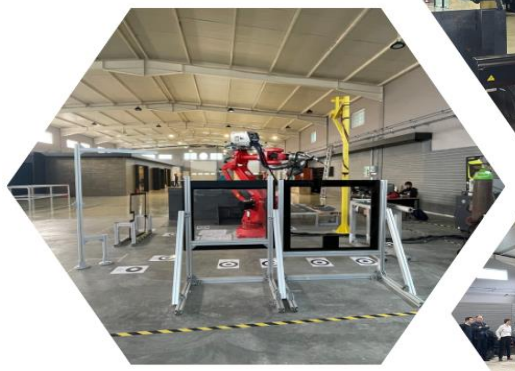
Teaching Factory Competence Center







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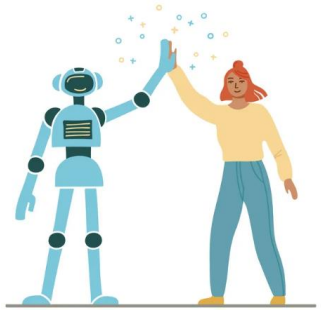
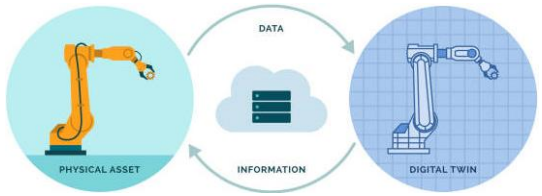
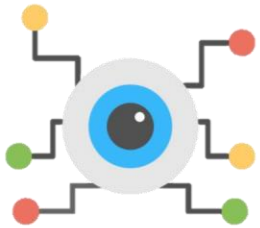
Scope of training

- **Familiarize** trainees with **High Payload Robots** and **Human Robot Collaboration** (HRC) concepts
- **Safety systems** integration for safe HRC
- **Digital twin** technology for autonomous robot motions and task executions
- **Human – Robot interaction**
  - using Force/Torque sensors (FT sensors)
  - using AR for advanced robot programming
- Vision based **process perception** for bin picking operations







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Challenges in shipbuilding, ship maintenance, repair and conversion (SMRC) industry

Challenges in Shipbuilding, repair and conversion

- **High customization**, lack of 3D-CAD models
- Confined spaces, lower productivity and health risks
- Manual welding resource intensiveness (**energy, materials, waste**)

- **Full automation not ideal** (space requirements and external conditions)
- **Manual** labor (human cognition and skills) cannot be replaced
- Transport of **heavy parts** causes **ergonomic concern**
- **Repeatable movements**
- Waste of resources (**multiple operators**)
- **Dangerous** environment and **condition**

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Human Robot Collaboration (HRC)

- **Human-robot collaboration (HRC)** aims to realize **an environment** where **humans can work side by side with robots in close proximity**. Humans and the robots share the **same workspace**, the **same resources**, and in some cases the **same tasks**.
- Using HRC, **higher overall productivity** and better product quality can be achieved.

Robots offer:

- High precision
- High repeatability
- High speed

+

Humans offer:

- High dexterity
- High flexibility
- Experience

=

Combination of advantages of robots and human operators

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Challenges in HRC

- Ensuring **Safety** without compromising productivity and quality
- **Human acceptance** and trust to robots
- Ensuring compliance with the **strict legislation**
- Ensuring effective and **intuitive** communication and **interaction**
- **Technology limitations** (systems employed may be working properly but are not suitable for long term/uninterrupted continuous operations)

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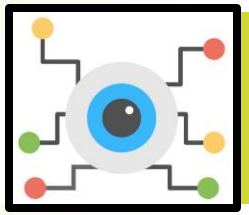
HRC Key Technology Enablers

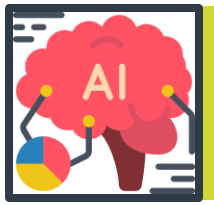
Augmented Reality and Virtual Reality

(Robot teaching, Operator support, Operator training, HRC cell validation and protype testing)



Machine/Computer vision

(Object/human detection and tracking, 3D pose estimation, 2D/3D mappings for autonomous navigation)

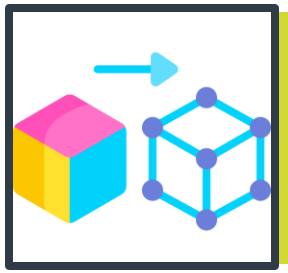


Artificial intelligence and advanced control

(Intention prediction , Anomaly detection, Predictive control, Reinforcement learning, Task/Actions planning)

Sensors and Perception Systems

(Force and Torque Sensors, RGB-D sensors for image and spatial data capturing, accelerometers, gyroscopes proximity sensors, Multi-modal sensing and data fusion)



Simulation and Digital Twins

(Pre-Deployment Testing (Virtual testing), Real-time Monitoring, Optimization of Human-Robot Interaction, synthetic datasets , virtual training, Autonomous behavior

Safety

(Design safety, Workspace monitoring, Safety sensors and configuration, Safety control logic, ISO directives)

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Approach to solution

A portfolio of tools designed for non-expert users:

- High Payload Robots with collaborative functions
- Tool-oriented solutions for non-expert users (each tool can be either stand alone or coexist along with other tools)
- Modular architecture (easily applicable to different systems, adjustable different scenarios etc,)
- Human - centric design (human safety, ergonomic approach, user friendly interfaces etc.)

Challenge	Approach
Fully automated solutions not feasible	Inclusion of human factor, HRC is needed
One-off parts – not expert operators	Easy-to-use, seamless tools
High flexibility/ Low repeatability	Cost-effective automated and manual tools, applied based on the use case needs
Lack of CADs and documentation	General flexible architecture and dynamic robot programming

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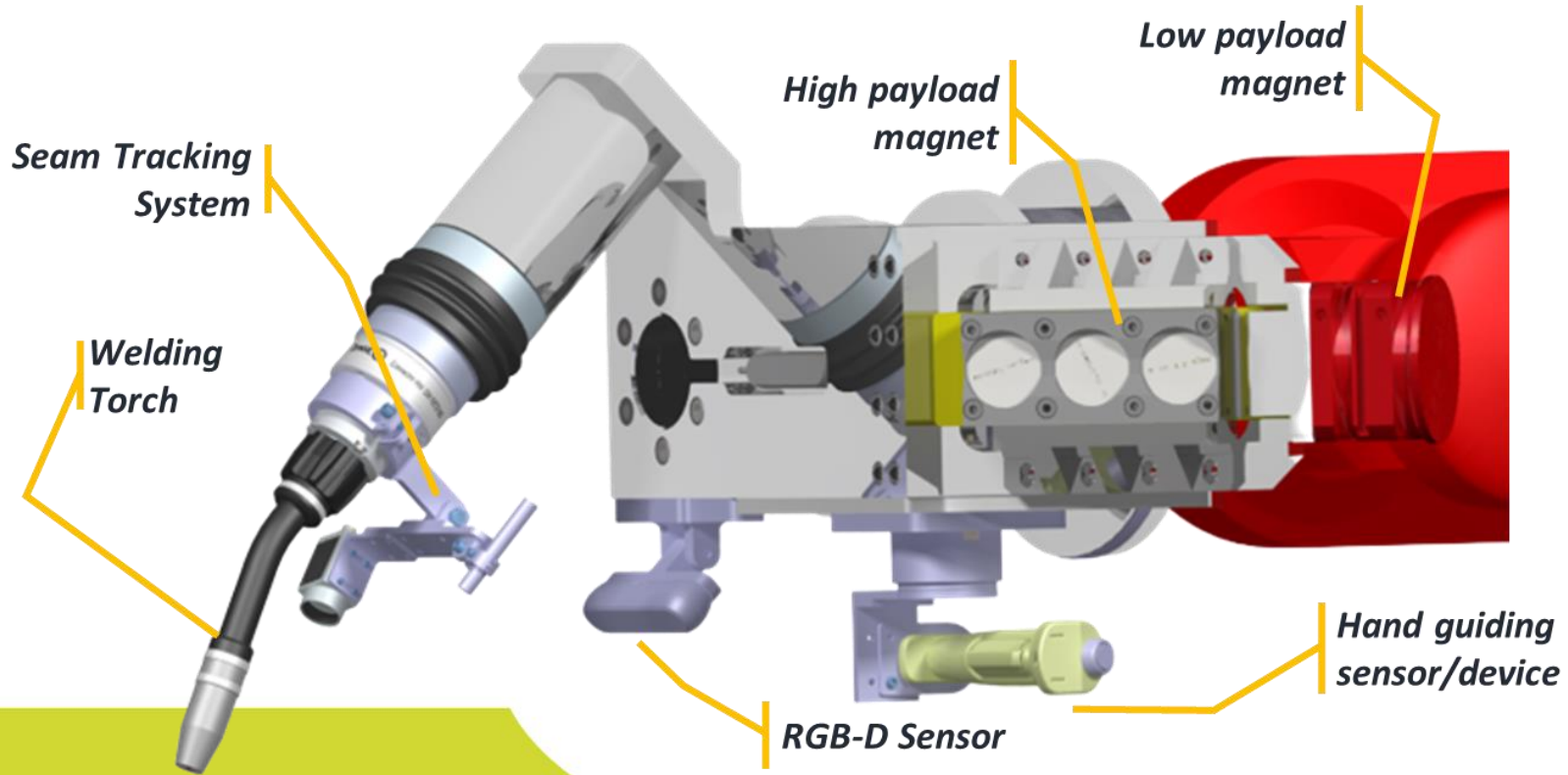
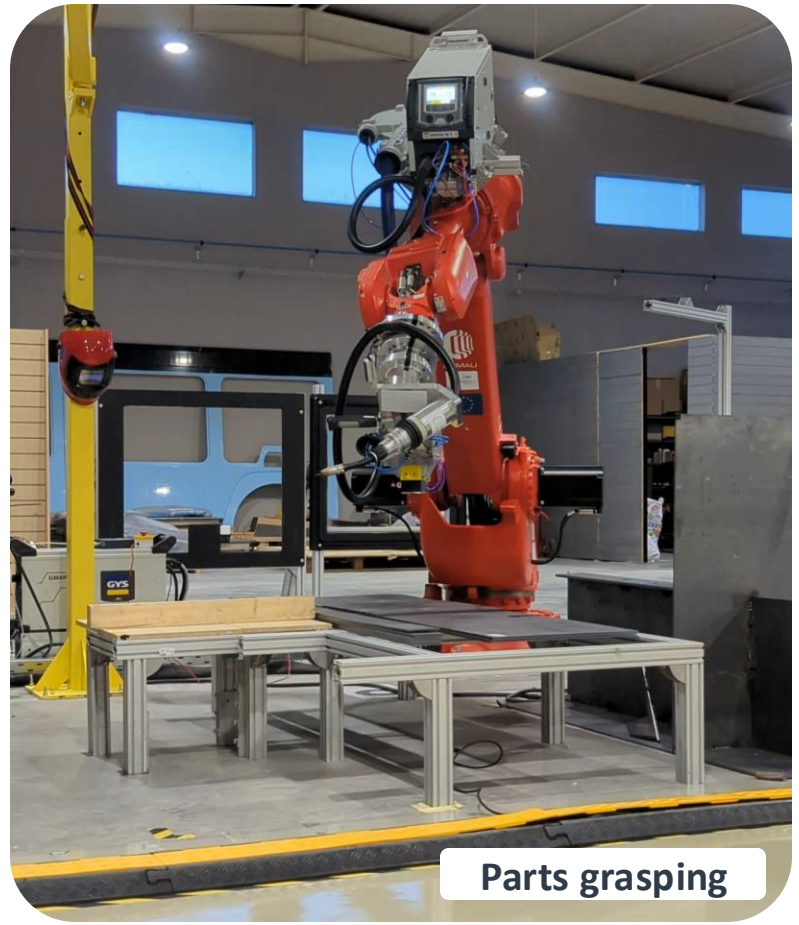
Key Technologies and Applications studied in Mari4_YARD

High Payload Robot for shared workspace

- Manipulation of heavy parts – workpiece holding device
- Welding operations
- Robot safety dynamics adjustments based on safety system inputs





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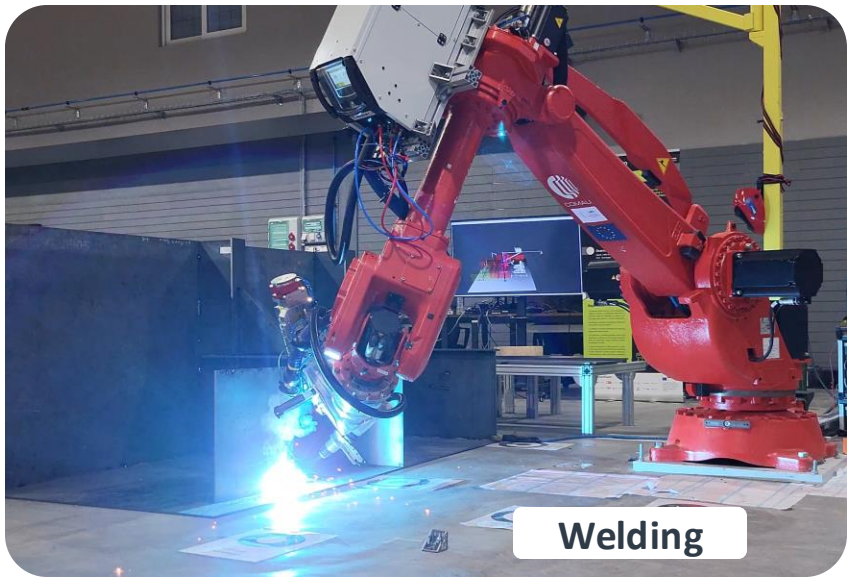
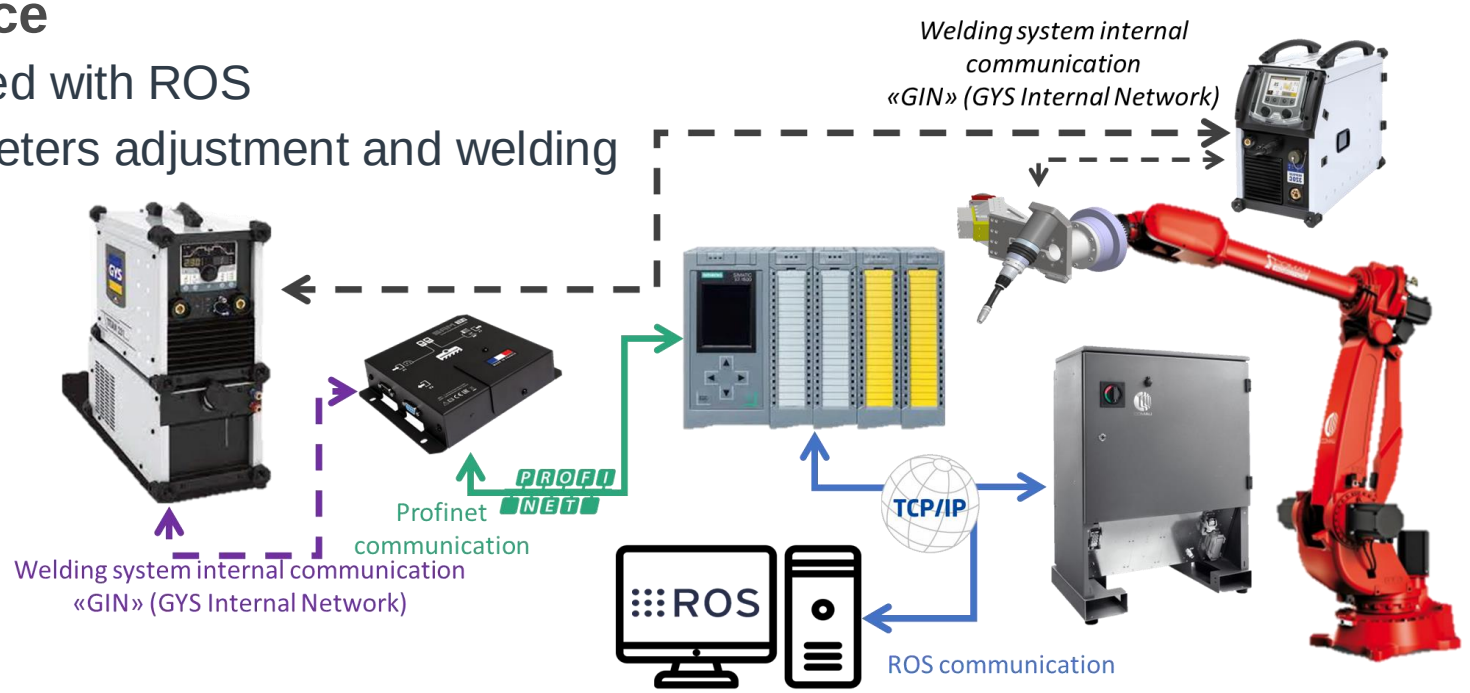
Key Technologies and Applications studied in Mari4_YARD

High Payload Robot for shared workspace

- Welding system for robot was fully integrated with ROS
- Service based approach for welding parameters adjustment and welding process triggering





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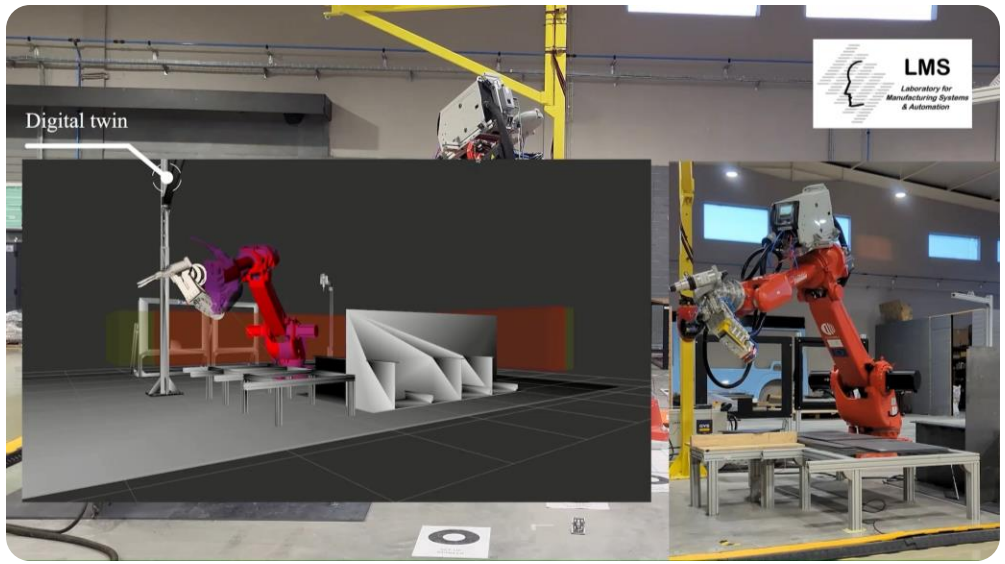
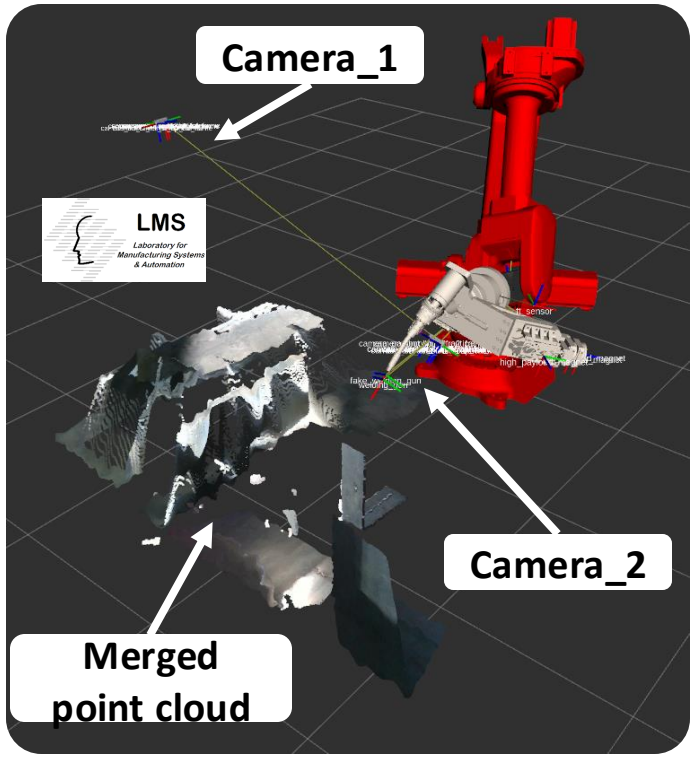
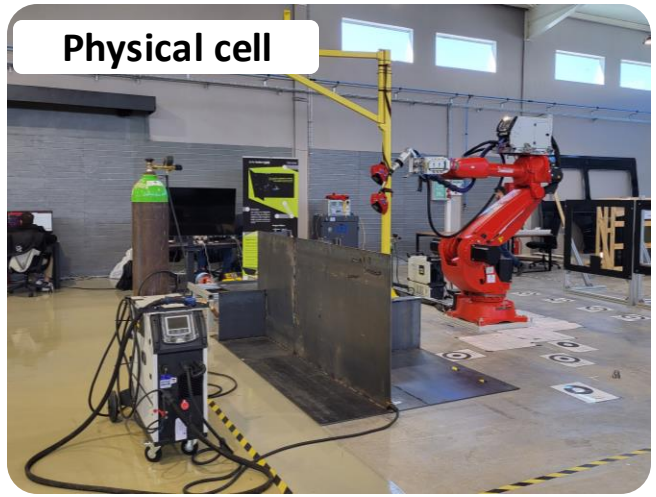
Key Technologies and Applications studied in Mari4_YARD

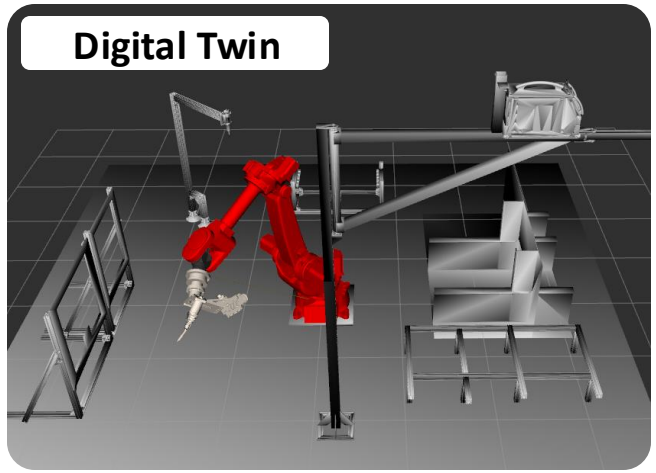
Digital Twins

- Digital Twin technology (allows autonomous and collision free path planning)
- Allows simulations prior to robot motion
- Integrated with ROS and MoveIt! motion planning library for path planning









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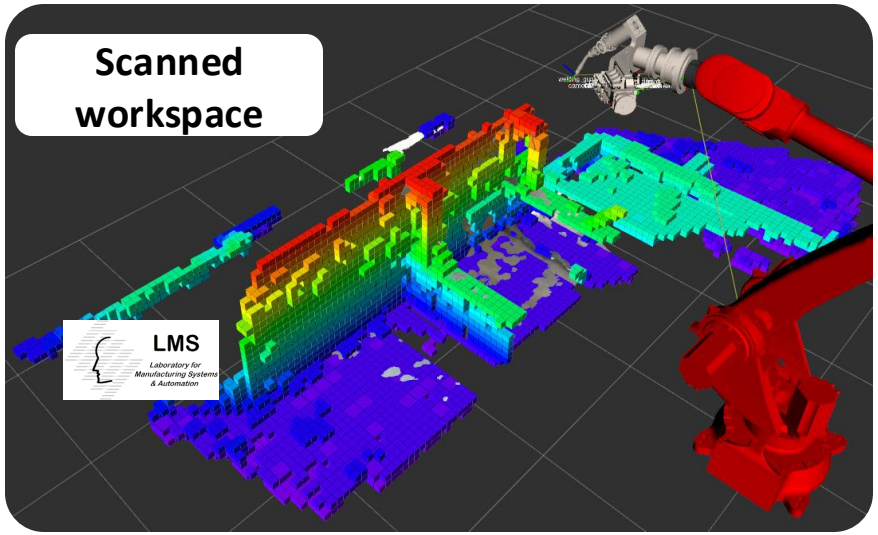
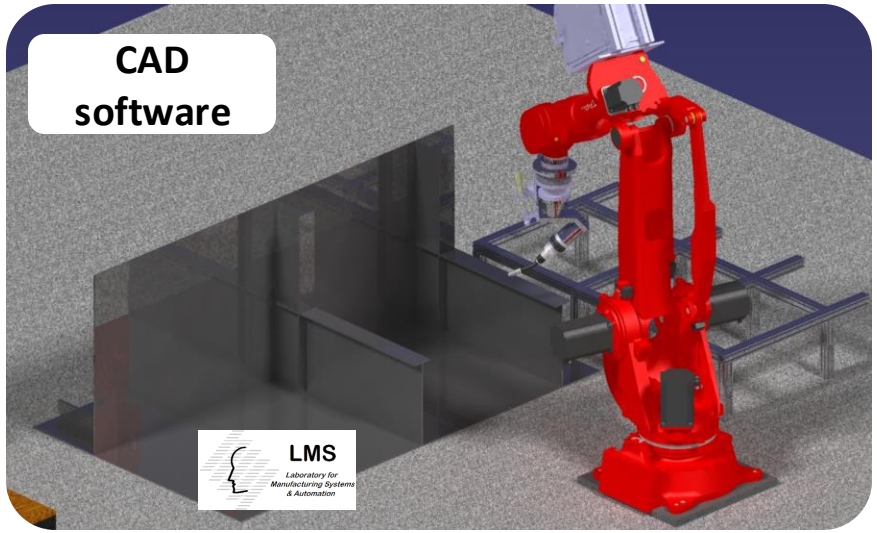
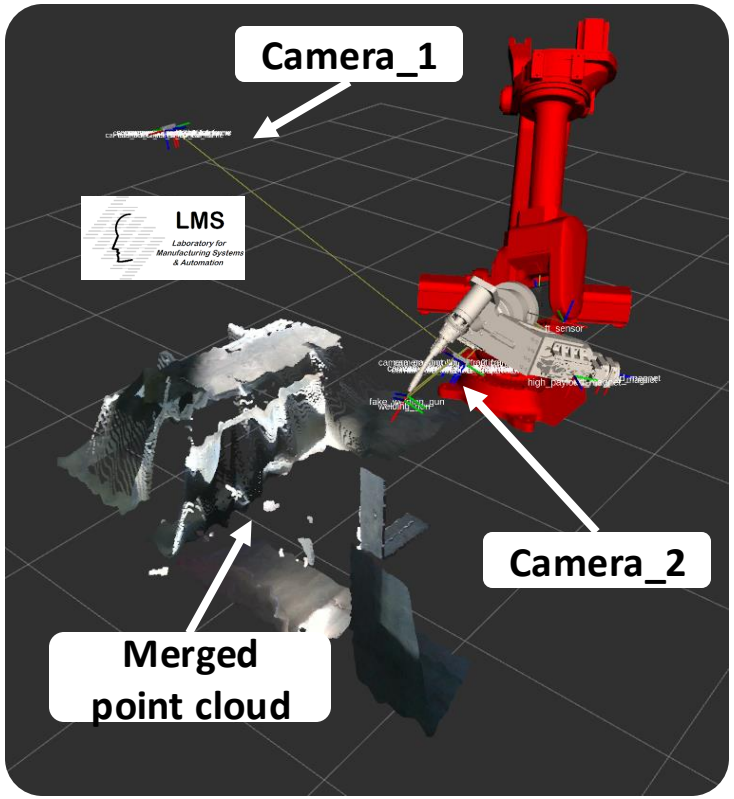
Key Technologies and Applications studied in Mari4_YARD

Digital Twins

- CAD-Free approach facilitates
- inaccuracies from thermal deformations
- self-deformations from parts weights etc.
- Reconfigurability and adaptation







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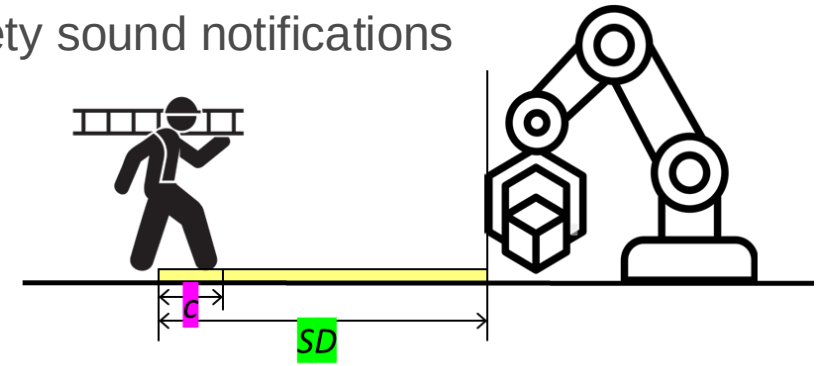
Key Technologies and Applications studied in Mari4_YARD

Workspace monitoring

- Safety directive deploy safety monitoring systems
- AR Robot trajectory, tasks, safety zones visualization
- Safety sound notifications



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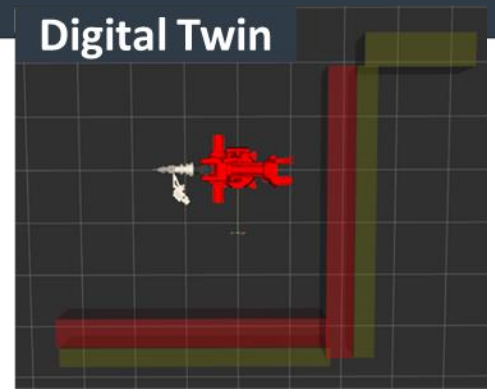

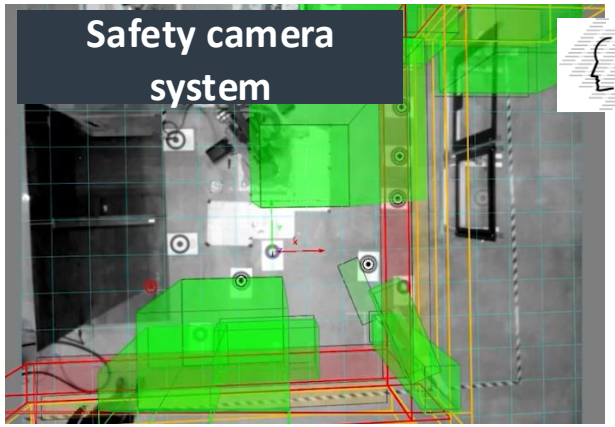

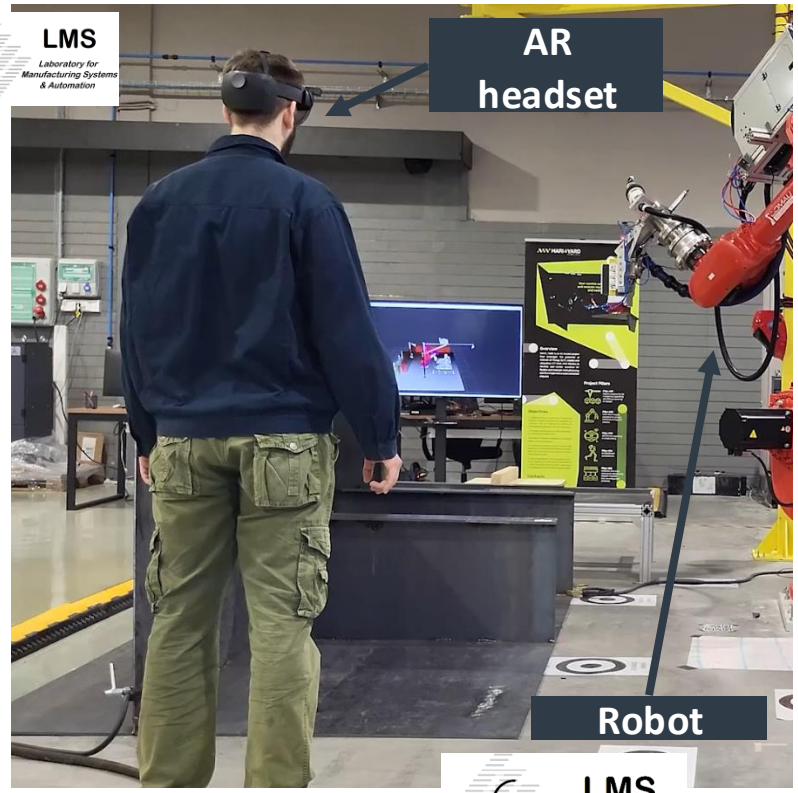

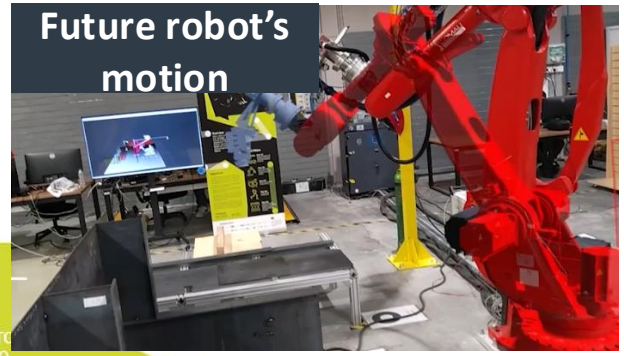

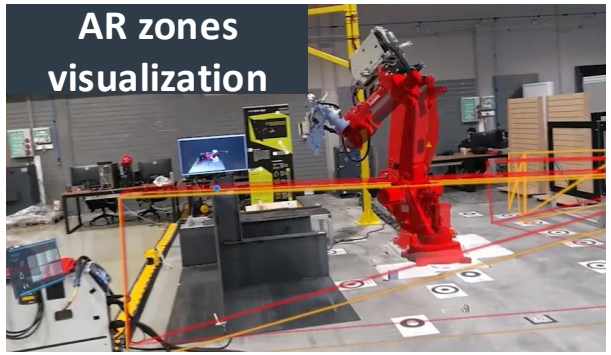

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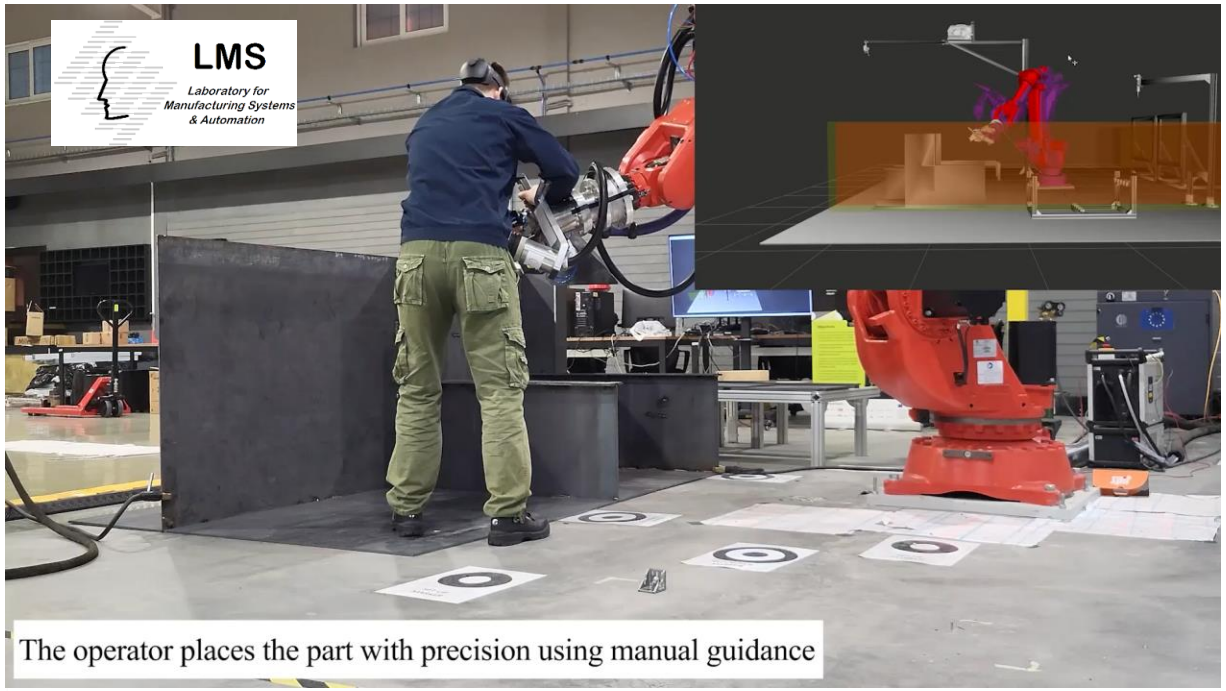
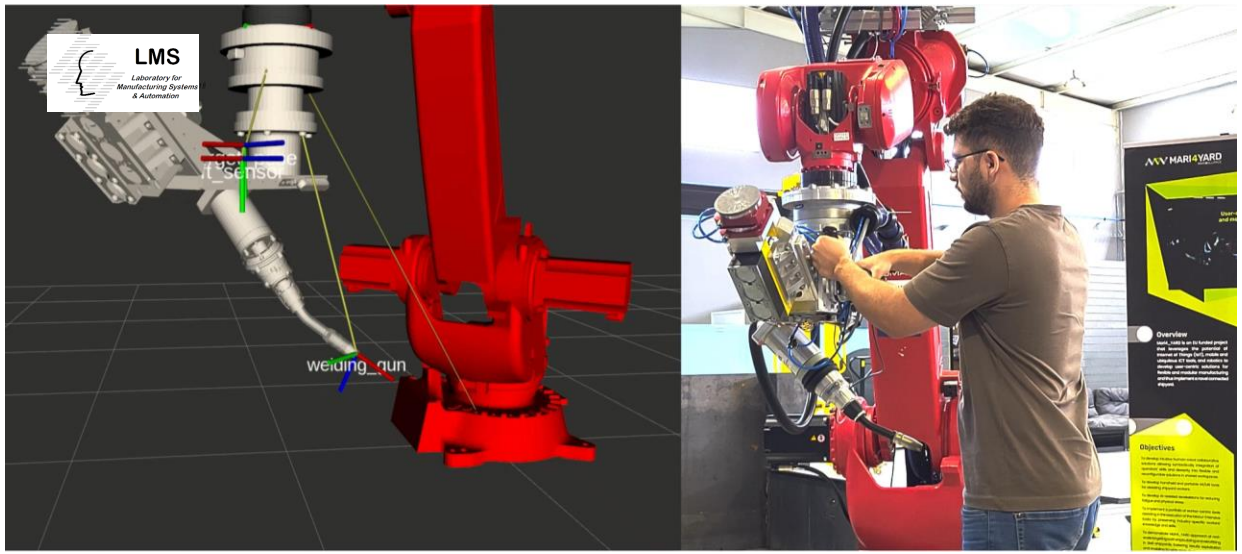
Key Technologies and Applications studied in Mari4_YARD

Human Robot Interaction – Manual Guidance

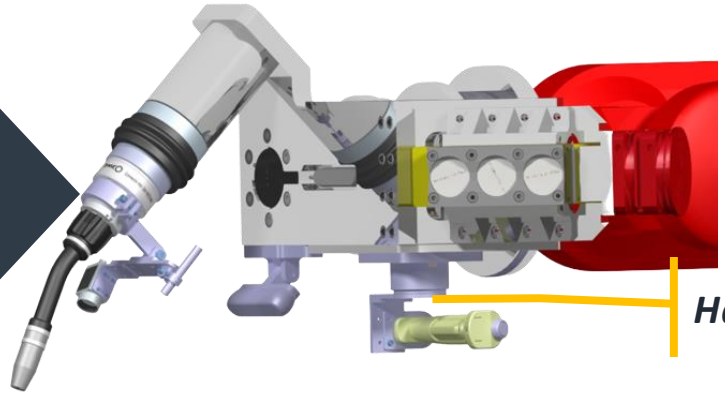
- Force/Torque based control of robot' Operator manipulates robot's end-effector in the desired pose



The operator places the part with precision using manual guidance



Sensor on gripper, grasped weight independent



Hand guiding sensor

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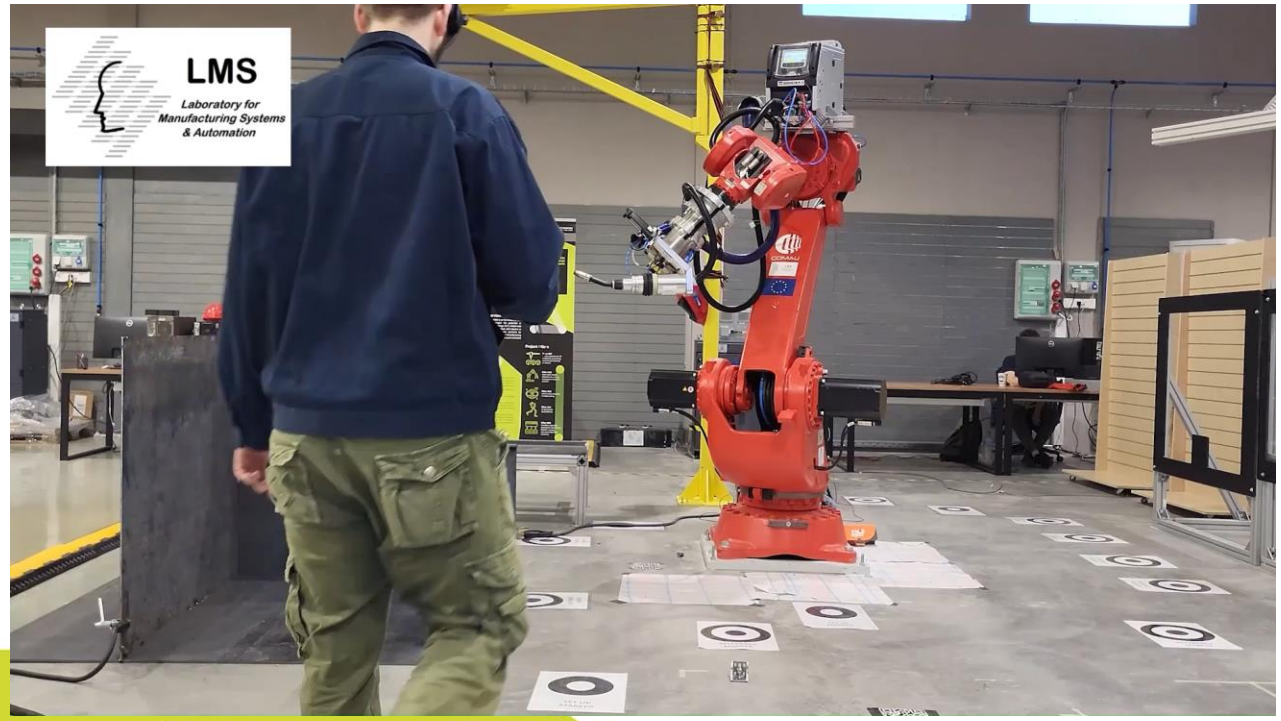
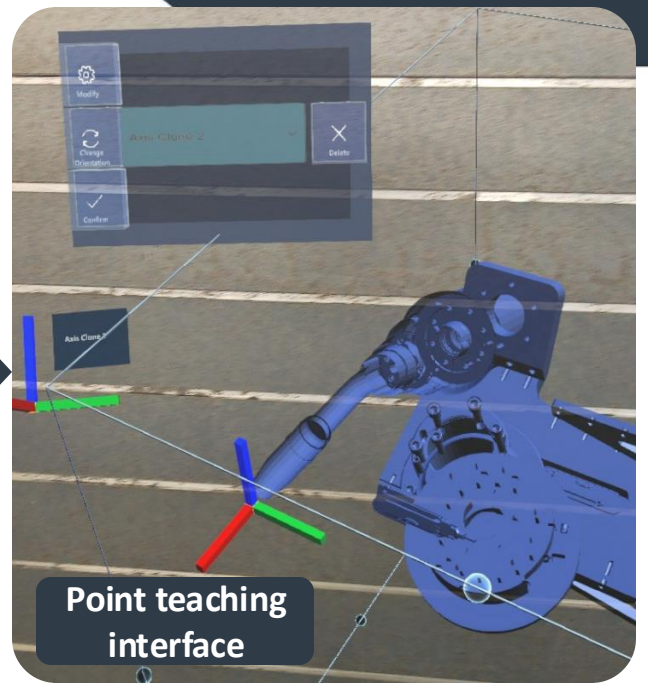
Key Technologies and Applications studied in Mari4_YARD

Human Robot Interaction – AR Robot Programming

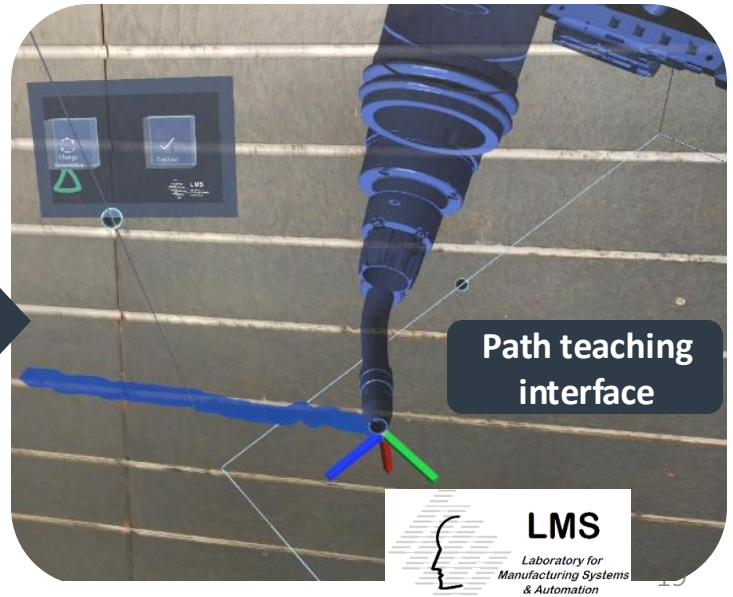
- Smart Pen and AR glasses for robot path/pose teaching
- No-expert programmers
- User friendly UI allow modifications



Operator can **teach** the **robot** to go to **certain poses**



Operator can **teach** the robot **full paths** for **robot welding**



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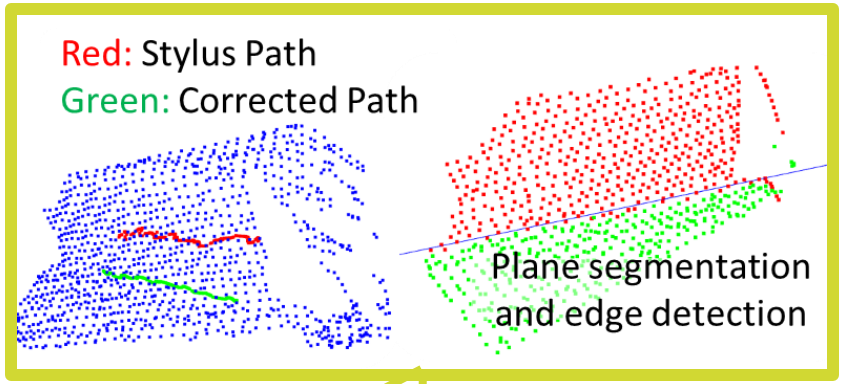
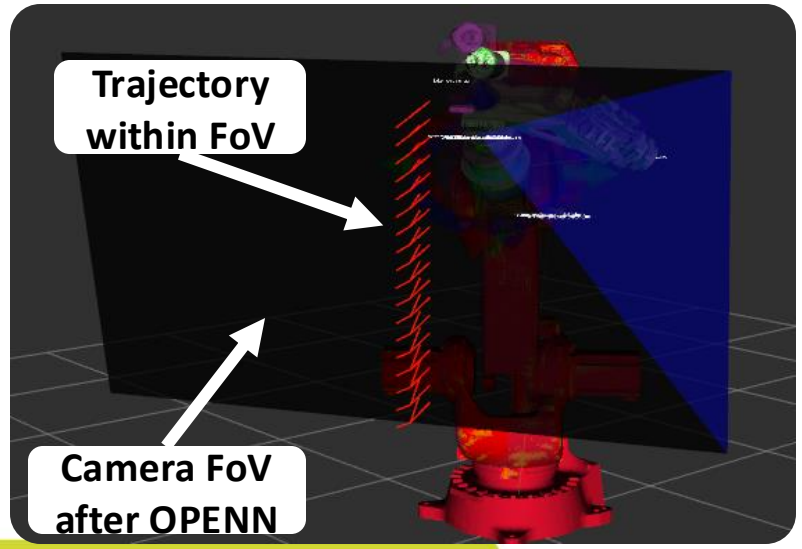
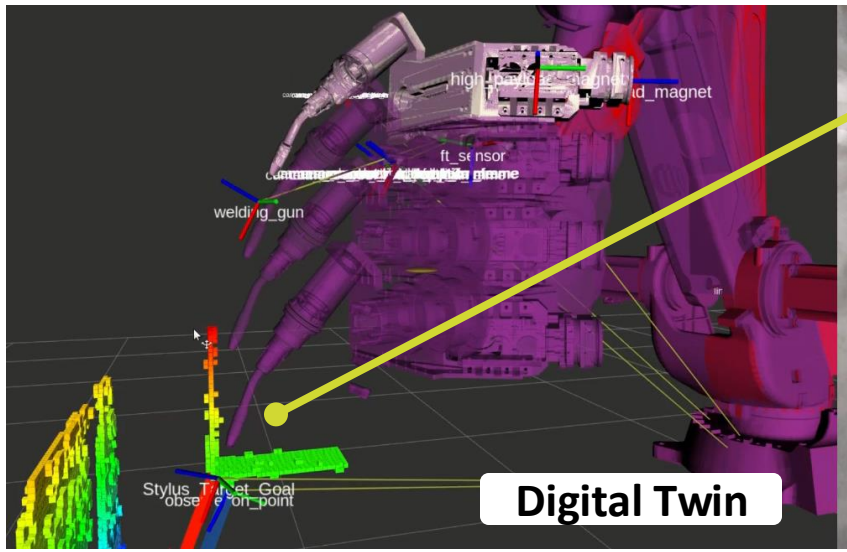
Key Technologies and Applications studied in Mari4_YARD

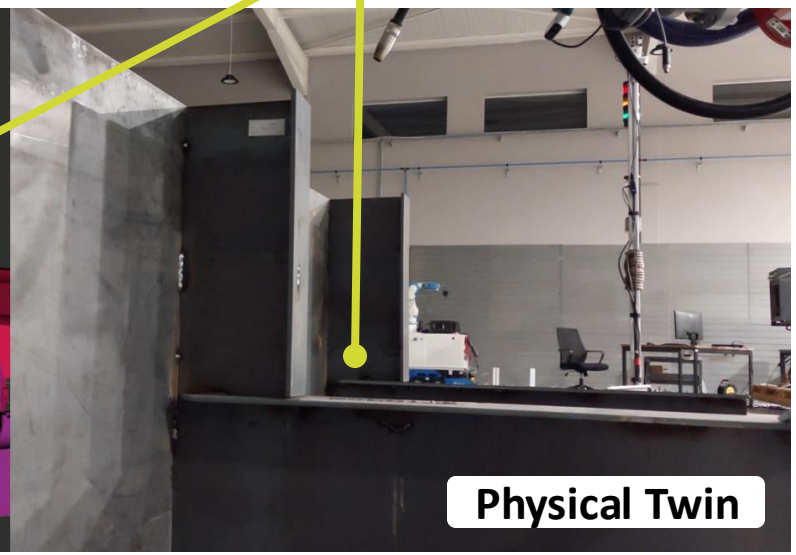
Human Robot Interaction – AR trajectory correction

- Stylus AR-environment present **inaccuracies**
- **Depth sensors** evaluates area for welding
- **Corrects the welding path** based on the **depth data**
- **Pose estimation** for correction check is done **via a DNN**
  → Observation pose estimator NN (*OPE - NN*)









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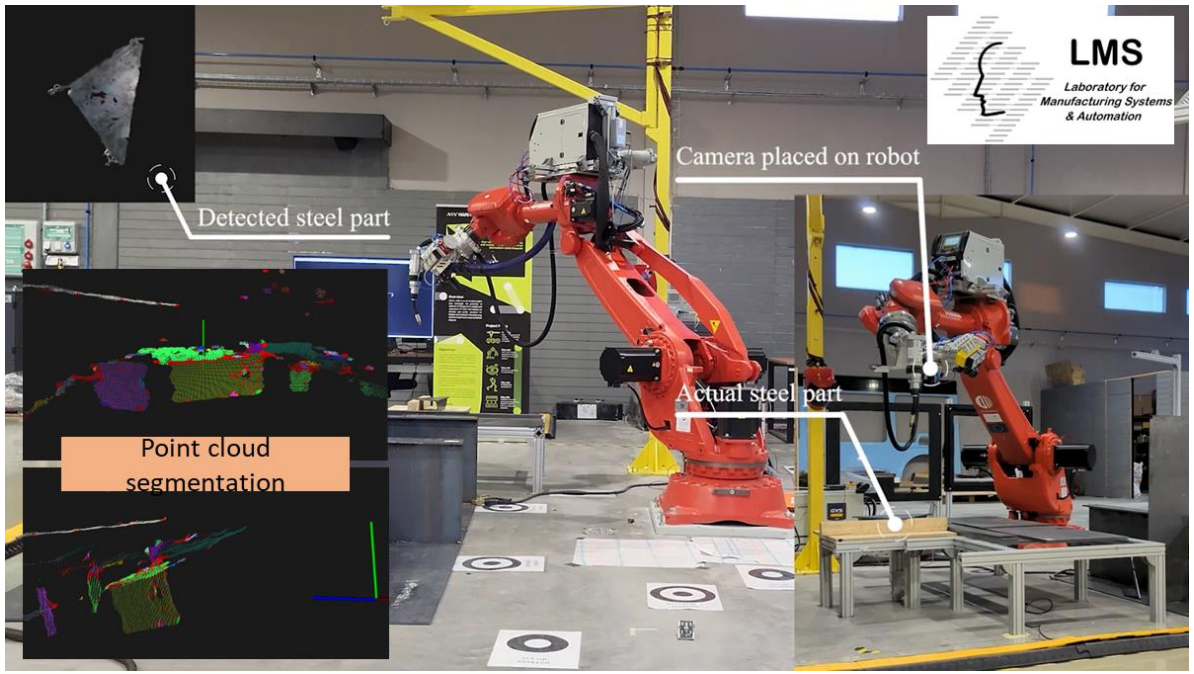
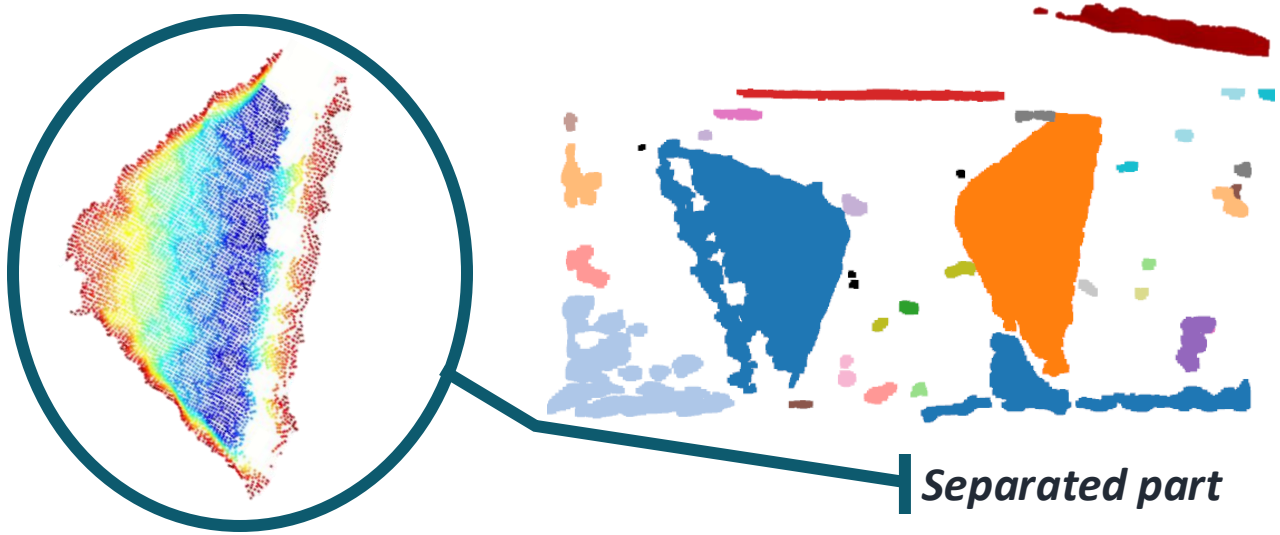
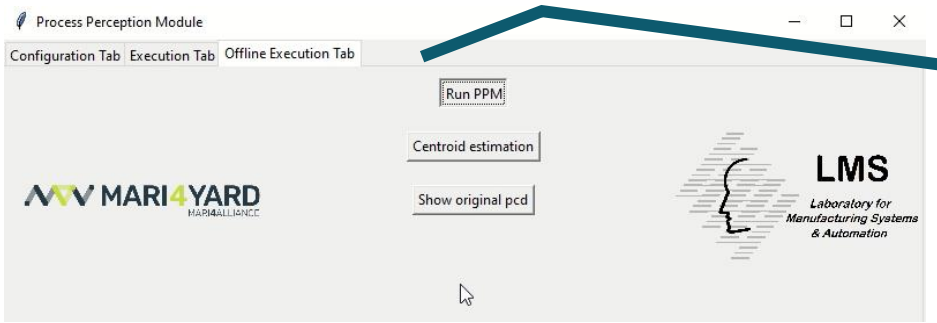
Key Technologies and Applications studied in Mari4_YARD

Process perception module for bin picking operations

- **CAD independent** part detection
- Center of gravity (CoG) identification
- **Grasping point identification** to command the robot grasp the part







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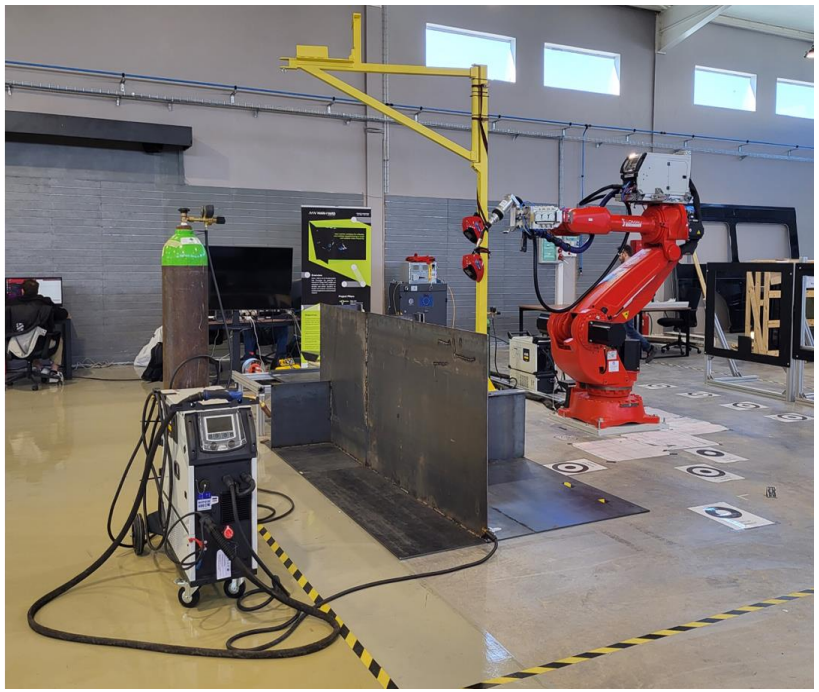
LMS Laboratory for Manufacturing Systems & Automation

Use case – heavy parts manipulation and welding

Scenario Description

- The robot uses a **machine vision** system to **detect parts** to be picked
- The robot **picks** and manipulates the heavy sheets and **roughly positions** them in place
- The **operator** guides the robot to the **final position**
- The operator **tack welds** the sheet to free up the robot
- The operator **teaches** the **welding seam** using the smart pen
- The **robot fully welds** the sheet in place



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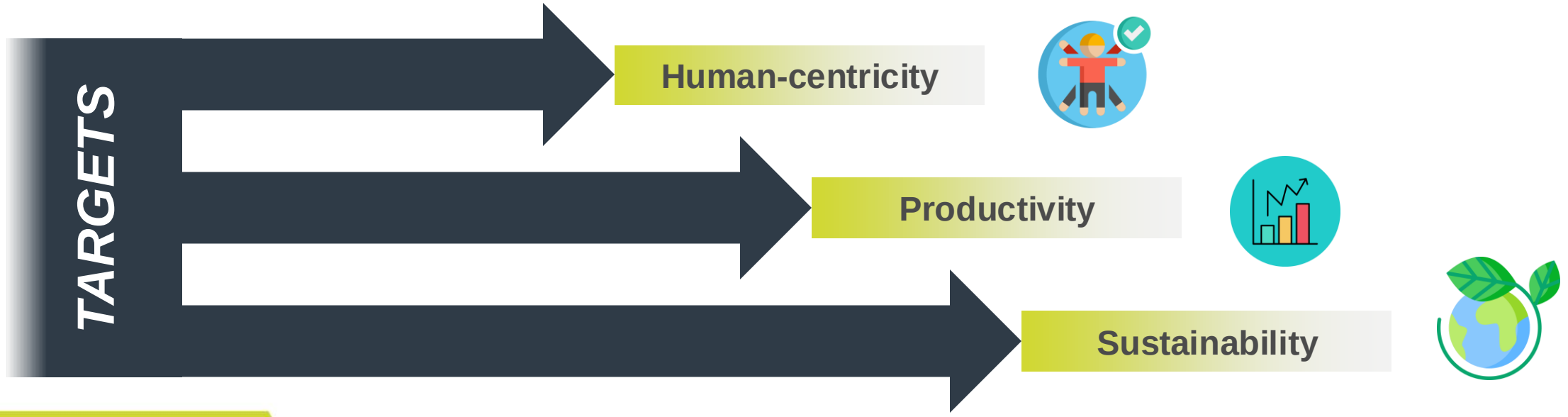
MARI4YARD
MARI4ALLIANCE
High payload robots in shared workspaces with humans
Robot portofolio for human-robot collaborative operations in shipbuilding
European Commission

Use case – heavy parts manipulation and welding

Target KPIs

- Ergonomics improvement (repetitive motions, weight reduction etc.)
- Cycle time
- Numbers of operators allocated for unergonomic weightlifting
- Improved product quality



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Questionnaire

Scan me!

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Thank you for your attention!

LMS

Laboratory for Manufacturing Systems & Automation

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