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LMS
Laboratory for Manufacturing Systems & Automation

RIS Industry 4.0 Hubs

Robots & Co-bots

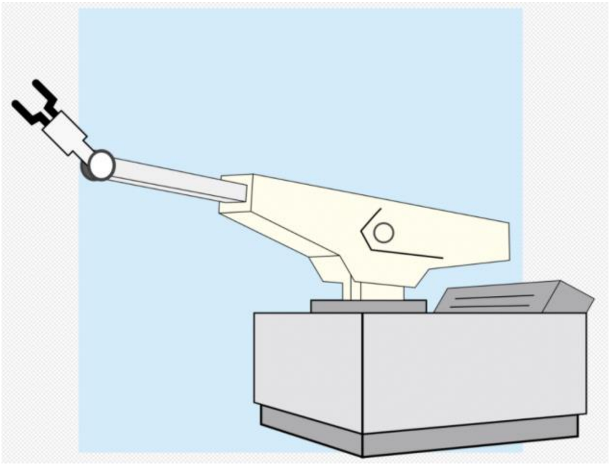
EIT Manufacturing is supported by the EIT, a body of the European Union

27 May 2021

Contents

Industrial Robot

- Comes from the Czech word “robota”, denoting forced labour or serf
- First used in story published in 1942 by Isaac Asimov
- First industrial robot came into existence in 1956 by George Devol



Unimate robot
(U.S. Patern 2,988,237)

Industrial Robot

- A programmable multi-function machine
    - Lead through programming
    - Programming languages
    - Simulation and offline programming
- Consists of a number of rigid links, moved by a motor and controlled by a PLC.
- Capable of performing a variety of tasks

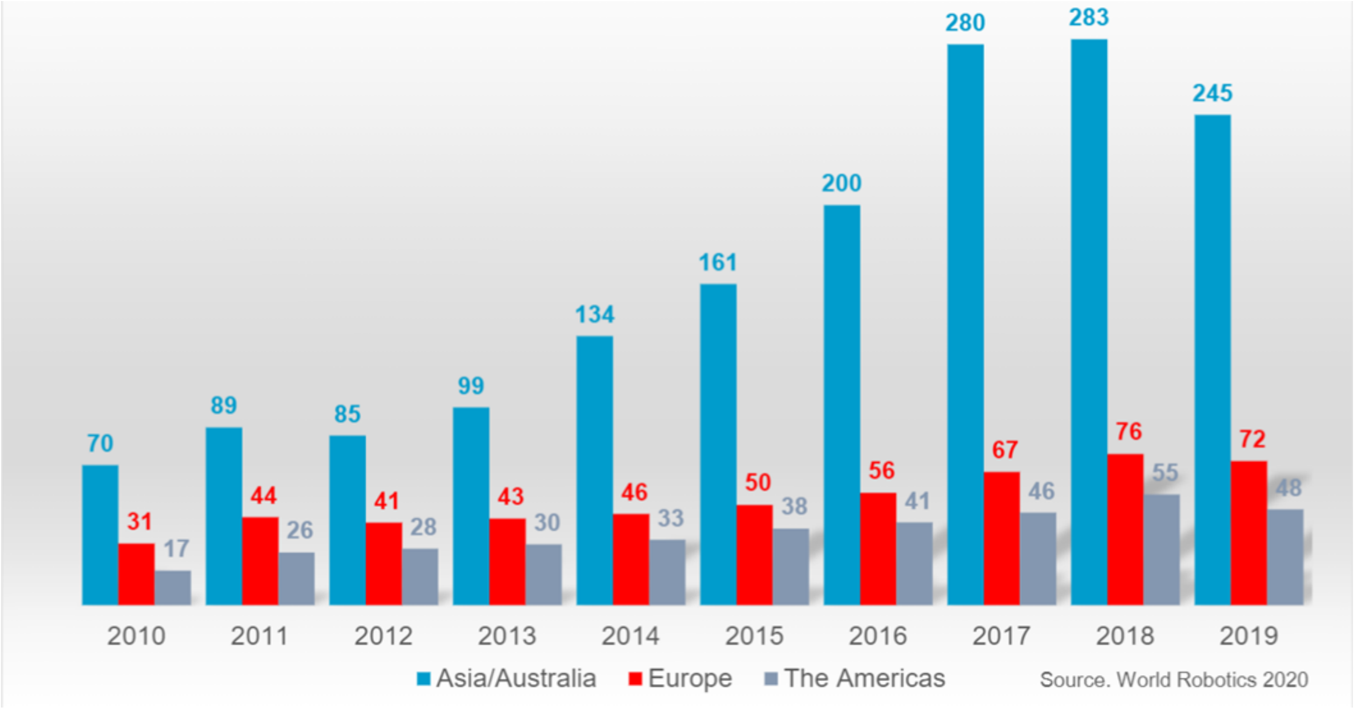
Advantages

- Programmable
- Fast
- Consistent
- Precise
- Reduced product damage
- Suitable for hazardous environments
- Lower labour costs

Disadvantages

- Investment cost
- Maintenance
- Energy consuming
- Autonomous operation
- Reduced adaptability
- Safety issues
- Replacing humans

Annual installations of industrial robots



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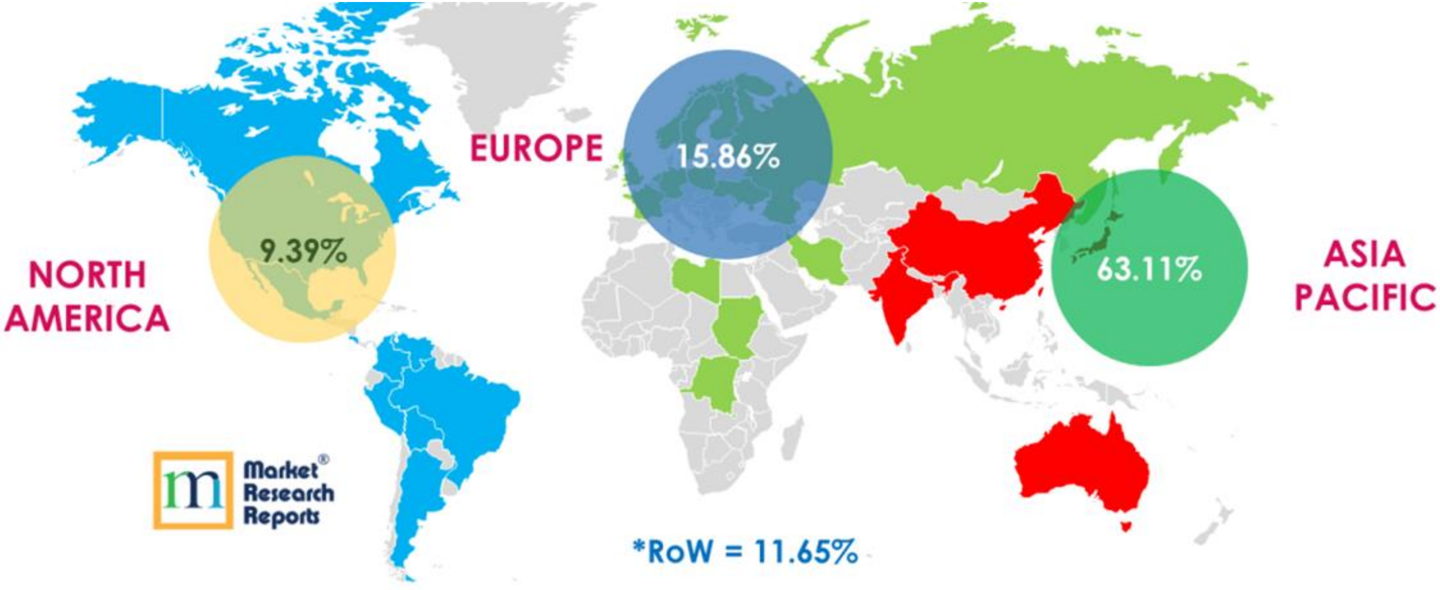
Industrial robotics market share by geography



Note : The 2019 Market Shares are Estimated.
*Row = Rest of the World

Company	Head Quarter
ABB	Zurich, Switzerland
YASKAWA	Kitakyushu, Japan
KUKA	Bavaria, Germany
FANUC	Yamanashi Prefecture, Japan
Kawasaki	Tokyo, Japan

Industrial Automation

- Robots are not profitable for small assembly lots or changing products

Robot vs Human Skills

Durability	Flexibility
Strength	Adaptability
Speed	Agility
Accuracy	Communication

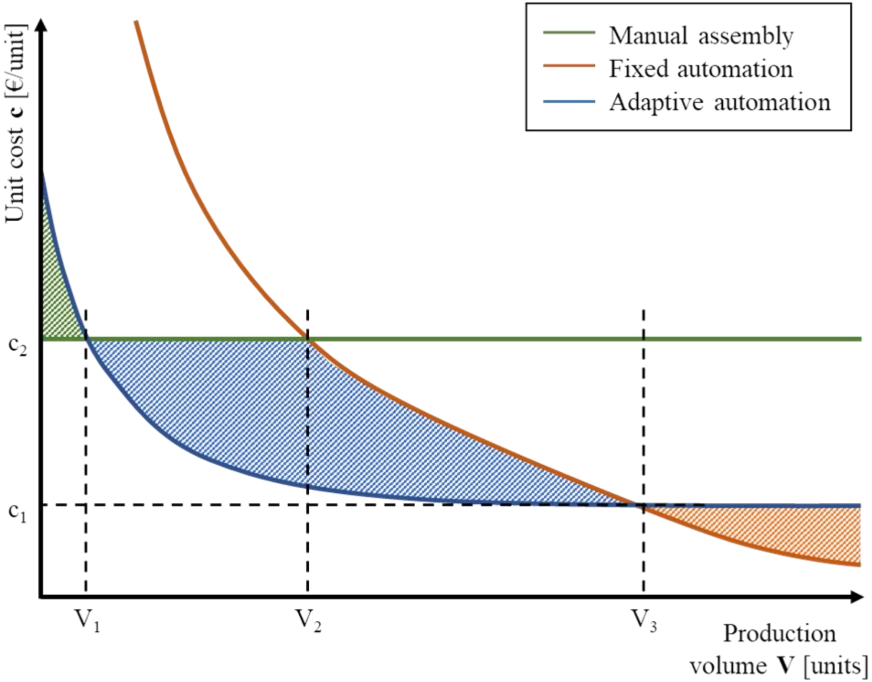
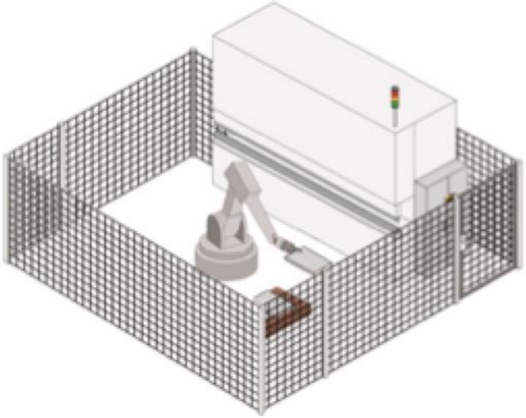
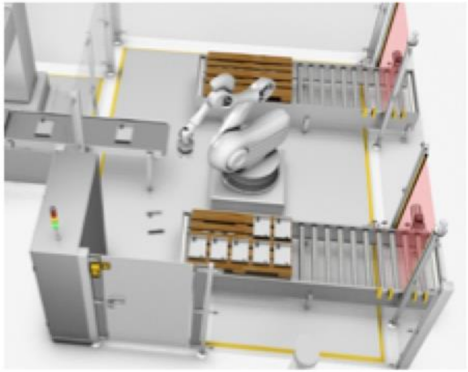


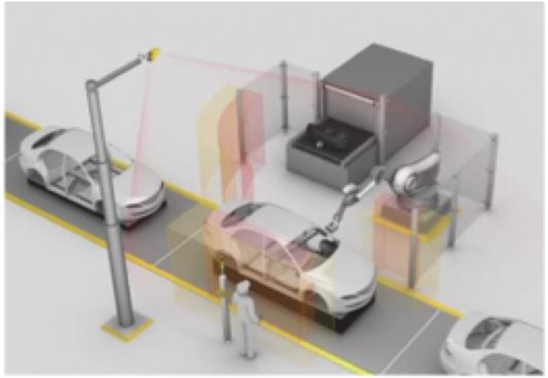
***Figure adapted from*:**
Schmidt, A. (2018). Two years' Experience with Cobots in a Low Volume Manufacturing Environment.

Human Safety

- Industrial robots operate (usually) in isolation

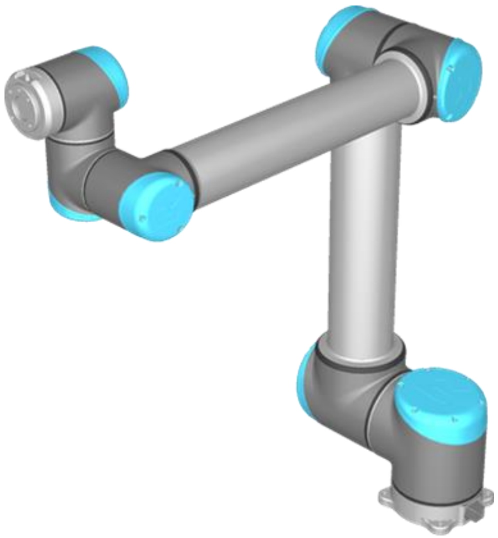






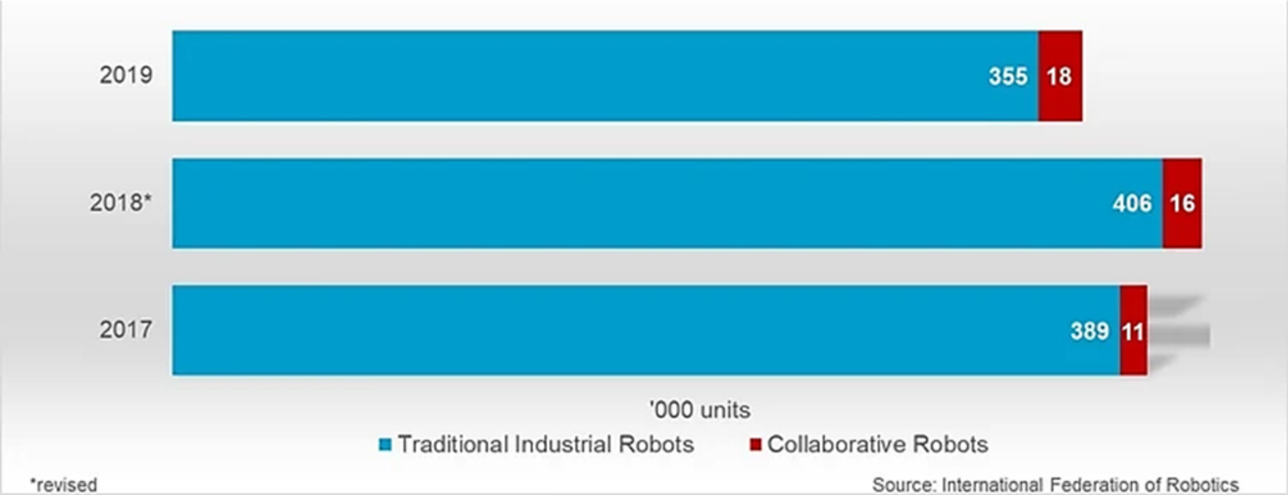
Collaborative Robots

- Designed to safely interact with humans in a shared workspace
- Force-limited joints and computer vision to detect the presence of humans in their environment
- Much smaller and lighter, easily moveable, and trainable to perform specific tasks



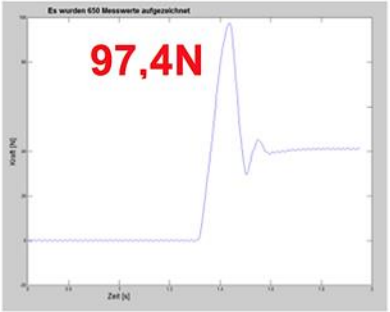
Robot/Co-bot installations

- Humans and co-bots offer a unique level of skill, which results in manufacturing products far better and faster



Human Safety Validation

- Essential to carry out a risk assessment
- Annex G in EN ISO 10218-2 for industrial robot
- ISO/TS 15066 annex A for collaborative robots



Body Region		Specific Body Area	Quasi-Static Contact: Peak Pressure p_s [N/cm2]	Quasi-Static Contact: Force [N]
Hands and fingers	17	Forefinger pad D	298	135
	18	Forefinger pad ND	273	
	19	Forefinger end joint D	275	
	20	Forefinger end joint ND	219	
	21	Thenar eminence	203	
	22	Palm D	256	
	23	Palm ND	260	
	24	Back of the hand D	197	

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Digital Solutions for Robotics

in

Manufacturing

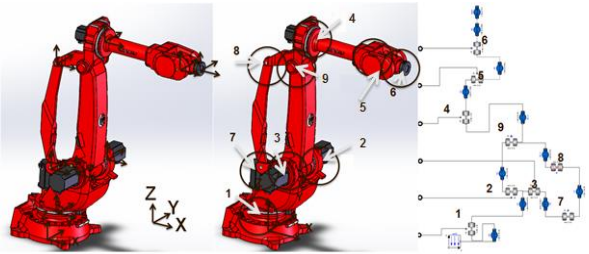
Applications (1/3)

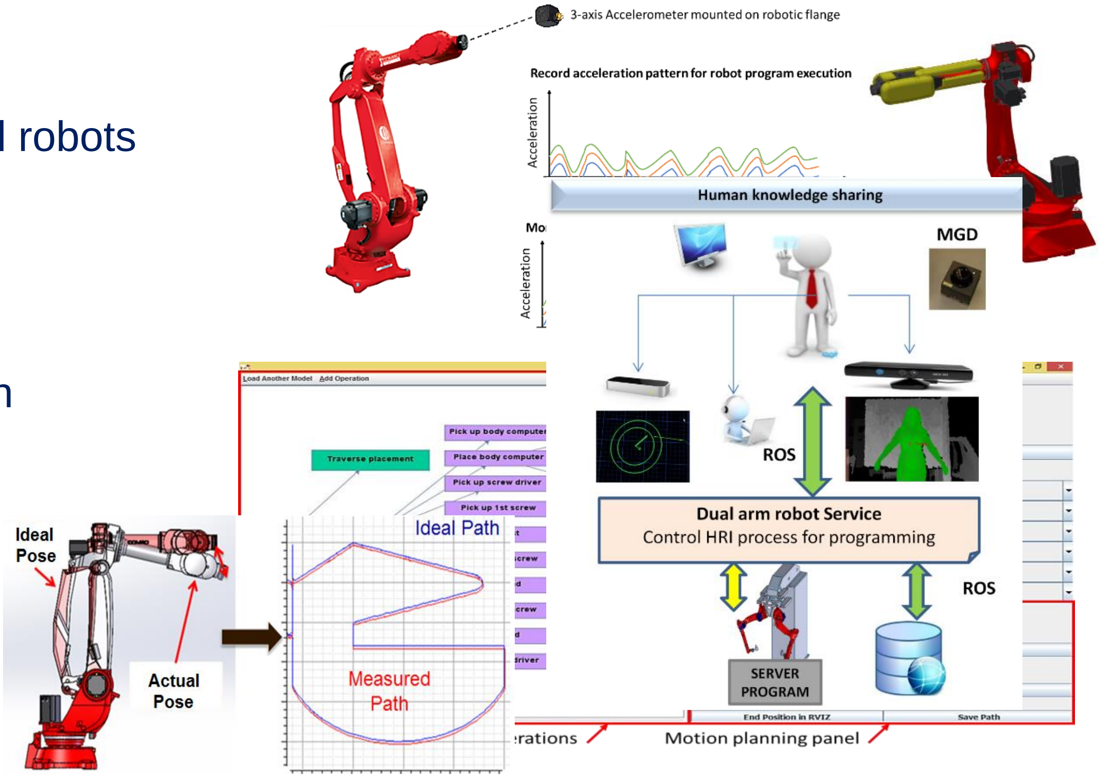
Cooperating robots

1. Robot to human – industrial robots
2. Robot to robot
3. Dual arm robot

Performance - Accuracy

1. Robot models for simulation
2. Robot models for control

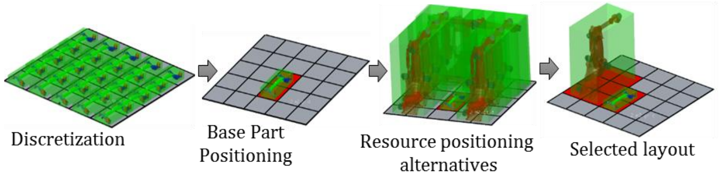




Applications (2/3)

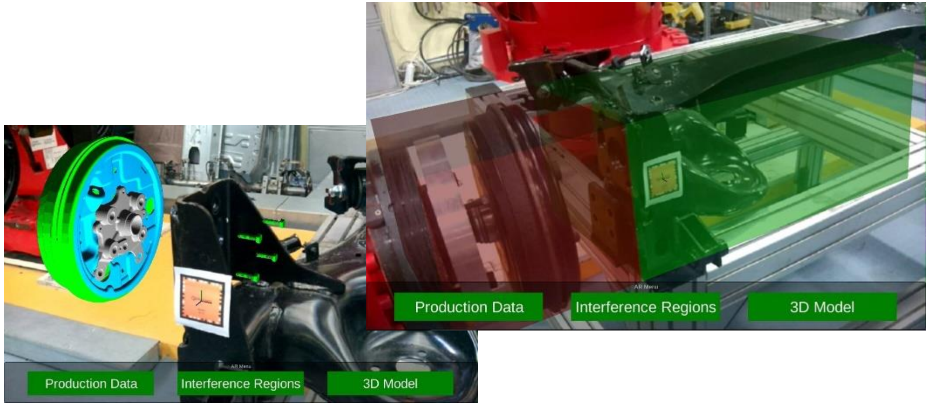
Planning of Human robot shared tasks

1. Task simulation
2. Allocation and scheduling between human operators and robots



AR based human robot collaboration

1. Visualization of cooperative tasks
2. Robot trajectory visualization
3. Alerts and safety related



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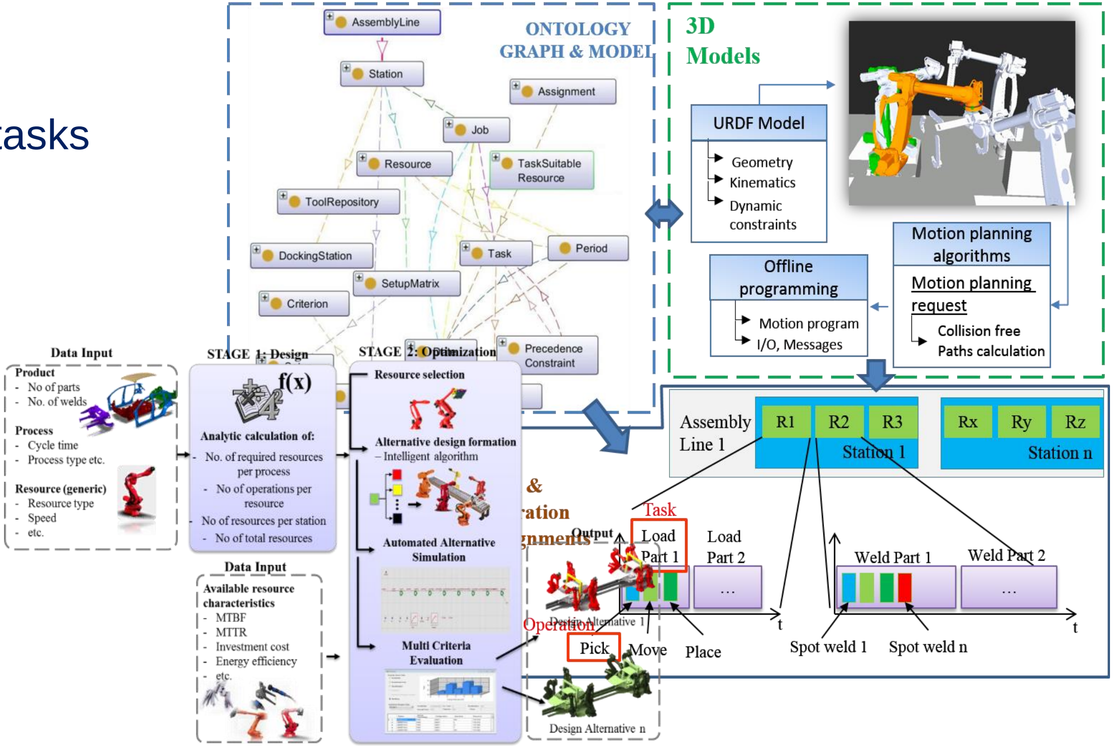
Applications (3/3)

Line design
1. Task simulation
2. Allocation and simulation of tasks

Control software
1. Control architecture
2. Systems integration
3. Offline programming

Logistics
1. Simulation
2. Performance assessment



Examples

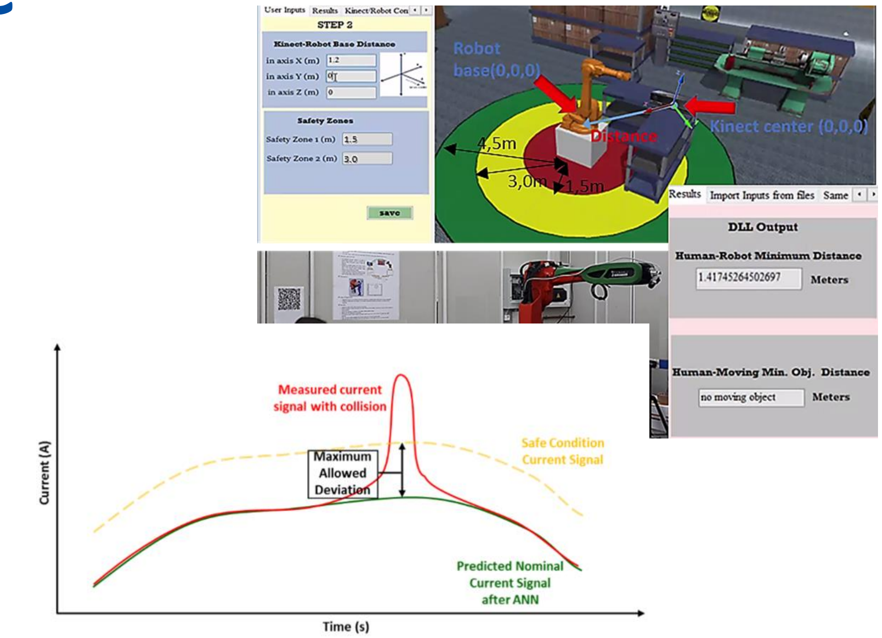
Safety assessment in HRC

Vision system

- Collision Risk assessment
- Proactive safety strategies applied

Power and Force Limiting

- Force detection strategy using current and position values
- Neural Network for predicting robot behavior

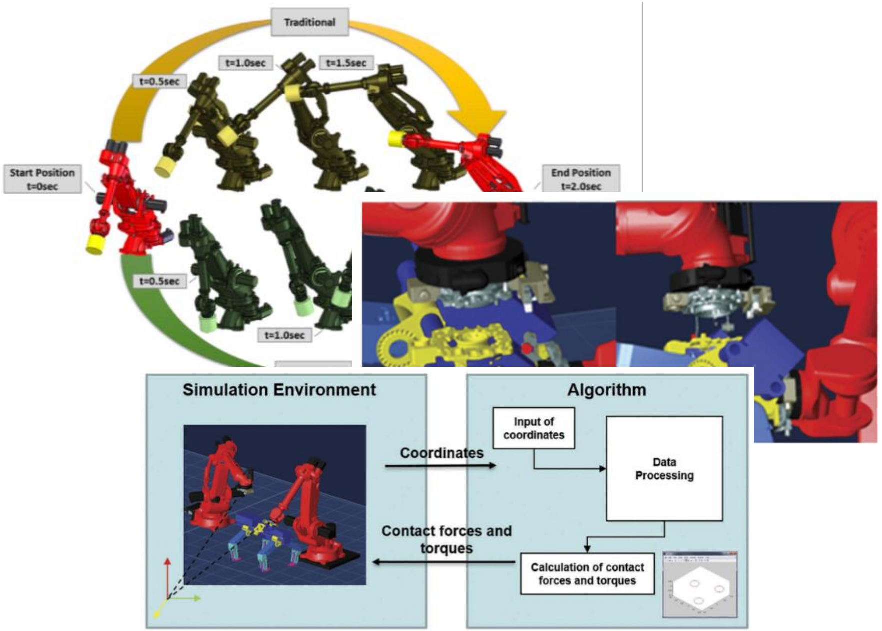


Nikolakis, N., Maratos, V., & Makris, S. (2019). A cyber physical system (CPS) approach for safe human-robot collaboration in a shared workplace. Robotics and Computer-Integrated Manufacturing, 56(October 2018), 233–243. https://doi.org/10.1016/j.rcim.2018.10.003

Aivaliotis, P., et al. "Power and force limiting on industrial robots for human-robot collaboration." Robotics and Computer-Integrated Manufacturing 59 (2019): 346-360.

Modelling & Simulation

- Motion planning
  - For optimizing energy consumption
  - Acceleration profiles
  - Simulation and motion execution update
- Automated tool exchange process
  - Cooperating robots
  - Contact forces and torques
  - Model based automation of the process

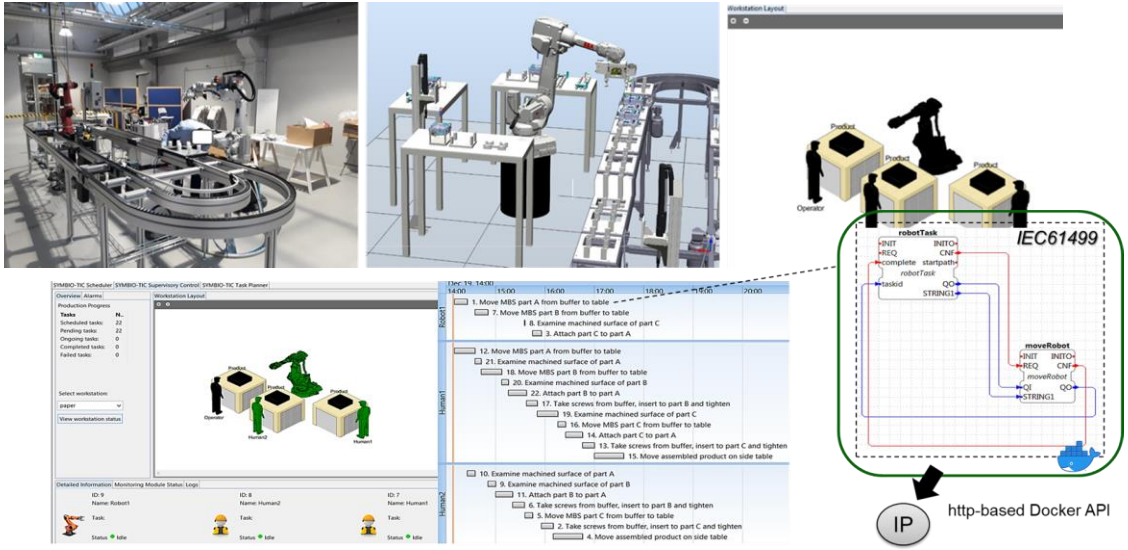


Pastras, Georgios, Apostolos Fysikopoulos, and George Chryssolouris. "A theoretical investigation on the potential energy savings by optimization of the robotic motion profiles." Robotics and Computer-Integrated Manufacturing 58 (2019): 55-68.

Aivaliotis, Panagiotis, George Michalos, and Sotiris Makris. "Cooperating robots for fixtureless assembly: modelling and simulation of tool exchange process." International Journal of Computer Integrated Manufacturing 31.12 (2018): 1235-1246.

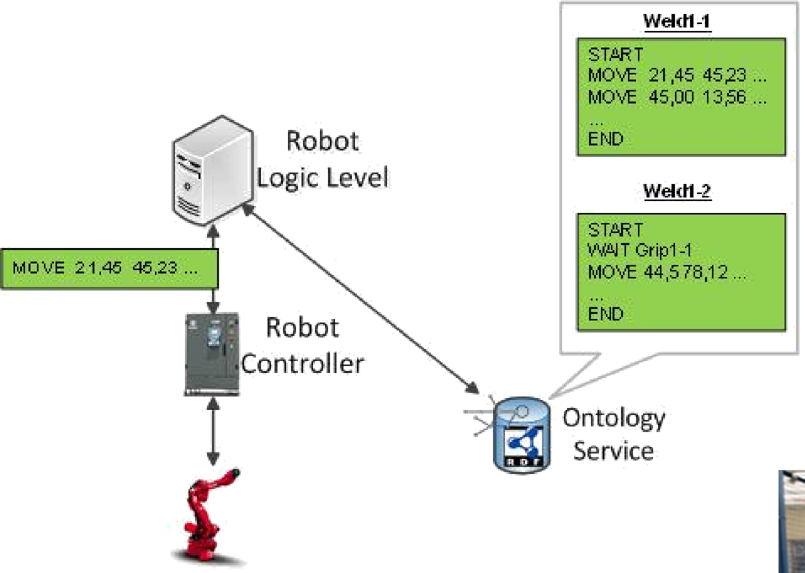
Assembly planning & control

- Virtual station
- Semi-automated CAD-based assembly planning
- Dynamic Scheduling
- End-to-end integration for automated assembly



Nikolakis, N., Senington, R., Sipsas, K., Syberfeldt, A., & Makris, S. (2020). On a containerized approach for the dynamic planning and control of a cyber - physical production system. Robotics and Computer-Integrated Manufacturing, 64(December 2019), 101919. https://doi.org/10.1016/j.rcim.2019.101919

Unit Level: Local Autonomous Decision Making



Michalos, George, et al. "Decision making logic for flexible assembly lines reconfiguration." Robotics and Computer-Integrated Manufacturing 37 (2016): 233-250.

- Local coordination
- Monitoring operations
- Main tasks:
  - ✓ Automated robot program generation, retrieval and execution
  - ✓ Gripper exchange coordination

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Challenges

- High cost of integration/acquisition
- Lack of standards
- Inflexibility
- Balance of speed and safety
- Enabling technologies (sensing, perception, gripping) need to improve

Outlook

- Increasing use
- Use of simulation tools for closing the gap between conceivability and installation/execution
- Simpler integration through industrial connectors, I/Os, communication
- Interactive/Intuitive interfaces facilitating programming and use


Q&A

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Thank you!

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