Mobile collaborative robots for flexible manufacturing and logistics

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Outline

- Industrial context
- A collaborative and mobile robotic platform for machine-tending tasks in automatic manufacturing lines for packaging:
  - EuRoC EU project
  - MaXima project
  - ROSSINI EU project
- A modular and reconfigurable mobile robotic platform:

  FlexCobot project
- Conclusions

Industrial Context

Re-shoring [1]

Ageing workforce [2]

Factory line [3]

Human-Robot collaboration
as key driver for
manufacturing sustainability

Collaborative

Robotics

Low cost, light weight and high degree of flexibility

Fenceless, shared working environment

Low impact on factory layout and facilities

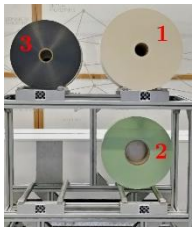
Possibility of being mounted on mobile robots

[1] Source: https://www.qualenergia.it/articoli/verso-il-reshoring-dei-settori-industriali-green-negli-scenari-post-covid/
[2] Source: https://www.icare.nsw.gov.au/employers/industry-and-partners/industry-hub/preventing-injury/managing-an-ageing-workforce/#gref
[3] Source: Videoclip from Samsara documentary movie.

A mobile robotic platform for machine-tending tasks in automatic packaging manufacturing lines

IMA S.p.A. is a world leader in the design and production of **automatic machines** for the processing and packaging of:

- Pharmaceuticals
- Cosmetics
- Food
- Coffee
- **Tea**



Example of a C-24E tea-packaging automatic machine [1]

Problem

Packaging machines periodically require a refill of the raw materials used to form the box and its content, e.g. reels and cardboards blanks.

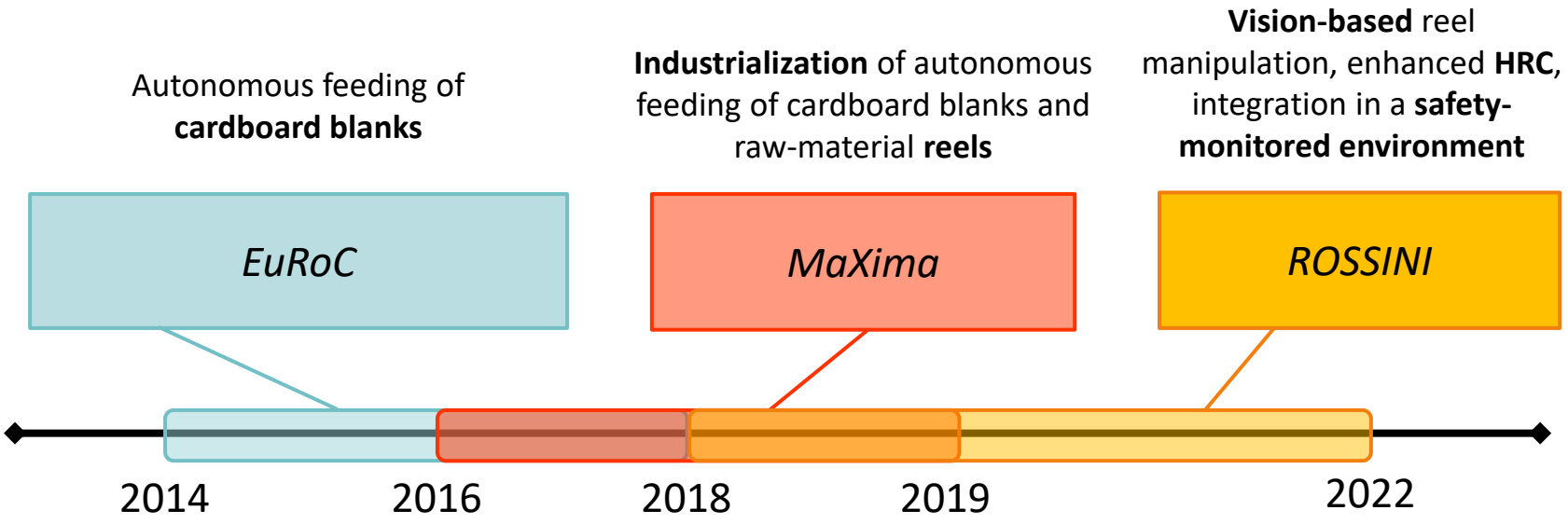
- The effort does not justify the employment of an operator assigned to only this task or a dedicated fixed robot
- Repeated loss of concentration
- Source of physical distress for human operators (weights up to 12 kg)
- Waste of time to move from current job location to machine location

A mobile robotic platform for machine-tending tasks in automatic packaging manufacturing lines

Envisioned solution

Employ a combination of sensors, serial manipulator(s) and a mobile vehicle (both characterized by collaborative features) to automatize the raw-material feeding operation to a tea-packaging automatic machine.

Timeline



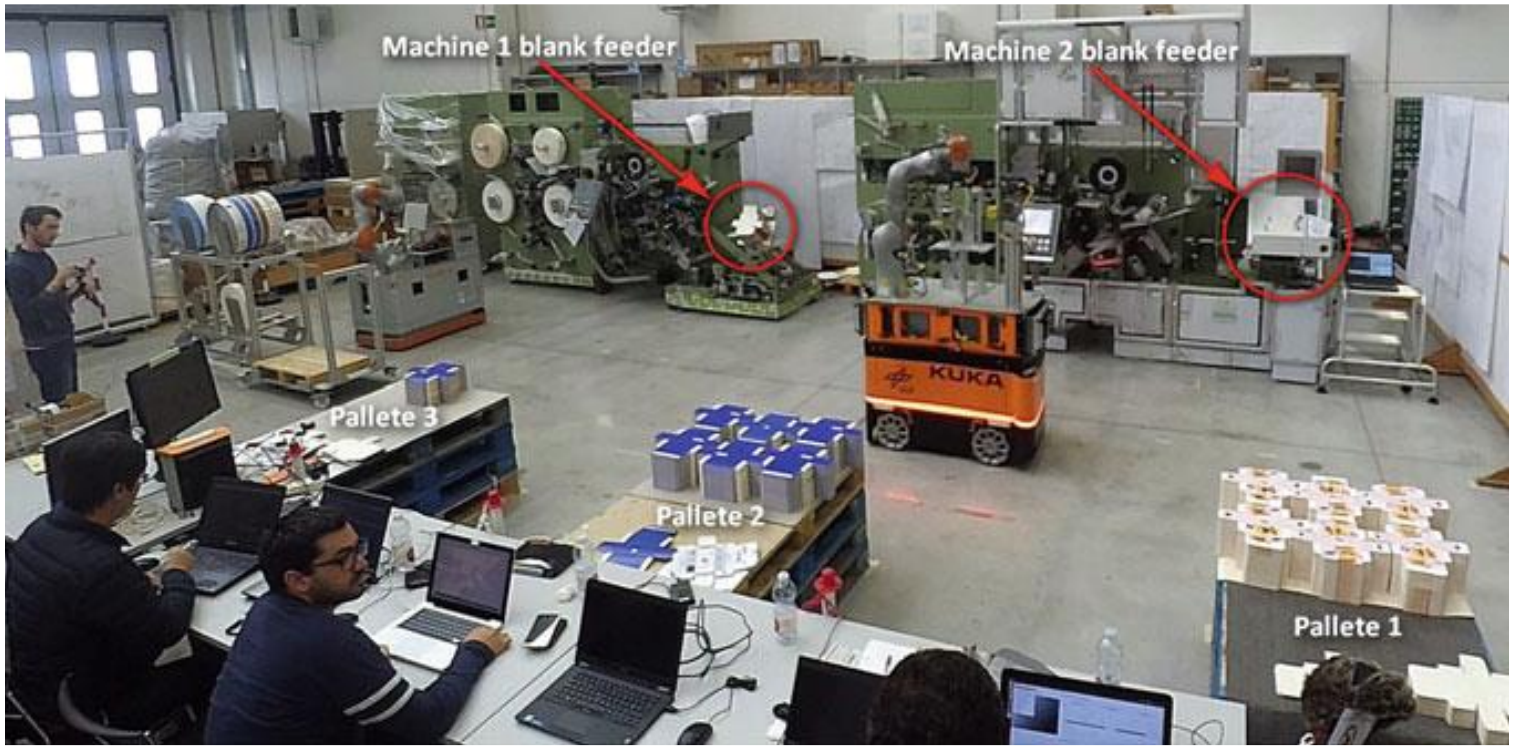
EuRoC project

Features:

- **Blank and pallet identification and pose estimation**
  - Several types of blanks
  - Different orientation of the blanks within the pallet
- **Multiple machine feeding and Planning**
  - Capability to feed more than one machine with the appropriate blank type
  - Prediction and intelligent scheduling
- **Blank grasping and manipulation**
  - Custom gripper with capabilities for grasping distinct types of blanks
- **Safety management**
  - Navigation and manipulation in a human-shared environment
- **Advanced communication/interaction**
  - Multimodal interface between the robotic platform and the human operator (gestures, text-to-speech, visual feedback on a tablet, graphical user interface)

EuRoC EU project

Field setup

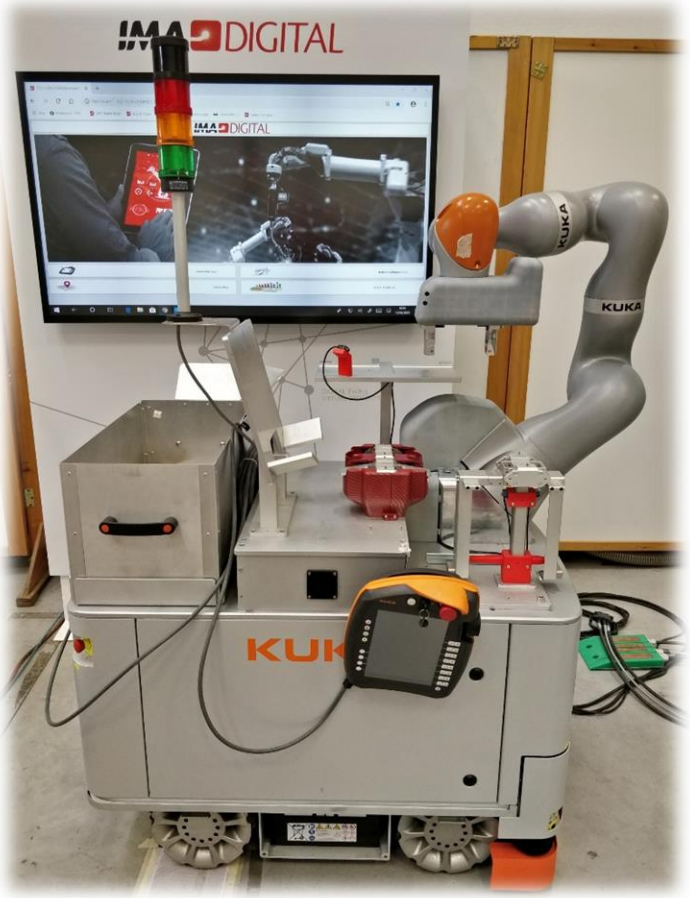


E. Pedrosa, G. H. Lim, F. Amaral, *et al.*, "TIMAIRIS: Autonomous Blank Feeding for Packaging Machines," in *Bringing Innovative Robotic Technologies from Research Labs to Industrial End-users: The Experience of the European Robotics Challenges*, Cham, CH: Springer International Publishing, 2020, pp. 153–186

MaXima project

- *Multiple Actions for Innovation in Machine Automation*
- Partially funded by the Italian Ministry of Economic Development

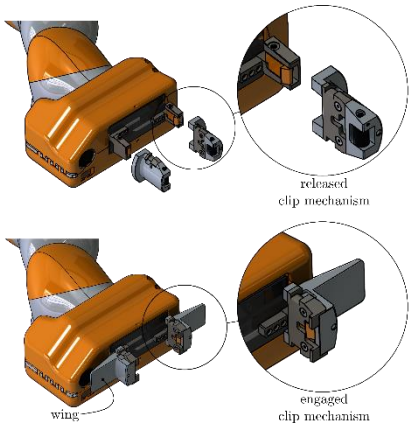
- **Main goals:**
  - bring the results and lessons learned in EuRoC into a real-case scenario
  - automatize the change of not only blanks but also raw-material reels
  - make the robotic system better suited for an industrial use and thus marketable

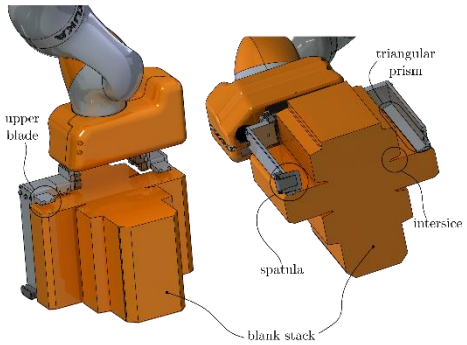


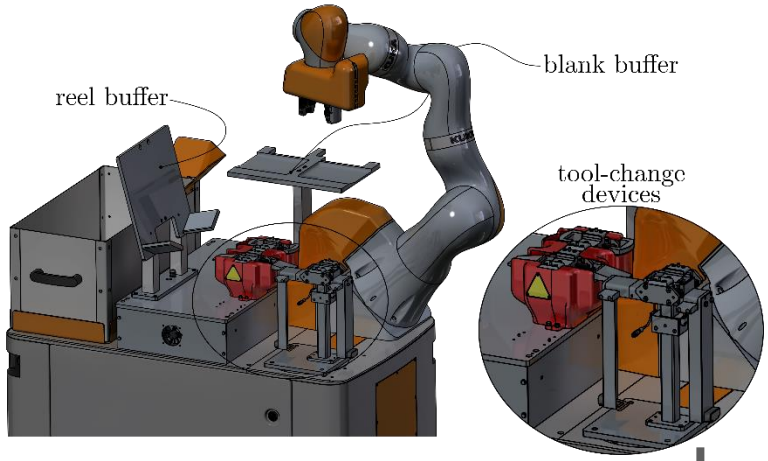
S. Comari, R. Di Leva, M. Carricato, et al., "Mobile cobots for autonomous raw material feeding of automatic packaging machines," *Journal of Manufacturing Systems*, vol. 64, pp. 211–224, 2022

MaXima project

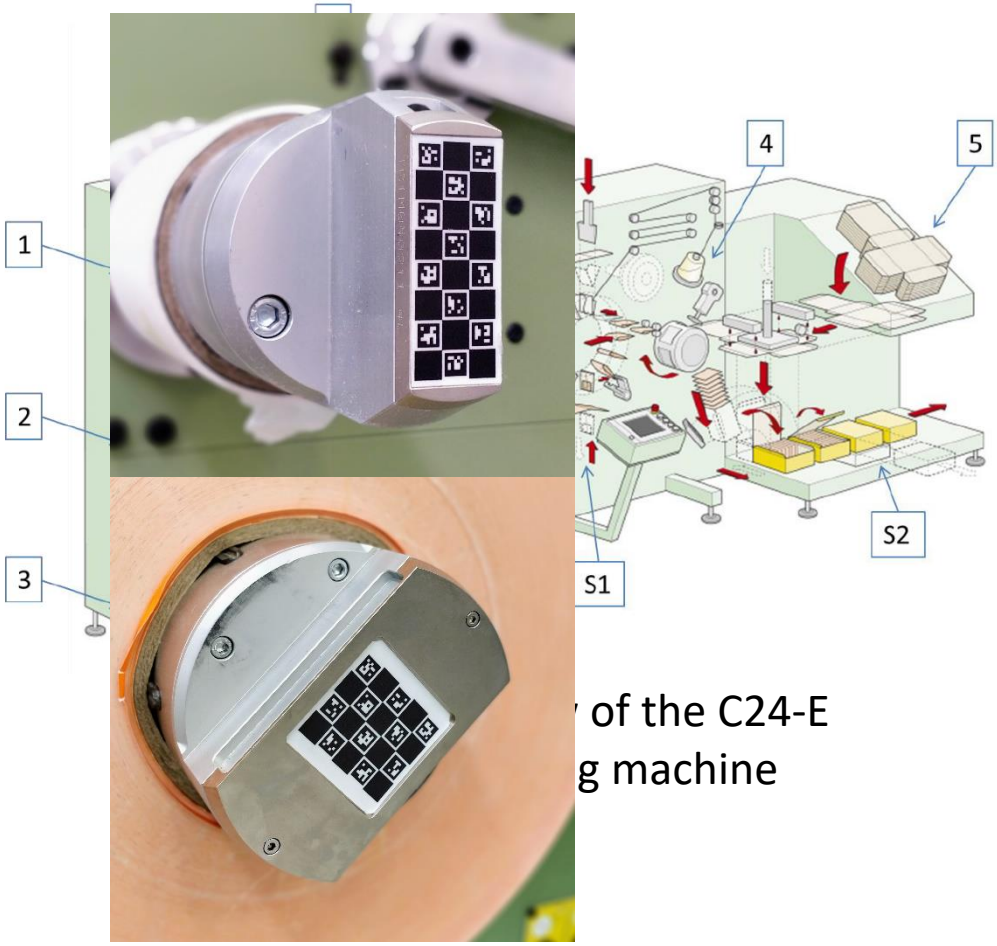
- A few adjustments to the EuRoC hardware:
  - Removal of the 3D vision system → KUKA AGV perception (laser scanners) was used to manage both safety and localization
  - Design of custom gripper fingers for distinct reel manipulation
  - Implementation of an automatic tool changer installed on board for fast finger change
  - Laser pointer at end-effector for reel-center detection
  - Use of ChArUco markers for accurate pose estimation of objects in the robotized cell







MaXima project

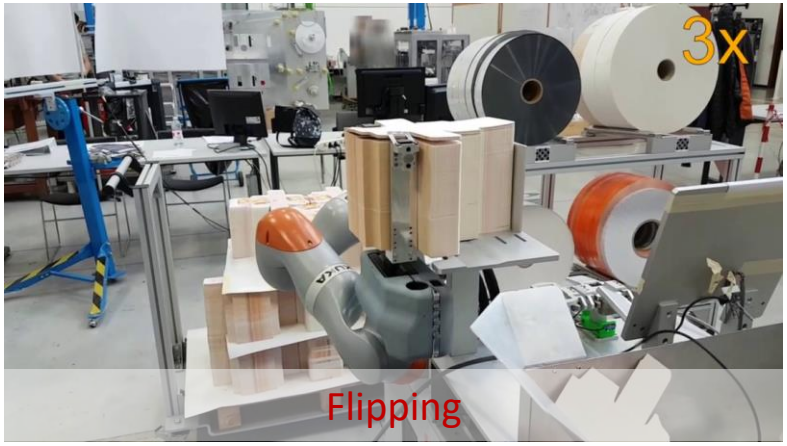


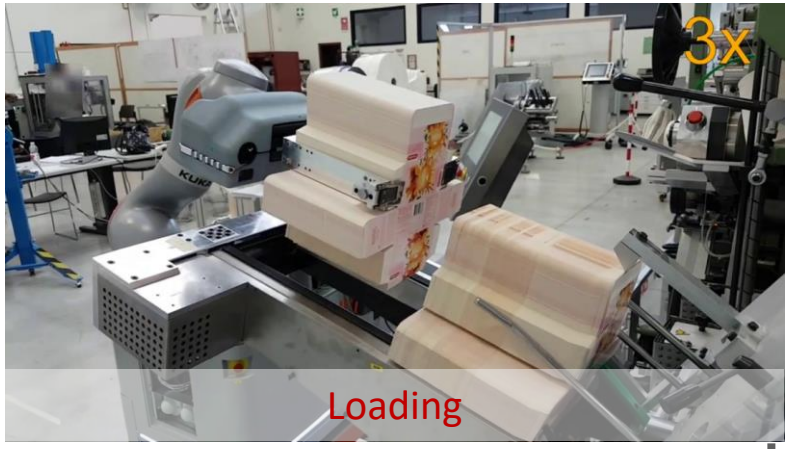
of the C24-E
g machine

Local warehouse («wagon»)

MaXima project

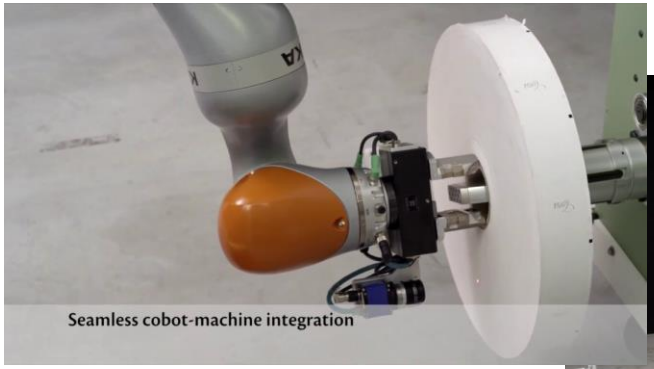
Blank feeding

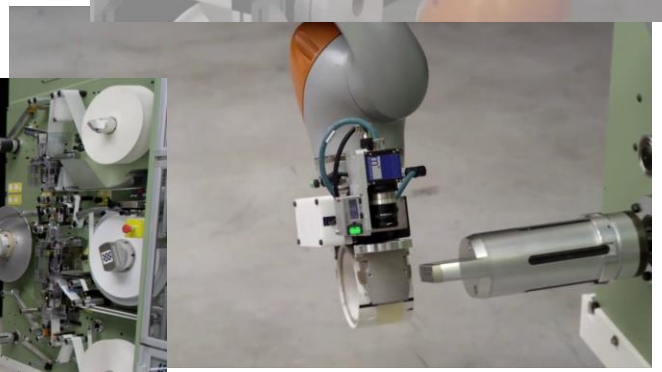




MaXima project

Reel loading



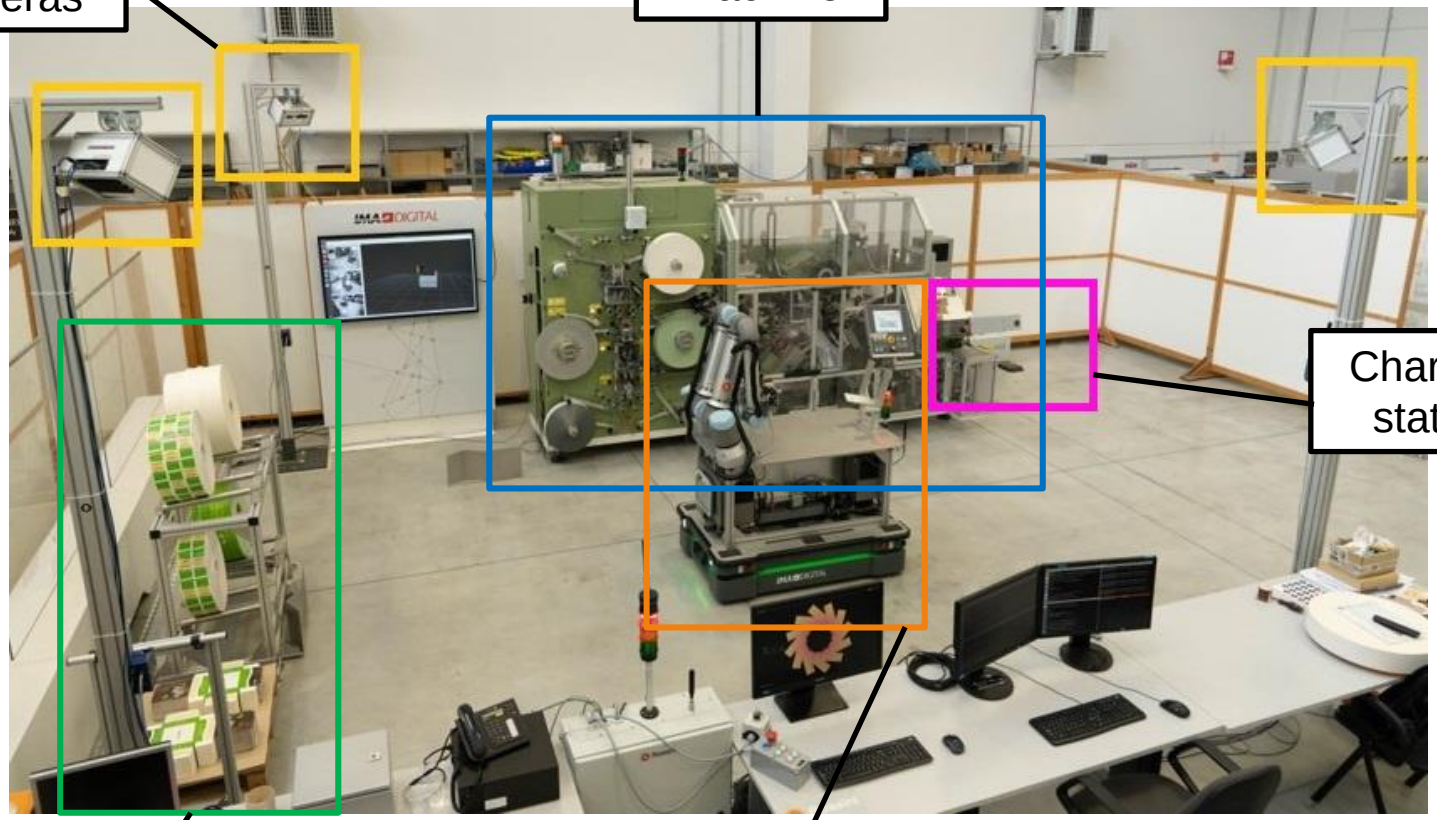


ROSSINI project

- *RObot enhanced SenSing, INtelligence and actuation to Improve job quality in manufacturing*
- **Main partners**: Datasensing, University of Modena and Reggio-Emilia
- **Goal**: design, develop and demonstrate a modular and scalable platform for the integration of human-centred robotic technologies in industrial production environments.

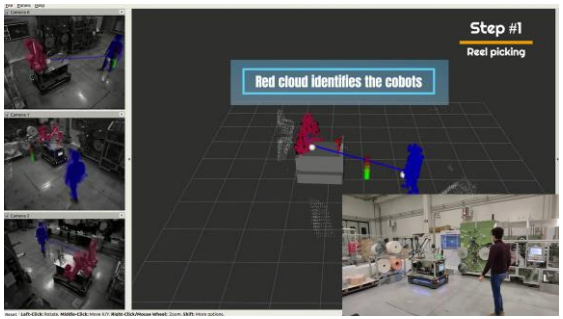
Rossini

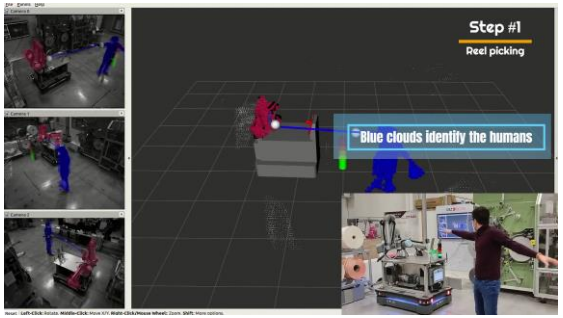
ROSSINI project

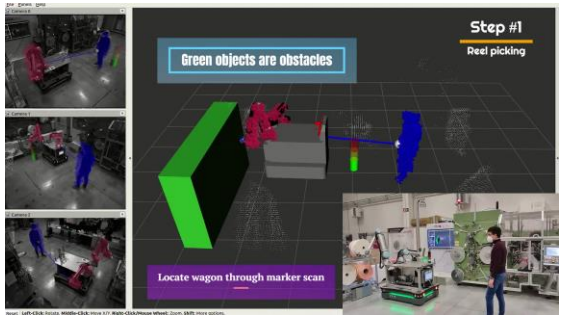


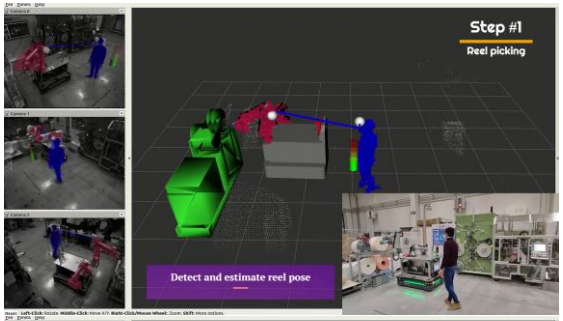
ROSSINI project

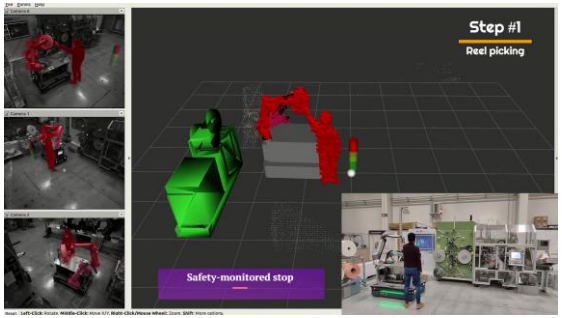
Autonomous paper-reel change in a safety-monitored work cell

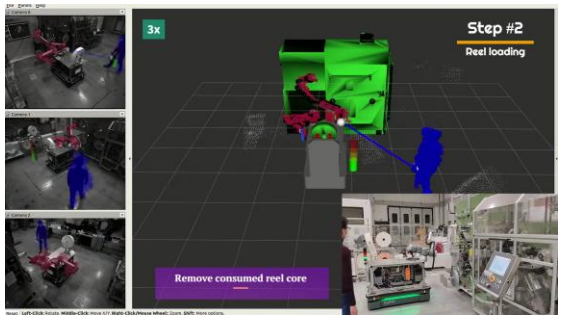


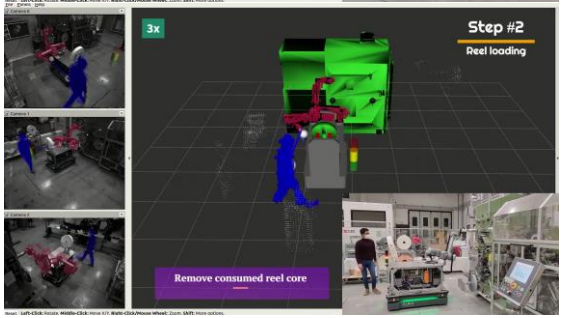


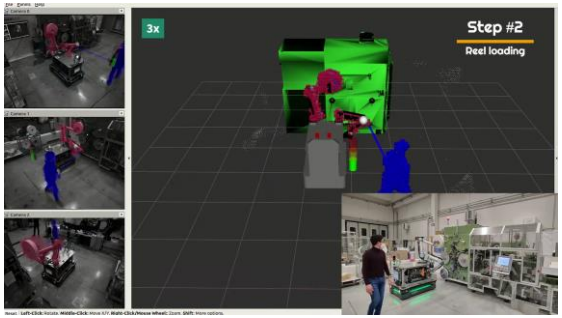












SENECA Project

- *Systems ENabling Efficient Cognitive Automation*
- **Main partner**: IMA Active
- **Main goals:**
  - investigating the usage of artificial intelligence techniques to automatize processes that currently require skills from a human agent,
  - cleaning pharmaceutical bins (containers used for storing, manipulating or mixing powders) up to a level known as critical.

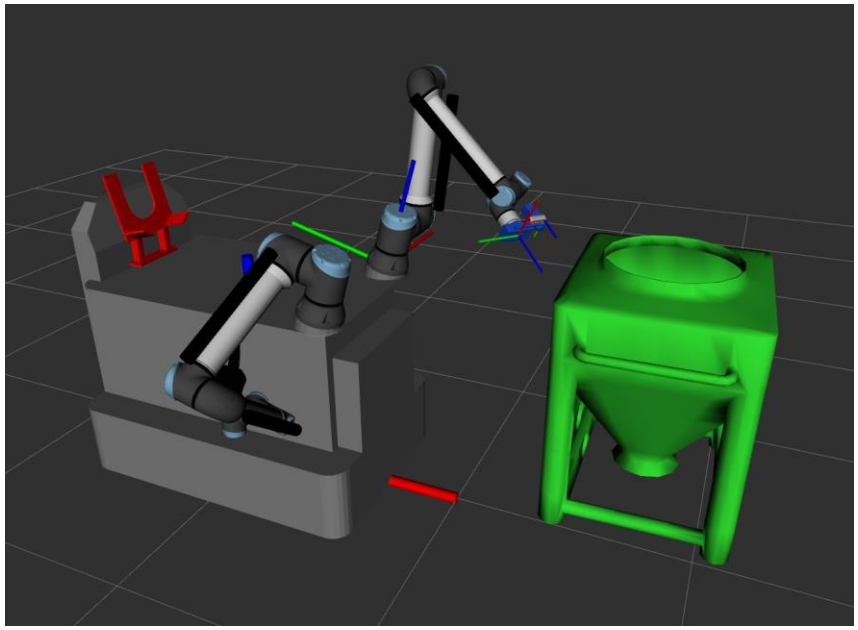
Current solutions:

1. *Atlantis*: specialised fully automatic washing booths
   - repeatable high standards of cleanliness
   - large dimensions, limited number of processable bins
2. *Hydrowash*: mobile module with a cleaning room
   - very flexible (can be used to clean any bin)
   - require a human operator to manually carry out the operation (subject to errors, low repeatability)

SENECA Project

- **Hardware**

- The operation can be completely automated by replacing a human operator with a robotic arm.
- The robotic arm can:
  - scan the inner and outer surface of the bin by using a RGB camera to recognize clean and dirty areas,
  - perform the cleaning operation by using a washing nozzle.
- The mobile robot allows an optimal placing of the arm with respect to the bin.

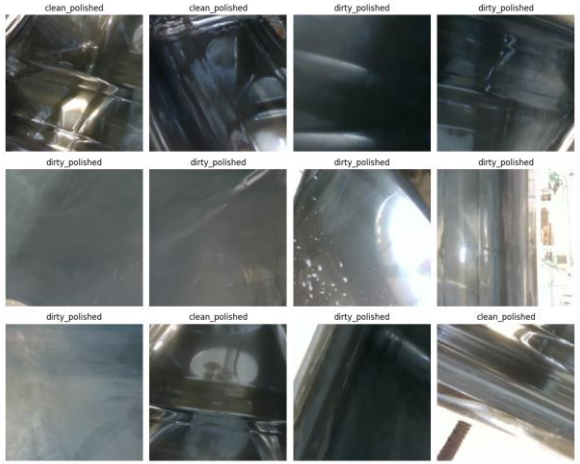


S. Comari, M. Carricato, "Autonomous Scanning and Cleanliness Classification of Pharmaceutical Bins through Artificial Intelligence and Robotics," submitted to *IEEE Access,* 2024

SENECA Project

Operation

- bin identification through a visual marker,
- on the basis of a 3D-model of the bin, an optimal set of viewpoints is identified for surface scanning,
- a virtual twin of the scene is used for collision-free trajectory planning of the robot,
- the inner and outer surfaces of the bin are scanned,
- artificial intelligence is used to identify clean and dirty areas,
- optimal washing trajectories are computed,
- the robotic arm performs the cleaning operation by using a washing nozzle.



SIMOD Project

- *Multi-robot mobile systems for the manipulation of deformable objects*
- **Main academic partners**: University of Modena and Reggio Emilia, U. of Ferrara, U. of Parma.
- **Main industrial partners**: Elettric80, IEMA, Aimag.
- **Goals:**
  - robotic manipulators installed on mobile platforms for perception and co-manipulation of deformable objects in industrial applications:
  - Use cases: electric wires, soft packaging, garbage bags.

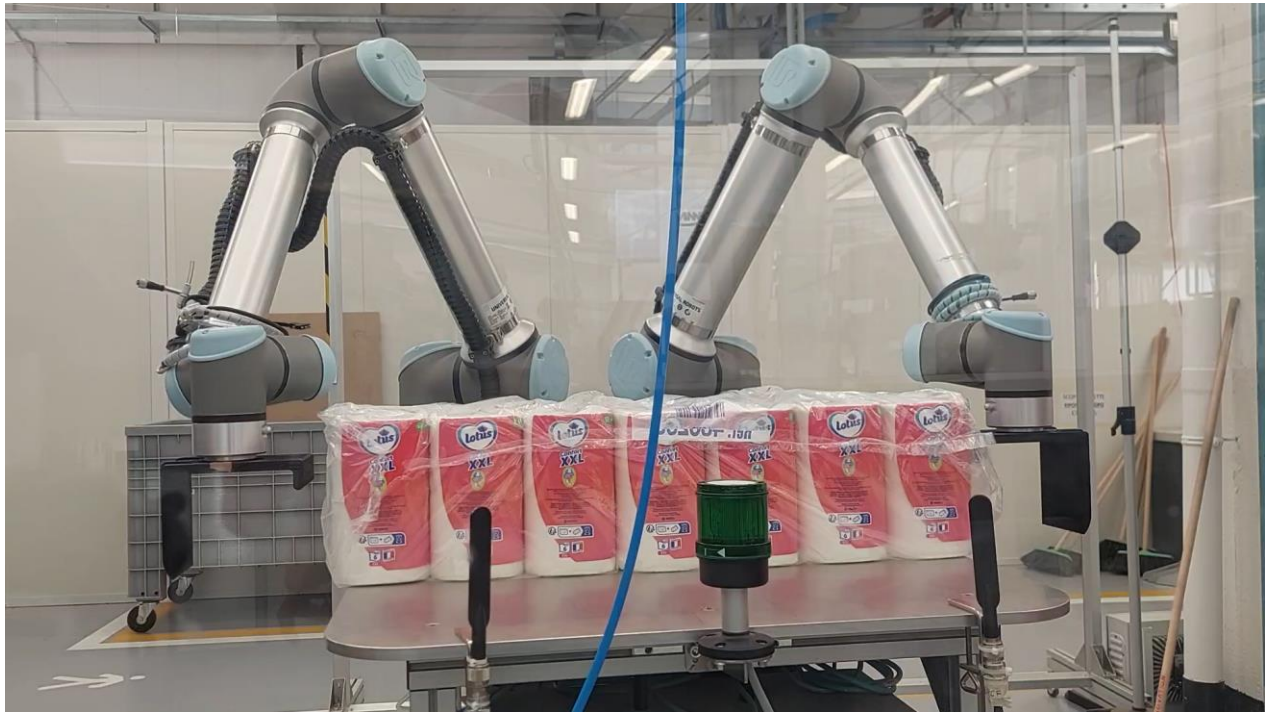
SIMOD Project

- **Current Scenario**

https://www.youtube.com/watch?v=RxZE4PiOKT8

SIMOD Project

- **Envisioned scenario**



FlexCobot Project

- *Collaborative robotics for advanced, interconnected and flexible manifacturing systems*
- **Main partner**: Alascom
- **Goals**
  - Reconfigurable and modular mobile manipulator
  - Pick&place operations between different work locations
  - Transport of goods within the plant
  - Decoupling between the mobile platform and the cobot

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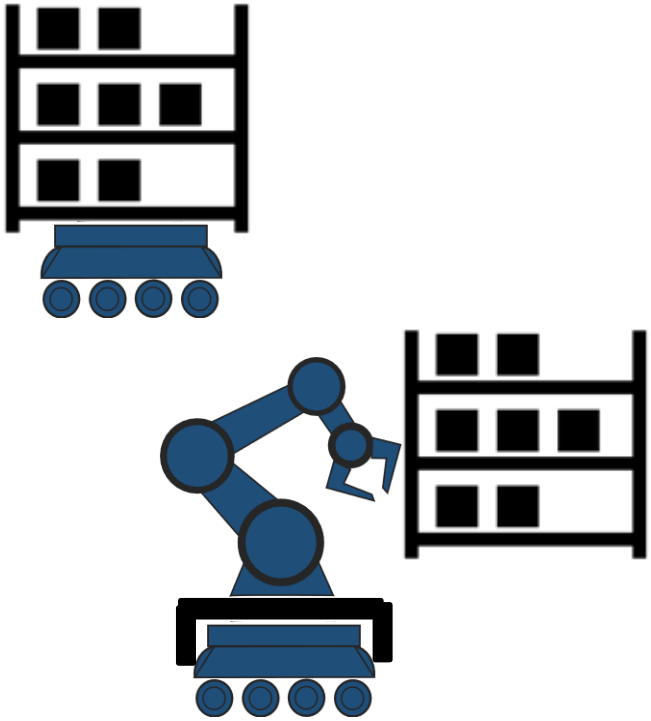
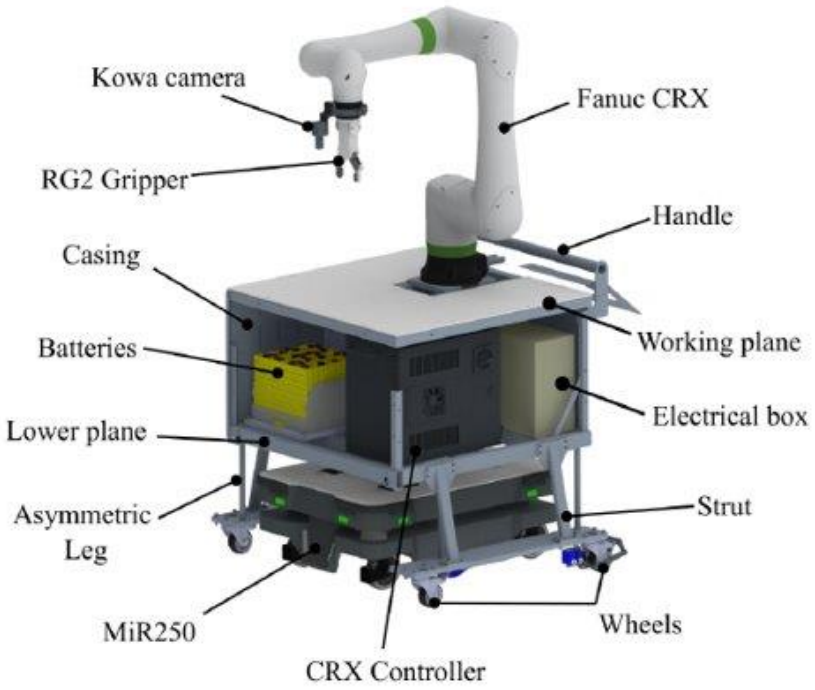


1. A. Baldassarri, M. Bertelli, and M. Carricato, "Design of a Reconfigurable Mobile Collaborative Manipulator for Industrial Applications," *ASME Journal of Computational and Nonlinear Dynamics, 18(9), Paper No. 091006, pp. 1-8.*

FlexCobot Project

- **Hardware**



- The cobot is installed on a mobile cart with 4 braked wheels.
- 4 asymmetric legs at the bottom of the cart are used by the MiR base laser scanners as a reference for the coupling procedure.
- Coupling is secured by vertical pins engaging the cart.
- The cobot is mounted on a telescopic actuator, which enables it to work at different heights.
- Compensation of the MiR positioning error is performed through computer vision algorithms, an eye-on-hand 2D camera and Charuco markers.

FlexCobot Project

- **Use cases**

  A. Pick&place of a tray

  1. The AMR couples with the cart
  2. The AMR transports the cart to the warehouse and decouples from it
  3. The telescopic column is lifted
  4. The cobot snaps a photo of the ChArUco marker
  5. The photo is post-processed to identify the pose of the ChArUco marker
  6. The tray is picked
  7. The tray is placed on the cart
  8. The AMR couples with the cart
  9. The AMR transports the cart to a different working location

Conclusions

- **Mobile robotic manipulator for machine-tending tasks**

EuRoC

- Autonomous feeding of cardboard blanks
- Custom gripper fingers for handling the cardboard pile
- A vision system for blank identification and manipulation
- Shared environment with the human operator (no interaction)

MaXima

- Industrialization of autonomous feeding of cardboard blanks and raw-material reels
- Custom gripper fingers for reel manipulation
- Vision-based reel manipulation
- Real-case industrial scenario

ROSSINI

- Enhanced Human-Robot Collaboration
- Integration in a novel safety-monitored environment
- Realtime digital twin of the working area

Conclusions

- **Automatic scanning and cleaning**

SENECA

- Automatic scanning-path generation of a 3D object
- Binary classification of images through AI
- Robotic manipulation relieving a human operator from repetitive and cumbersome job

- **Reconfigurable mobile manipulator for pick&place and logistic operations**

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FlexCobot

- Autonomous pick&place tasks
- Autonomous transport of goods
- Decoupling between cobot and mobile platform

Thank you for your attention

Q&A