Department of Information Engineering

Marche Polytechnic University - Ancona - Italy

Automation LAB

# Research & Develpment – Technology Transfer

## STAFF







## WHO AM I

- Engineer in Electronics and Automation
- PhD in Artificial intelligent systems
- 15+ years leads the Automation Lab @UNIVPM
- 15+ years Professor of Robotics, Automation, Control System Engineering and ICT @UNIVPM
- 2+ EU funded projects as PI,
- 8+ national projects
- 4 patents
- Expert evaluator of EU projects

# Where we

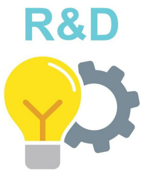
**Automation-Lab** research group
DII - UNIVPM


The **Automation-Lab research group** has a laboratory facility focused on **research & development and technology transfer** activities:
Embedded systems, Robotics and AI, Cyber-Physical-Systems, machinery diagnosis and predictive maintenance, factory automation, Smart manufacturing, Industry 4.0 and 5.0, production monitoring and optimization, Industrial energy monitoring, technological packaging solutions, autonomous mobility and transportation, control system design, autonomous systems … and more …. .

The **Department of information Engineering - DII** is a UNIVPM's department that houses Automation Lab facility and operates in the areas of ICT Engineering such as: **Automation and Control, Computer Science, Electronics, Telecommunication, Bioengineering**

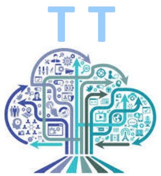
The **Università Politecnica delle Marche** is a research and teaching public entity operating in technological areas as:
**Engineering - Physical science - Biology and Agriculture - Economy - Health and Life Science**.

# What we do



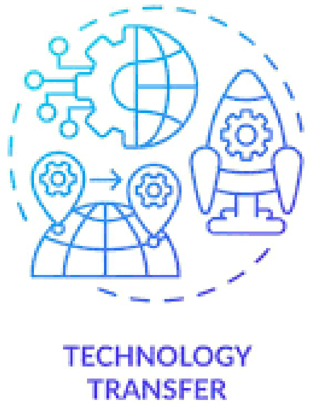

## Research & Development

75% of our activity is R&D


## Technology Transfer

25% of our activity is Technology Transfer



# Which Areas

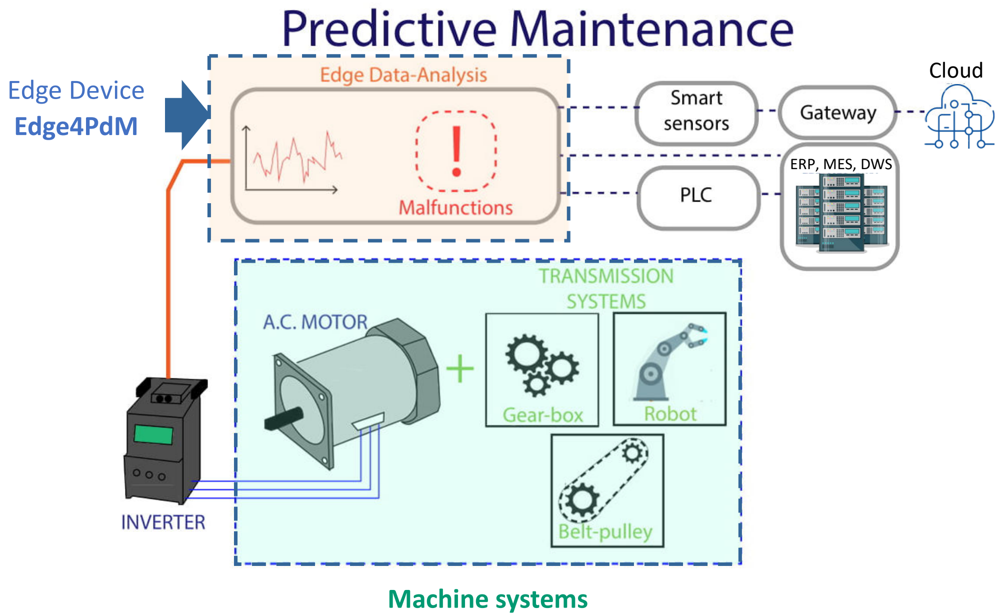


- Mobility and Transportation
- Automotive
- AI Artificial Intelligence
- Robotics
- Smart manufacturing
- Autonomous Systems
- CPS Cyber Physical Systems
- Control & Automation engineering
- Performance monitoring and optimization
- Embedded systems
- Predictive maintenance
- Energy monitoring

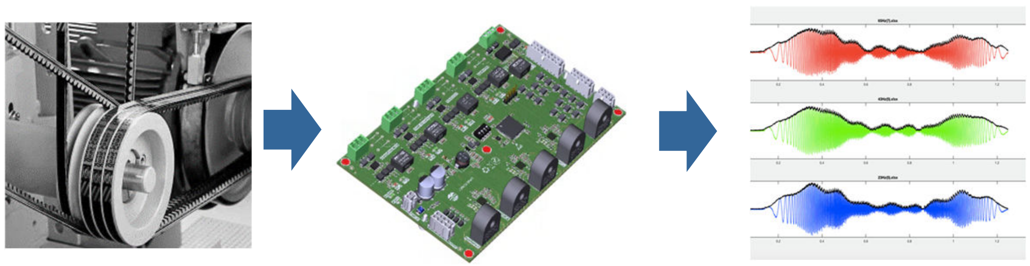
Machinery
Fashion and Apparel
Composite Materials
Food packaging
Autonomous Cars
Byke & Motorcycles
Aerospace
....

# **Edge4PdM:** Edge computing for diagnosis and predictive maintenance

**Why:**
high-frequency and large-scale continuous equipment monitoring and condition estimation are unrealistic for Big Data and Predictive Analytics

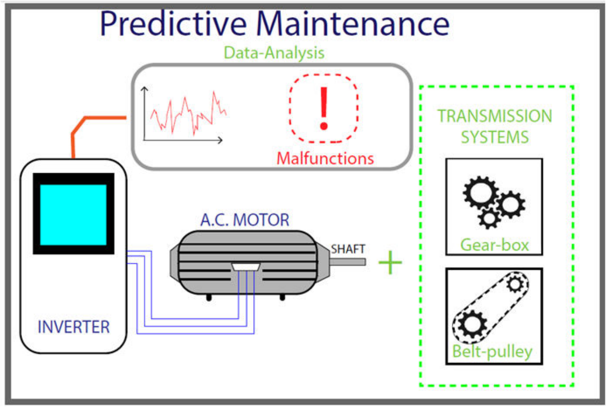



**How:**
Sensor less edge device for diagnosis and predictive maintenance of machine driven by electric motors (current signal-based approach + AI)

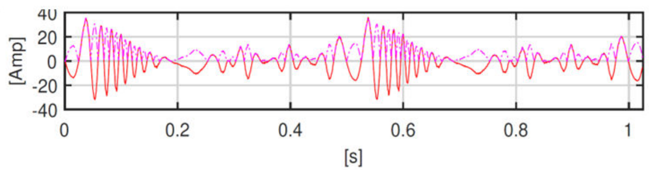


**Where / Who:**
1) shafts of automatic machines for working wood, metal or ceramics,2) bearings and reducers, 3) electrospindles, 4) axes of Cartesian robots or manipulators, 5) packaging machinery, 6) motion transmission parts of electric vehicles, 7) motion parts of automated test benches

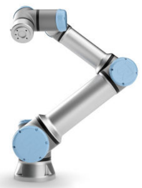
# PREDICTIVE MAINTENANCE (application examples)




**a)** Software tools and an **embedded device** to allow condition monitoring for predictive maintenance of **electric motor operated devices** basically working on **current signals analysis** with **no any other sensing** also **working in variable speed and transient conditions**



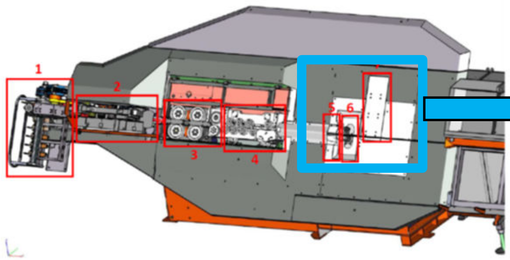

motor operated devices (pulleys, belts, gears, … )



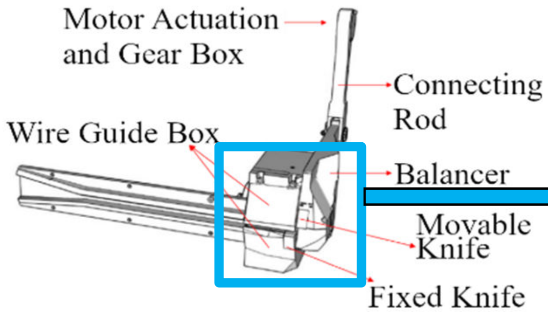
robots/mechatronics

automotive driveline

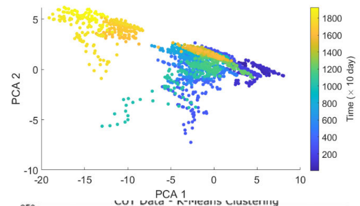
**b)** Learning algorithms oriented to wear classification and predictive maintenance (PdM) of the cutting tool (CT) of a clamping machine for producing structural steel bars

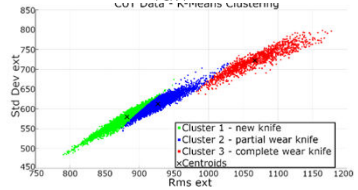


steel bar **cutting machine** layout




**Cutting equipment diagram**

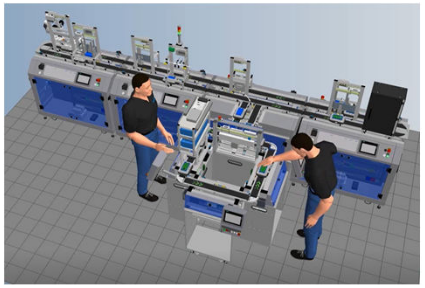


# I5.0: Assessing workers efficiency in manufacturing

**Why:**
Be able to evaluate the efficiency of the workforce;
Integrate the human factor in the performance evaluation and not only the equipment;
Have a global vision of all production phases to act promptly;

**How:**
Solutions for automatic monitoring of efficiency parameters during production;
Having metrics capable to assess efficiency of the workforce;
Having metrics parameters whose measurements can be easily automated.

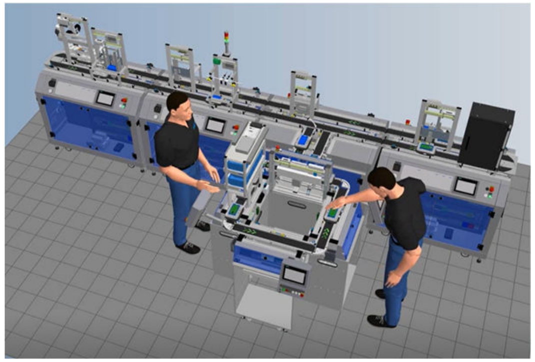


**Where / Who:**
1) manual/semi-automated production lines, 2) shopfloor, 3) production plants, 4) Digital Twin simulations, 5) offices, 6) factory-level performance evaluation, 7) improvement of training paths

**WORKER EFFICIENCY** to **IMPROVE MANUFACTURING COMPETITIVENESS** in human-centered approach

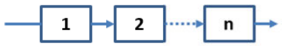
How to use worker effectiveness indicators to enable the monitoring and diagnosis of human performance at the factory level.

1. How to assess labours efficiency in manufacturing environment?
2. Is it possible to relate a Human Factor Indicator with Productivity Indicators at factory level ?
3. A Human Factor Indicator can be related with LEAN Instruments ?

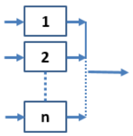


Employees are ⟺ a very important resource of the company organization / at the same time are a cost for the company.

It is given a method to **take an indicator into account** when evaluating **aggregate factory-level indicators of production**




$$OTE^{(s)} = \frac{\min_{i=1,\ldots,n}\left\{ROLE_{(i)} \cdot R_{(i)}^{(th)}\right\}}{\min_{i=1,\ldots,n}\left\{R_{(i)}^{(th)}\right\}}$$

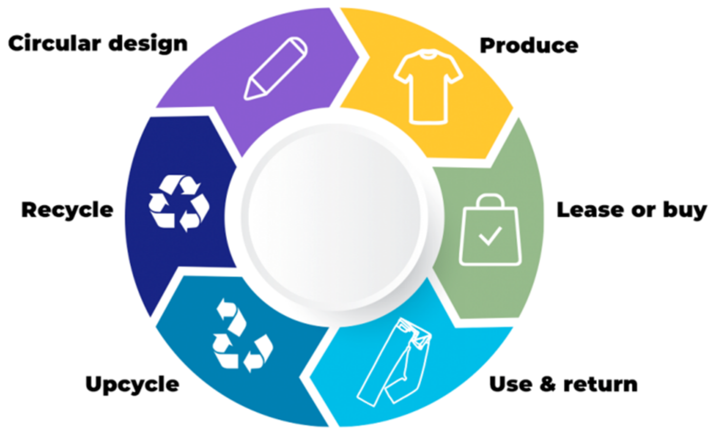



$$OTE^{(p)} = \frac{\sum_{i=1}^{n} ROLE_{(i)} \cdot R_{(i)}^{(th)}}{\sum_{i=1}^{n} R_{(i)}^{(th)}}$$

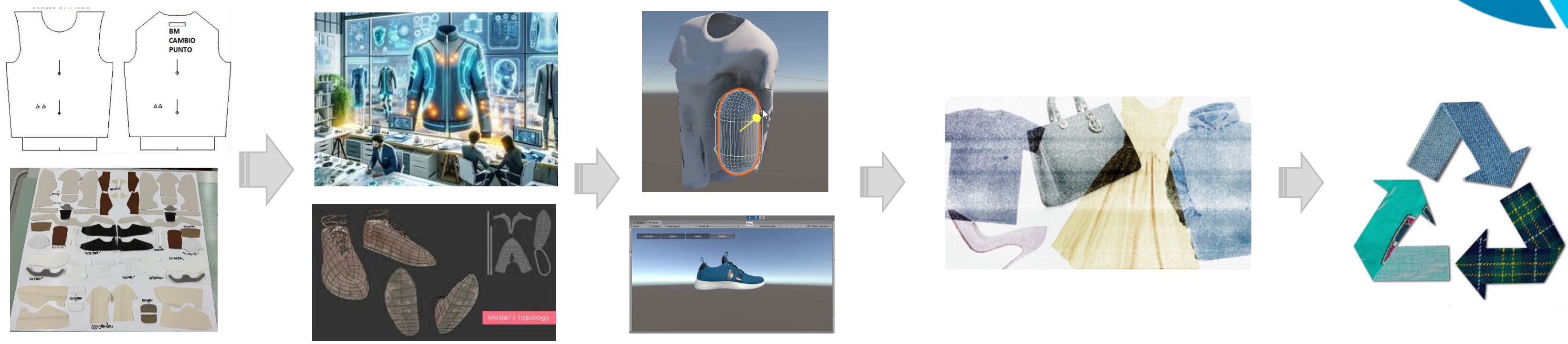
$$LEA - ROLE = \frac{VA}{NAT} = \frac{VA}{VT} \cdot \frac{VT}{OT} \cdot \frac{OT}{EAT} \cdot \frac{EAT}{NAT}$$

## **Circular fashion:** digitalization of pattern-making and prototyping phases of apparel

**Why:**
Eco-design solution for textiles and apparel products;
Integration of digital technologies across the full product life cycle;
Effective automating and digitizing fashion products until end of life;




**How:**
Viable solutions in the design phase to digitize and facilitate disassembly and recycling;
Digitalization of pattern-making and prototyping phases of apparel (clothing, knitwear, jackets, footwear).

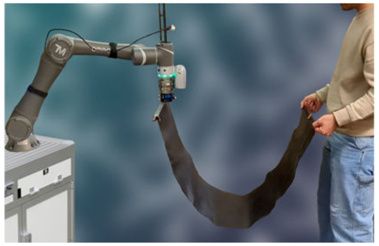


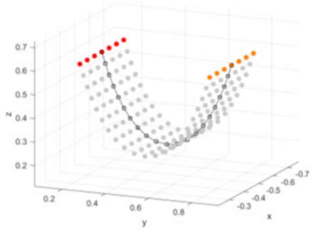
**Where / Who:**
1) Fashion brands, 2) textile and fashion SMEs, 3) complex textile production, 5) dismantling services for recycling, 6) best practices for sustainable product regulators, 7) re- and de-manufacturing operators

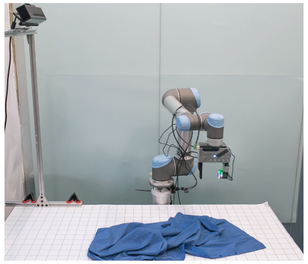
# **Robotics for apparel:** automated disassembly of textile and apparel products

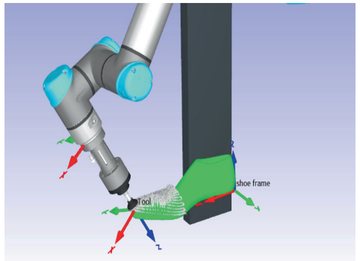
**Why:**
Save time to train robot in simulation phase for disassembly apparel products;
Automate the deployment of disassembly sequences and operations on real robots;
Facilitate eco-design solution for textiles, shoes and apparel products;

**How:**
Simulation environments to train robots to handle and disassemble apparel products;
Developed selective robotics disassembly techniques and tools for textiles, shoes etc.;
Human-robots co-transportation of textile products;
Increased cognitive and dexterity capabilities of robots.



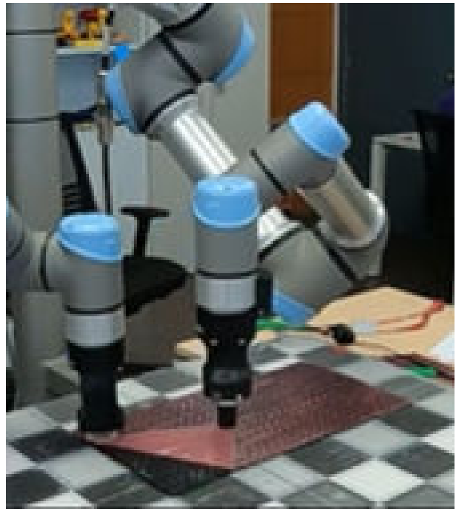







**Where / Who:**
1) Fashion brands, 2) textile and fashion SMEs, 3) fashion product creation, 4) complex textile production, 5) dismantling services for recycling, 6) best practices for sustainable product regulators, 7) re- and de-manufacturing operations

## **Robotics for composites:** automating the hand layup process

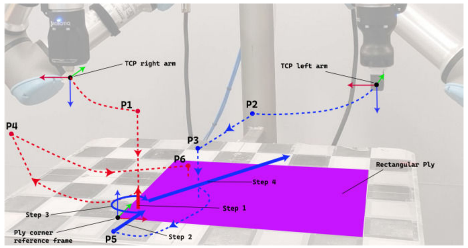


**Why:**

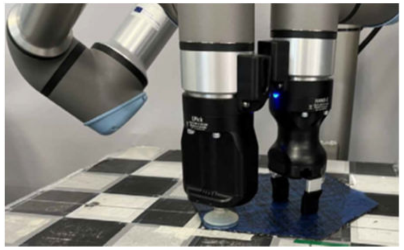
Hand layup process is a skill-intensive task performed by multiple expert workers;
Automate manual removal of protective films as tedious and valueless task;
Remove the  bottleneck of film removal in achieving automation of the layup process;

**How:**

Framework for protective film removal from prepregs using collaborative robot;
Easy-to-integrate framework;
Human-robots co-transportation of composite materials;
Increased cognitive and dexterity capabilities of robots.







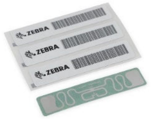
**Where / Who:**

1) Aerospace industry, 2) automotive industry, 3) motorsport, 4) composite materials supply chain, 5) SMEs of composite materials, 6) Robotic integrators

# Smart footwear manufacturing

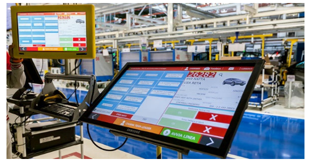
**Why:**

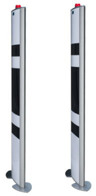
Footwear manufacturing requires multiple experienced workers with little inclination to share skills.
Automate manual and non-value-added tasks as well as improve agility in the manufacturing process.
Improve efficiency and reduced waste.
Remove bottlenecks of manual processes and improve process automation.

**How:**

Robotic polishing, manipulating and disassembly of shoes
Traceability system with RFID and NFC, track flows of raw materials and finished products
Record, process and display of production data and production KPIs
Automatic handling and transport system using AGVs, UGVs
Move trolleys used in production between the factory and warehouse





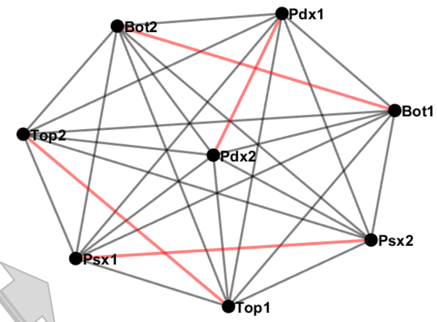
**Where / Who:**

1) Footwear SMEs and Large Enterprises, 2) apparel and fashion, 3) supply chain, 5) System and Rbotics integrators

# Autonomous Optimization and Self-Sequencing of Robotic Operations

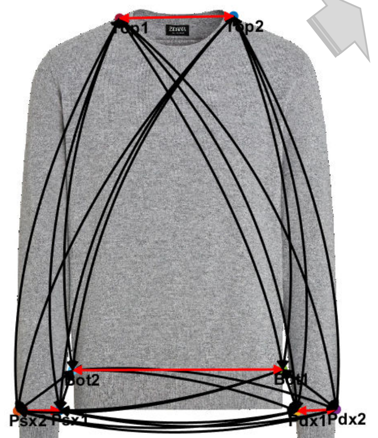
**Why:**
Real-Time Adaptability (robustness, flexibility, context-aware re-planning);
Operational Efficiency & Speed;
Optimal Resource utilization (few constraint, the customized cost functions);
Superior Performance in adapting planning to perceived context;

Graph-based sequencing





autonomous identification of operational paths



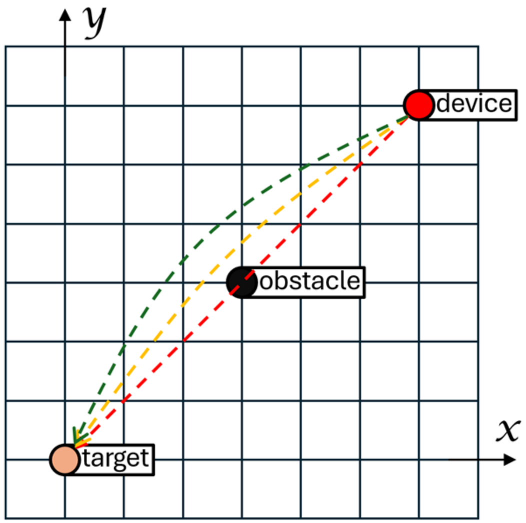

finding sequence of operations allowing operational paths


identification of optimal operating sequence

**How:**
Customizable cost function depending on desired behaviour;
Representing operations as nodes on a graph
Defining logical sequential constraints;
Finding sequence of operations with the lowest cost;

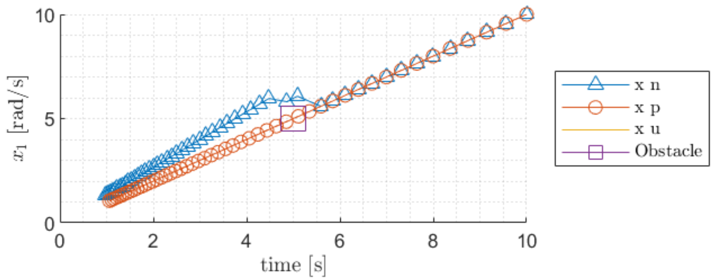
**Where / Who:**
1) Manufacturing Assembly & Disassembly, 2) Logistics & Warehousing (AGVs, AMRs, Sorting), 3) Vehicle's routing, 4) human-robot tasks management, 5) Agriculture (Agri-tech), 6) Exploration & Remote Operations, 7) Healthcare & Surgery.

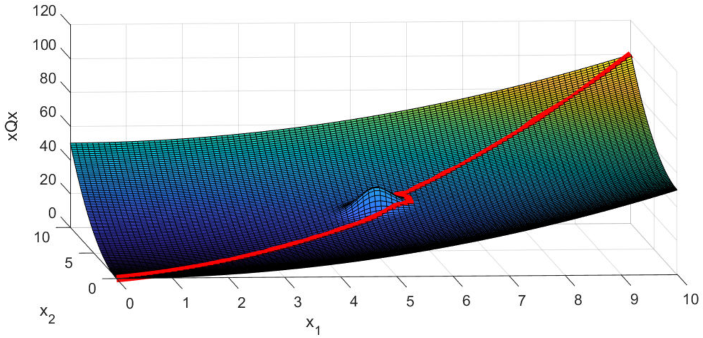
# Autonomous obstacle avoidance by robots




**Why:**
Autonomous reaching of target points without colliding;
Customize effort and efficiency of the movement;
Update planning strategy in real-time for moving obstacles.

**How:**
Application of edge non-linear optimal control based on Riccati Equation;
Using numerical strategies to speed up algorithms without loosing stability and safetyproperties;
Use of different and customable cost-function for different kind of obstacles;
Adaptability to any kind of robot (manipulators, mobile AGVs, etc.) without constraint.

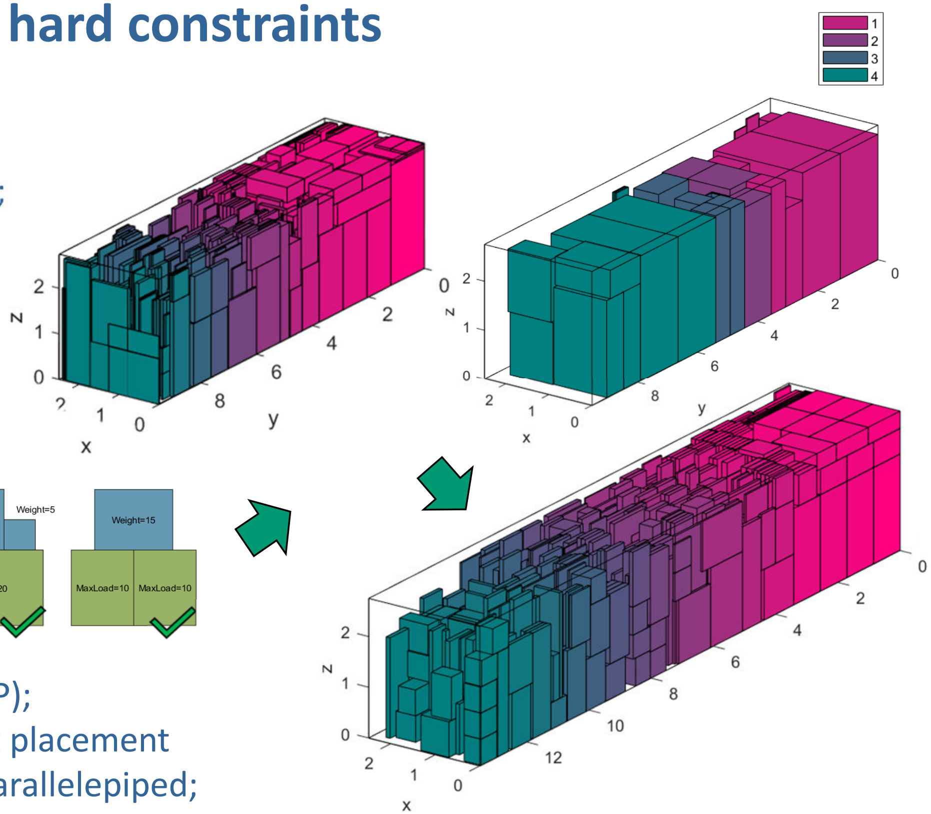


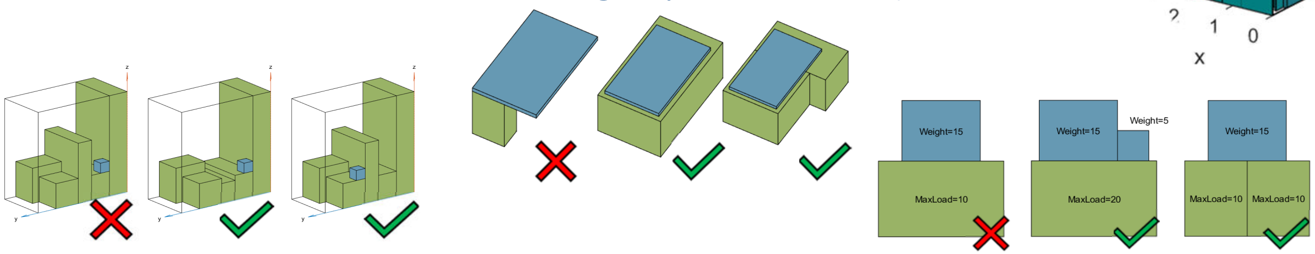




**Where / Who:**
1) Autonomous vehicles, 2) autonomous warehouses, 3) drone control, 4) robot vacuum cleaners, 5) robots exploring hazardous environments

# Autonomous Cargo Space Optimization with hard constraints

**Why:**
Provide optimal loading instructions to a loading operator;
Quickly find the optimal arrangement of lots of many objects in limited space;
Quickly estimate the maximum number of objects that can be allocated;
Allow optimal object placing while respecting strict constraints;
(Objects must: support a limited weight, rest on a sufficient surface, and be accessible based on the order in which the group was removed)

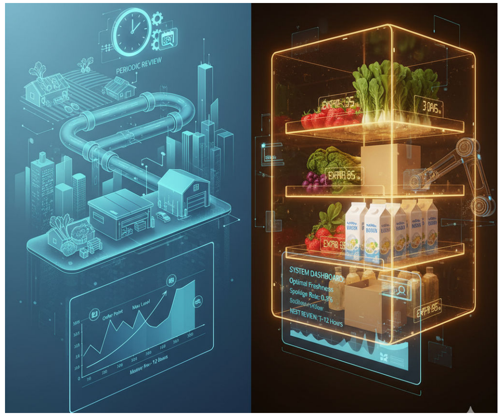



**How:**
A list of items to be allocated to a loading cargo is provided (e.g., from an ERP);
An intelligent algorithm uses a customizable cost function to choose the best placement and configuration for each item (e.g. items and cargo volume are assumed parallelepiped; the items can be flipped, rotated, and can subject to constraints);

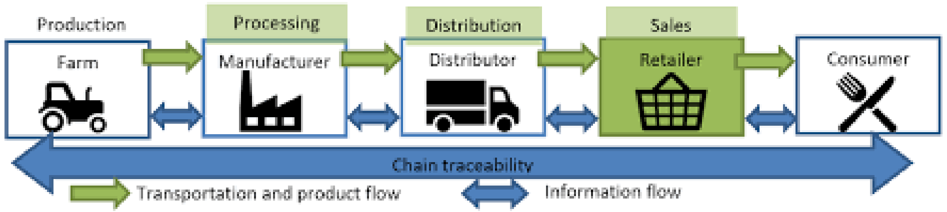
**Where / Who:**
1) Logistic and shipping, 2) warehouses and e-commerce, 3) manufacturing: products storage 4) industrial buffers, 5) product storage and management in stores

# Optimal Inventory Management in Perishable Supply Chains with periodic review



**Why:**

Minimize inventory levels of perishable goods to reduce storage costs and spoilage risk ;
Define an effective replenishment policy of perishable goods;
Maximize Demand Fulfillment;
Mitigate the Bullwhip Effect (small changes in retail demand are amplified into large fluctuations on supply chain);



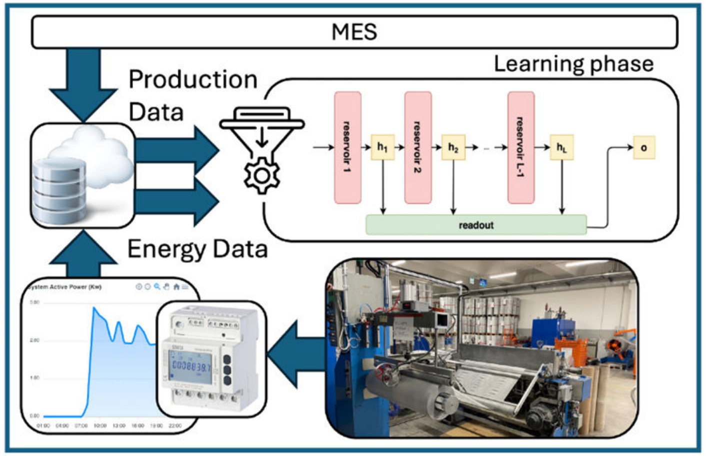

**How:**


Optimal Control Methods based on 'Data-driven Min-Max Model Predictive Control';
AI-based forecasting methods for random fluctuations in customer demand;
Considering of perishable goods with uncertain spoilage rates
Considering not synchronized internal dynamics for inventory level, delivery and receipt of goods

**Where / Who:**

1) Warehouses inventory management, 2) Retail & Grocery, 3) Pharmaceuticals 4) Chemical & Cosmetics, 5) Food Service, 6) Distributed manufacturing systems, 7) E-commerce & Last-Mile Delivery

# **Edge AI for energy:** AI-Based Energy monitoring and anomaly detection

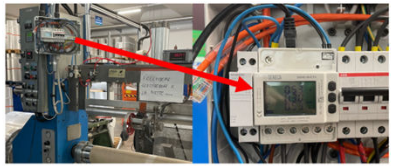


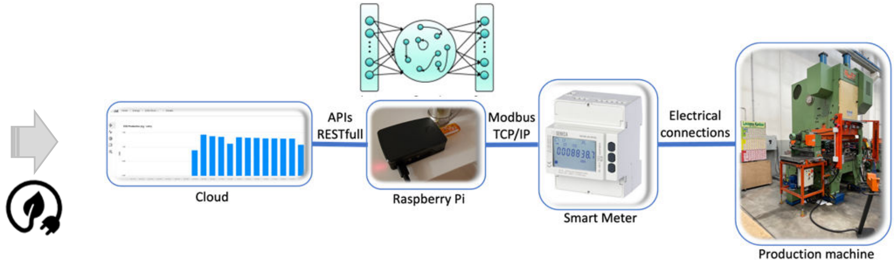

**Why:**

Predict consumption from production planning and detect both energy and production anomalies;
Correlate the energy consumption of machines and their planned production;
Energy consumption monitoring and prediction for utilities and energy management;

**How:**

Combine data from IIoT smart meters (energy) and MES software (production plans);
Easy-to-integrate framework, also in existing plants or energy utilities;
Lightweight AI framework running at the edge for online prediction and detection.

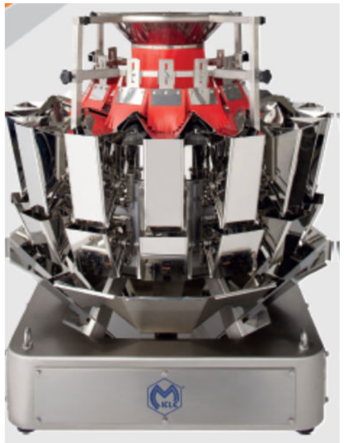





**Where / Who:**

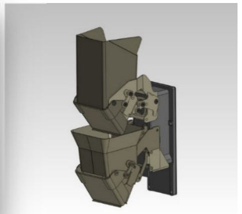
1) manufacturing, 2) utilities energy management, 3) production lines, 4) shopfloor, 5) production plants, 5) Digital Twin, 6) factory-level monitoring, 7) energy utilities

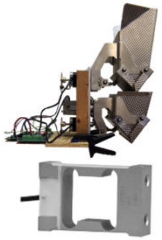
## **Smart packaging:** fast weighing estimation with load cells

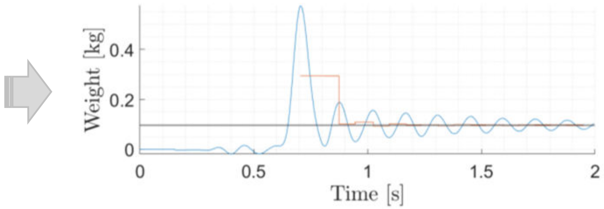


**Why:**
Perform weight measurements with high processing speed and high accuracy;
Reduce weighing cycle time without reducing accuracy and vice versa;
The **measurement time is reduced of about 50%** for granular, solid and liquid materials
Increase production volume and accuracy of weighing machines;

**How:**
Perform measurement estimation without waiting for the settling time;
Weight measurement obtained already during the first oscillations of the transient regime;
Embedded hardware with weight measurement performed via microcontroller processing.

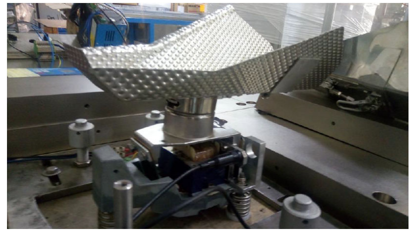







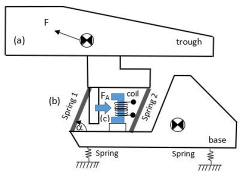

**Where / Who:**
1) Food and beverage packaging, 2) pharmaceutic, 3) metalworking, 4) agriculture, 5) constructions, 6) load cells, 7) weighing machine systems, 8) dosage machines, 9) multi-head weighing machines.

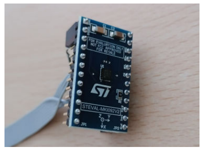
# **Smart packaging:** industrial vibratory feeders, time-optimal control

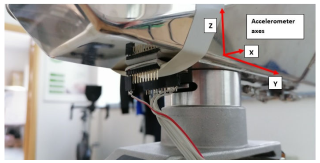


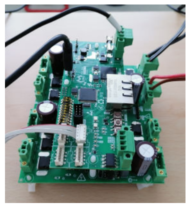
**Why:**
Perform transport of fine, granular and non-grain materials in the shortest time;
Improve energy performance and reduce transient time of vibrating conveyors;
**Reduces cycle time** of conveying granular and non-grain products **at least of 50%**;
Increase production volume and energy efficiency of vibrating conveyor machines.

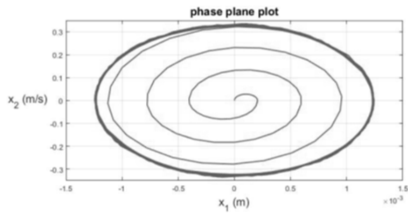
**How:**
Performs a time-optimal control to achieve resonance of vibrating conveyors in a minimum time;
Accelerometric feedback of the vibrations allows to generate time-optimal excitation law that reduces the transient while maintaining persistent oscillations at resonance;
Switching control reduces the current conduction time, thus improving energy efficiency;
Simplified control hardware compared to traditional solutions with the developed embedded hardware.



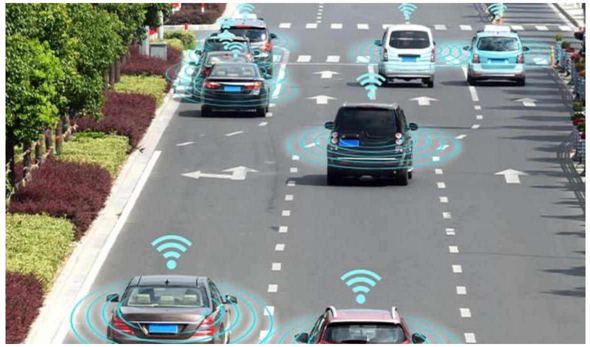




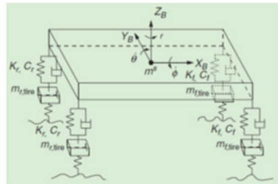

**Where / Who:**
1) Food and beverage packaging, 2) pharmaceutic, 3) processing industries, 4) agriculture, 5) plastic industries, 6) vibratory feeders, 7) vibrating conveyor machines, 8) dosage machines, 9) feeding of weighing machines.

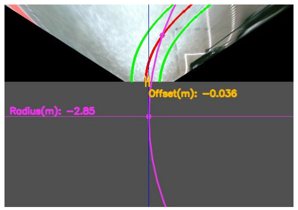
## **Automotive and mobility:** autonomous driving and mobility technologies

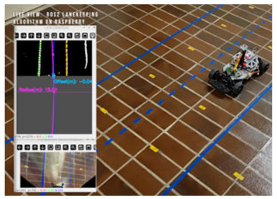


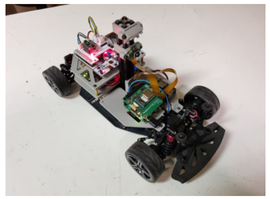
**Why:**
Navigate autonomously and using communication networks in smart cities;
Embedded solutions in real-time with high reliability and minimum hardware resources;
Face complex tasks as: lane keeping, navigating intersections, reacting to traffic lights, navigating based on localization data, reacting to other traffic cars or pedestrians, V2V / V2X communication.

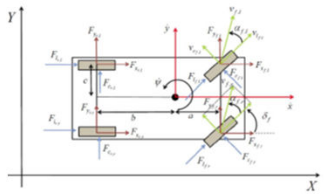
**How:**
Develop autonomous driving and connectivity algorithms on 1/10 scale vehicles to scale up;
Use of Artificial Intelligence to support and improve autonomy solutions;
Develop architecture and algorithms, and embedded advanced control on microcontroller;
Vehicle systems modelling, simulation and control of 4-wheeled vehicles and Formula SAE vehicle.









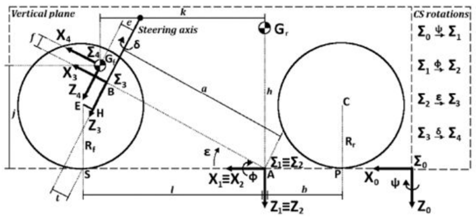


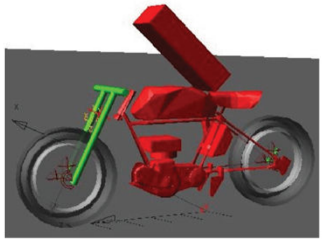
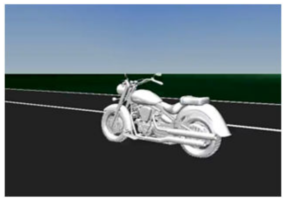
**Where / Who:**
1) Automotive, 2) smart cities, 3) transportation, 4) supply chain, 5) autonomous delivery, 6) warehouses, 7) AGV / AMR in manufacturing, 8) agriculture, 9) safety.

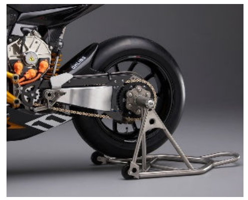
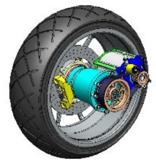
# **2-wheels vehicles:** bicycle and motorcycle technology and mobility

**Why:**
New markets for two-wheeled electric mobility due to sustainability and ecological transition;
Develop ADAS (advanced driver assistance systems) for two-wheeled vehicles to prevent accidents and improve safety;
Shared mobility platforms such as bike and scooter sharing.
Support functionality using AI solutions

**How:**
Modeling and simulation of vehicle dynamics for bicycles and motorcycles;
Innovative 2-wheeled vehicles with all-wheel drive and complex dynamics;
Advanced control and sensing in panic or critical situations;
Prototyping and testing of 2-wheels vehicles



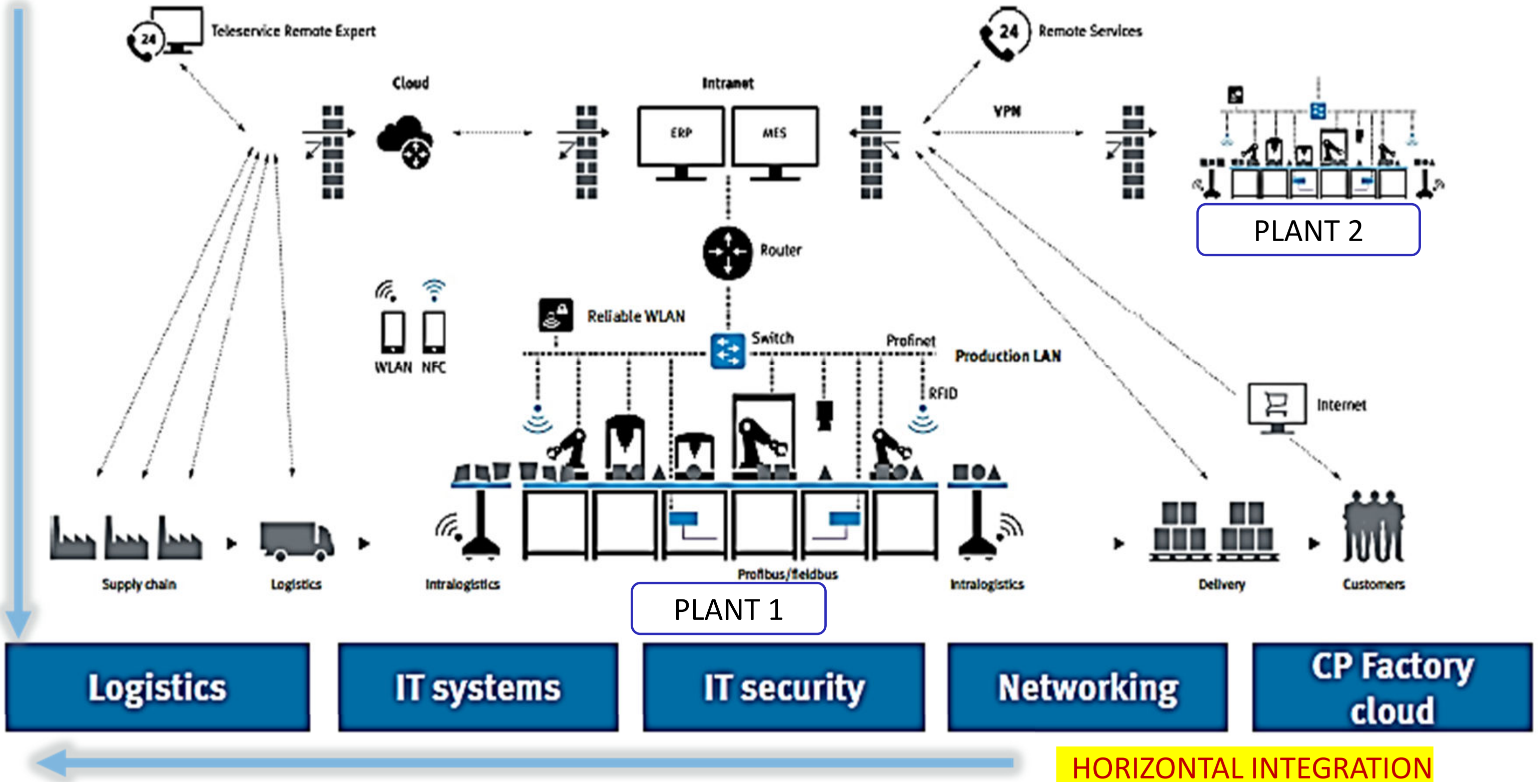



**Where / Who:**
1) Automotive, 2) smart cities, 3) transportation, 4) autonomous bikes, 5) safety and accidents prevention.

# CYBER PHYSICAL SYSTEMS FOR MANUFACTURING

**Distributed production system**, flexible and **able to adapt and self-configure**

VERTICAL INTEGRATION

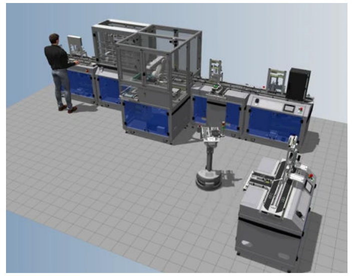


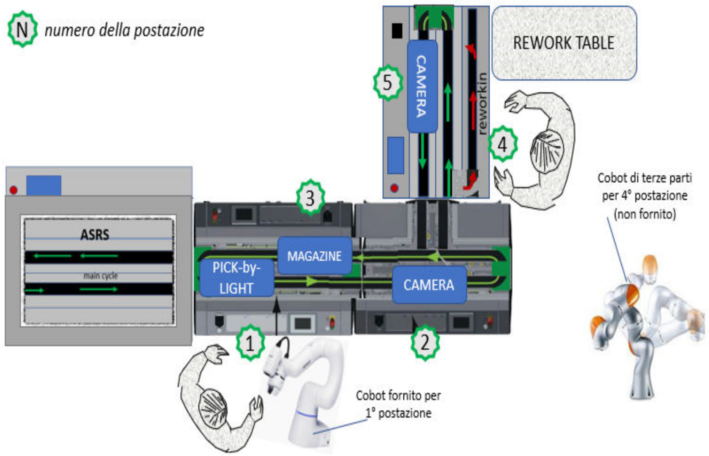

HORIZONTAL INTEGRATION

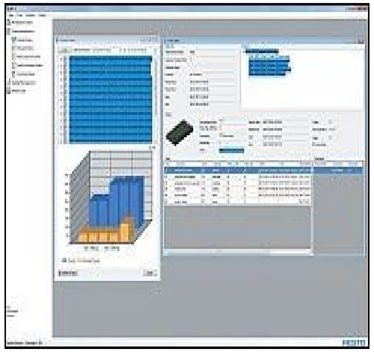
# Manufacturing Facility

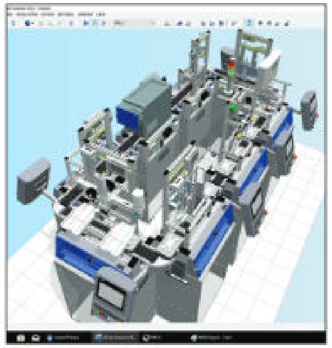
## CYBER-PHYSICAL FACTORY FACILITY

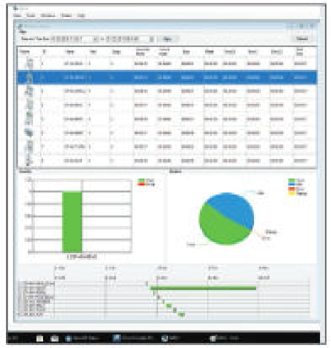
The CP Factory is a testbed open for experimenting with original assembly and flow handling processes with an I4.0 approach, delivered with a sample process:
► rough storage ► assembly by operator or robot ► conformity testing ► finishing or reworking depending on outcome ► final testing ► finished storage

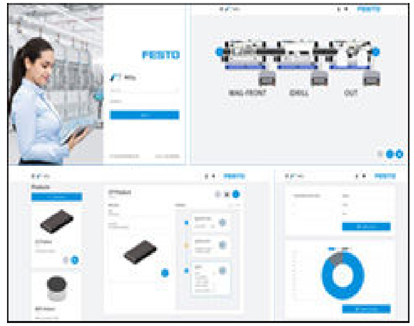










exchange and management of process data for reconfiguration, planning, monitoring of the system according to user requirements

►Graphic system configurator, which includes the library of all stations ►Graphic editor of the work program according to the configured product ►Production control via service-oriented architecture (SOA) ►Communication with resources via TCP/IP and OPC UA ► Order management ► Real-time graphical tracking of work steps ►Editor for database analysis, e.g. OEE or quality, with real-time diagrams ►Import and export functions for layouts, work schedules, orders and evaluations in standard formats such as CSV and JSON ► Multilingual user interface

## AT A GLANCE

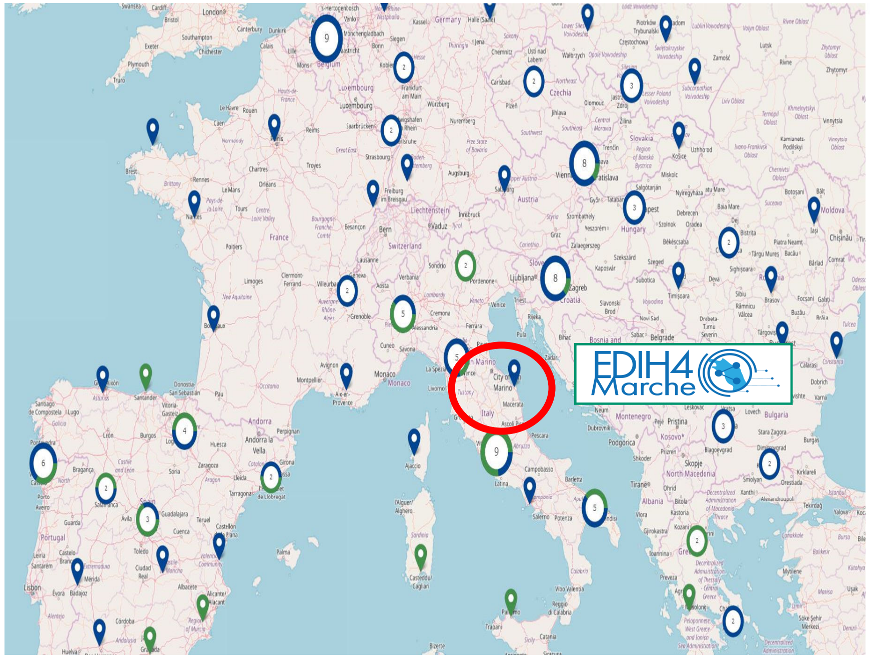
EDIH4Marche is **one of the 13 Italian European Digital Innovation Hubs** funded by the European Union.

**The goal:** to create real added value for SME's companies, particularly for those who have difficulty accessing innovative technologies related to Industry 4.0.

**Strength:** interdisciplinary and network capability of the whole regional ecosystem of the Marche region.

The target sectors reflect the local economy and are in line with the Smart Specialization Strategy of the Marche Region.

The partnership is composed of 11 Partners with *strong expertise* which are *key stakeholders for Digital Transformation*.



https://european-digital-innovation-hubs.ec.europa.eu/edih-catalogue

www.edih4marche.eu

## TECHNOLOGIES AND APPLICATION AREAS

The **technological focus**: applications areas of **Industry 4.0**, mainly in manufacturing, but also agrifood, tourism, trade and public services.

**cutting-edge technologies** related to artificial intelligence (AI) and cybersecurity.

Focus on specializations and skills in the Region and existing research infrastructures / expertise.

**FOCUS & APPLICATION AREA**

INDUSTRY 4.0

**TECHNOLOGIES**

ARTIFICIAL INTELLIGENCE

CYBER SECURITY

**SECTORS**

MANUFACTURING

AGRI-FOOD

TOURISM

TRADE

BUSINESS, PEOPLE AND COMMUNITIES SERVICES

## SERVICES PROVIDED

EDIH4Marche thanks to expertise and partnership's laboratories, provides services to support companies in.

### DIGITAL STRATEGY

Support to:

define company's **digital strategy**.

define the company's **digital transformation path** with measurable objectives.

### TEST BEFORE INVEST

Support to:

carry out **tests**, **feasibility studies**, **prototypes** using technologies of EDIH4MARCHE partners.

Make **experiments to evaluate choices before** making **investments**.

### SKILLS AND TRAINING

The digital transformation journey is supported by:

**courses on digital transformation** on topics according to needs and business level:

- Soft skills
- Executive
- Tailor-made
- Vertical courses on technologies

**Support to find investments**

**Networking e matchmaking**

### European, National, Regional projects

- EU Project DIGITAL “**EDIH4Marche**” – European Digital Innovation Hub for Marche region.
- EU Project H2020 “**ENCORE**” - ENergy aware BIM cloud Platform in a COst effective Building REnovation Context.
- INVITALIA R&D Project “**CIRCULAR FASHION -** IN.CO. Industria Confezioni S.p.A.» About robotic disassembly solutions for circular fashion and digital solutions for eco-design of apparel and fashion products
- MIMIT Project ““**Perseo** - enhancement of the GUCCI Logistic S.p.A. and PIGINI S.r.l. production capacity of footwear articles, through the technological development of new production methods and machinery”.
- National Competence Center: “**ARTES 4.0** - Advanced Robotics and enabling digital TEchnologies & Systems 4.0”.
- **PRIN MIUR** Project, “A Distributed Digital Collaboration Framework for Small and Medium-Sized Engineering and Construction Enterprises”.
- MISE, Agreements for Innovation, Smart Factory Project “**Electrospindle 4.0,** Zero Defect Manufacturing”.
- MISE, Agreements for Innovation, Smart Factory Project “**Intelligence 5.0**: from cyber-physical systems for the creation of 'self-aware' machine tools to innovative models of advanced industrial services”.
- MIUR PON "Research and Innovation" 2014-2020 Project “**REACT** - Innovative methods and tools for REACTive Product Design and Manufacturing”.
- MISE Call for Major Projects R&S (FRI), Project “**SMART SHOE MANUFACTURING**: Innovative Methodologies and innovative technological tools for the simplification of production processes in Santoni SpA”.
- Cluster Smart Factory Project 1, Project “**Sustainable Manufacturing**”.

## European, National, Regional projects

- POR MARCHE FESR 2014/2020, Project Title: “**H3DFlab**” - Laboratory of the Factory of the Future, digital, flexible and human-oriented”
- PR MARCHE FESR 2021-2027 – Project «**TANDEM** (Testing tool AND Energy Maker)» development of automotive electric motor test stations for electric, hybrid and hydrogen cars and also quadricycles, motorcycles, e-bikes.
- PR MARCHE FESR 2021-2027 – Project «**PENTA** (Energy efficient production, ergonomic and tracked assisted for furniture sector)» improve energy efficiency in production, assisted manual load handling, optimization of goods loading and zero-defect quality control.
- PR MARCHE FESR 2021-2027 – Project «**VERTIcALL** (VERTIcal Autonomous Landing)» surface equipped for electrically powered vertical take-off and landing aircraft (eVTOL, EASA SC-VTOL-01) as cargo drones and two-seater air-taxis.

## Thanks for listening

**Andrea Bonci**

a.bonci@univpm.it