III Man-Machine Collaboration on a Shop Floor

Flexible Human-Robot Collaboration

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Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry

Why is Human-Robot Collaboration?

Brainstorming ideas to the dashboard on Padlet

Scan me

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Human–Robot Collaboration (HRC) in Manufacturing

Discussion and Presentation

How collaboration between

Human and Robot in manufacturing process

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Human–Robot Collaboration (HRC)

Experience Collaborative Robot Automation with Flex-N-Gate

FANUC America Corporation

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Development of HRC (During 2009-2018)

- Control system of HRC
  - Safety and performance →

vision systems, position systems,
impedance control systems,
admittance control, audio systems.

- Applications
  - Assembly, human assistance, machine tending
- Productivity
  - task allocation, quality increase, reduction of cycle time
- Safety
  - collision avoidance, increase in human ergonomics, reduction of mental stress
- HRI-human robot interaction voice → recognition

(Matheson et al., 2019)

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Control system of HRC

Control systems used in selected human–robot collaboration

- Vision systems
- Position-controlled systems
- Impedance control (e.g., through haptic interfaces)
- Admittance control (e.g., through torque sensors)
- Audio systems (for voice/speech recognition)
- Other systems

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Collaboration methods for HRC

- Hand guiding (HG)
- Safety-rated monitored stop (SMS)
- Speed and separation monitoring (SSM)
- Power and force limiting (PFL)

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Applications of HRC

- Assembly tasks
- Human assistance e.g., handover of parts, quality control tasks
- Machine tending, i.e., loading and/or unloading.

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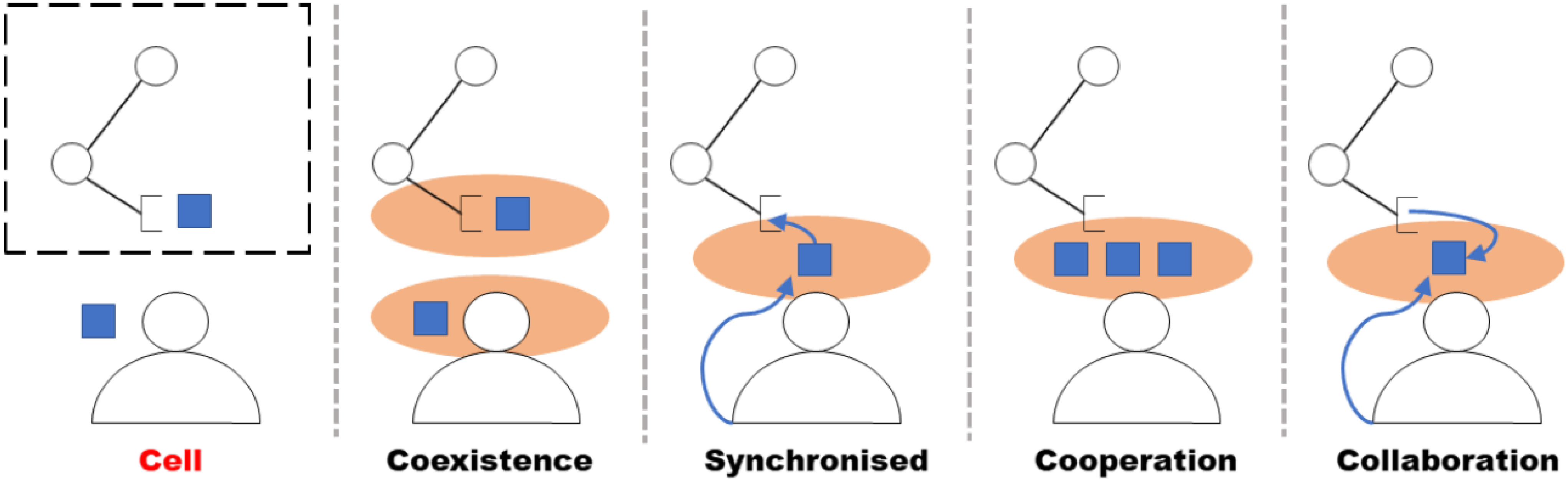
Human–Robot Collaboration (HRC) in Manufacturing

Different Methodologies of Human–Robot Collaboration



(Matheson et al., 2019)

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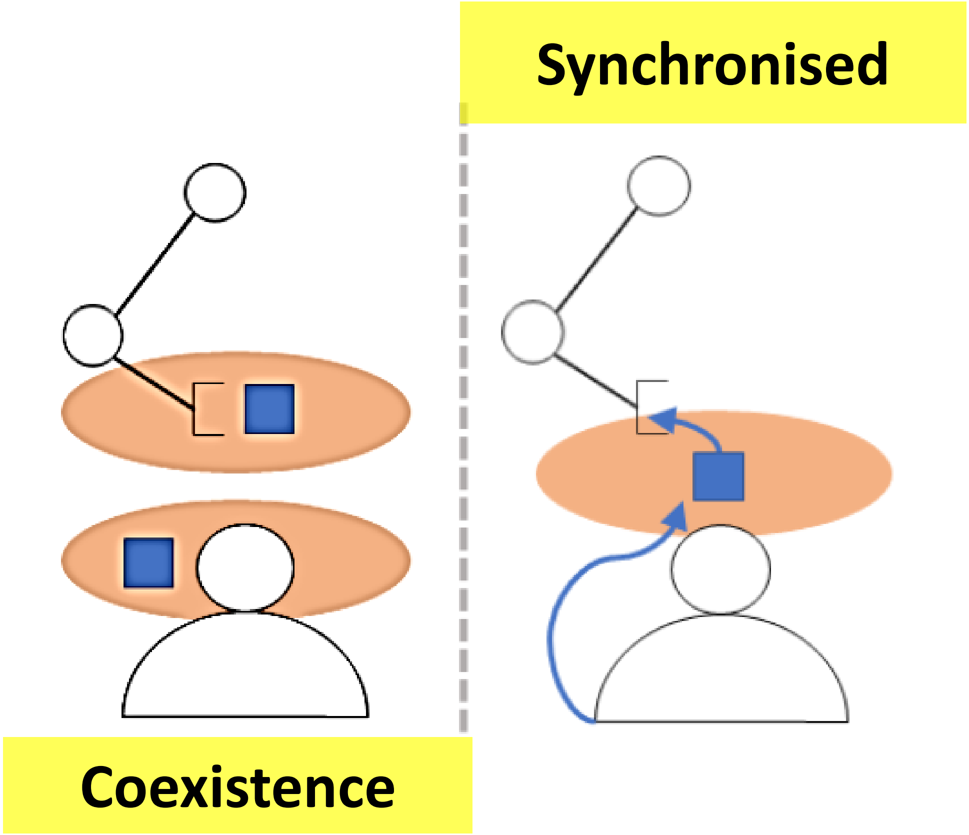
Human–Robot Collaboration (HRC) in Manufacturing

Different Methodologies of Human–Robot Collaboration

Coexistence

Apply when the human operator and cobot are in the same environment but generally do not interact with each other.



Synchronised

Apply when the human operator and cobot work in the same workspace, but at different times.

(Matheson et al., 2019)

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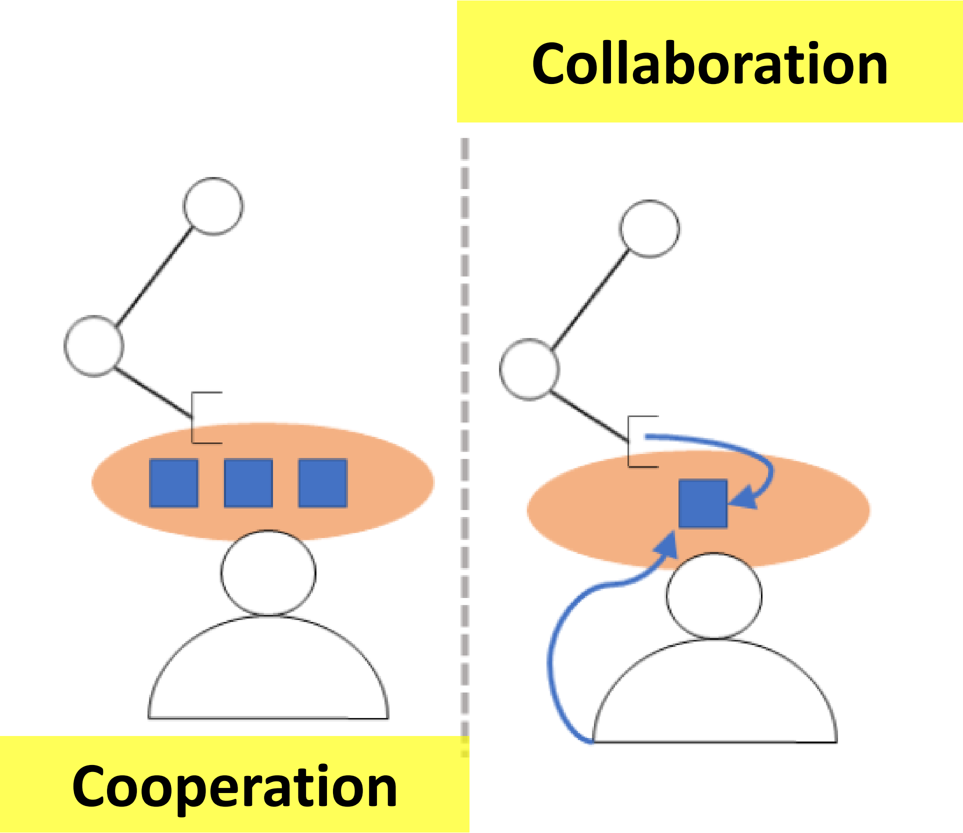
Human–Robot Collaboration (HRC) in Manufacturing

Different Methodologies of Human–Robot Collaboration



Cooperation

Apply when the human operator and cobot work in the same workspace at the same time, though each focuses on separate tasks.

Collaboration

Apply when the human operator and the cobot must execute a task together; the action of the one has immediate consequences on the other, thanks to special sensors and vision systems.

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Reasons for human-robot collaborative system

- Economic motivations
- Occupational health (ergonomics and human factors)
- Efficient use of factory space
- Simplification in the robot programming

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Human-Robot Collaboration for BMW/MINI vehicle

KUKA - Robots & Automation (https://www.youtube.com/watch?v=keh99z1M5LI)

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Industrial robotic systems

Discussion and Presentation

Factors for applying collaborative Robot with Human

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Safety Requirements for Collaborative Robots

➢Safety-rated monitored stop (SMS)

It is used to cease robot motion in the collaborative workspace before an operator enters the collaborative workspace to interact with the robot system and complete a task.

➢Hand-guiding (HG)

It is used where an operator uses a hand-operated device, located at or near the robot end-effector, to transmit motion commands to the robot system.

International standard UNI EN ISO 10218 1 and 2 & ISO/TS 15066:2016

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Safety Requirements for Collaborative Robots

➢ Speed and separation monitoring (SSM)

It is used where the robot system and operator may move concurrently in the collaborative workspace. During robot motion, the robot system never gets closer to the operator than the protective separation distance.

➢ Power and force limiting (PFL)

It is used where the robot system shall be designed to adequately reduce risks to an operator by not exceeding the applicable threshold limit values for quasi-static and transient contacts, as defined by the risk assessment.

International standard UNI EN ISO 10218 1 and 2 & ISO/TS 15066:2016

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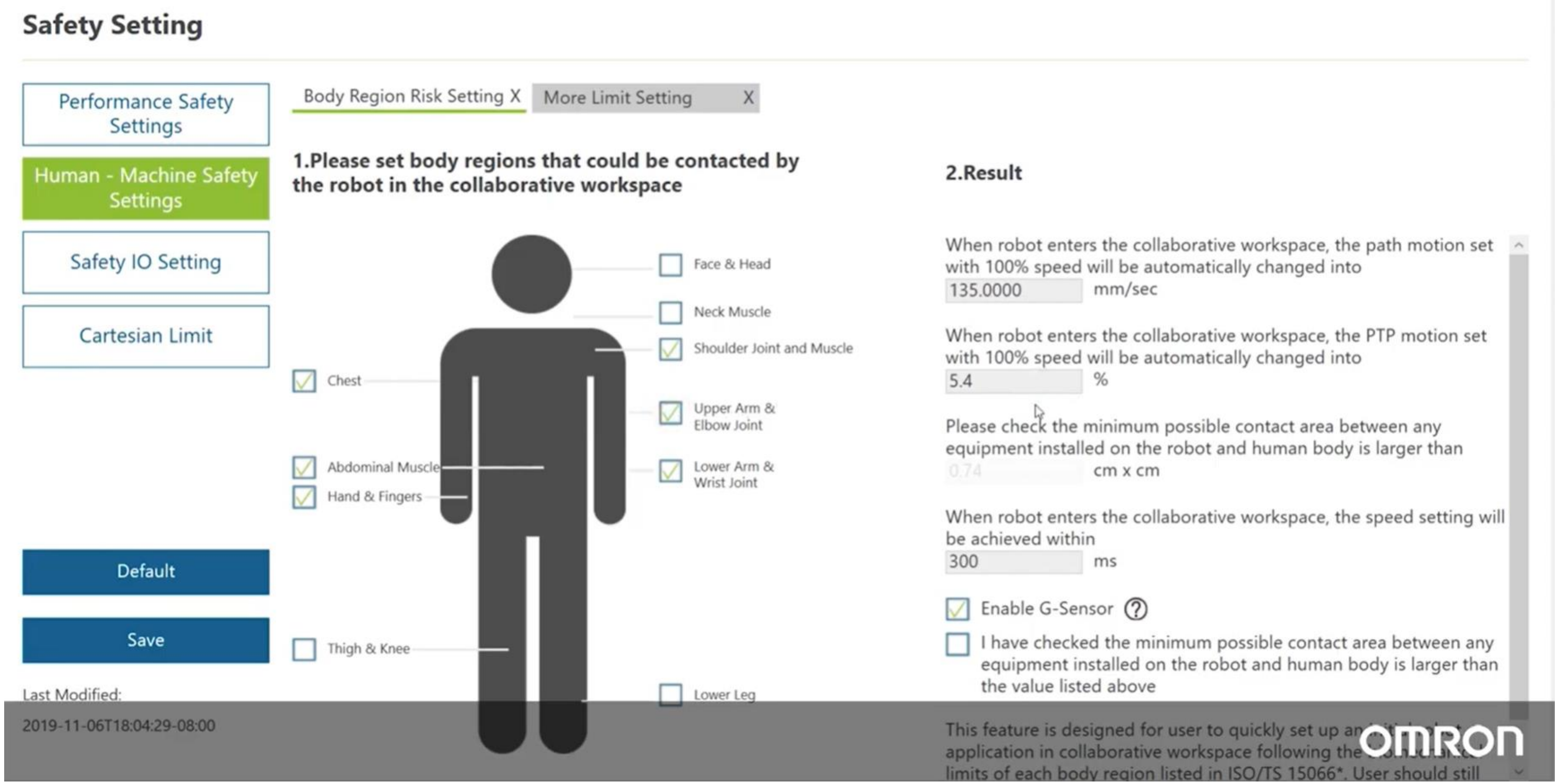
Safety of Human-Robot collaboration



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Omron Industrial Automation EMEA

Convenience of Collaborative Robotics

Comparison between collaborative and traditional systems for different tasks

	Human Operator	Collaborative Systems	Traditional Robot	Handling Systems
Assembly	High dexterity and flexibility	Combines human dexterity with robot capabilities [24]	Dexterity/flexibility could be unreachable [24]	No complex tasks with commercial end-effectors [21]
Placement	High dexterity	Commercial cobots have lower repeatability	High repeatability and payload	High payload
Handling	Product weight restricted [19]	Typical cobots have low payload	High payload and speed [23]	High payload
Picking	Product weight restricted [19]	Typical cobots have low payload	High payload and repeatability [23]	Bin picking difficult due to size

(Matheson et al., 2019)

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Convenience of Collaborative Robotics

How flexibility of Human-Robot collaboration?

https://www.canadianmetalworking.com/canadianfabricatingand welding/article/automationsoftware/human-robot-collaboration

https://www.industr.com/en/coexisting-with-humans-and-the-need-for-them-today-2337396

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Flexibility of Human-Robot collaboration

Issue of assembly parts while sharing production activities

↓

Difficulty in both trajectory generation and path planning algorithms

Conventional method of collision-free and smooth trajectory in dynamic

↓

Computing of configuration space (C-space)

↓

Difficult to achieve because of the strong nonlinearities equations of the dynamics systems and algorithms free path planning

How to improve this

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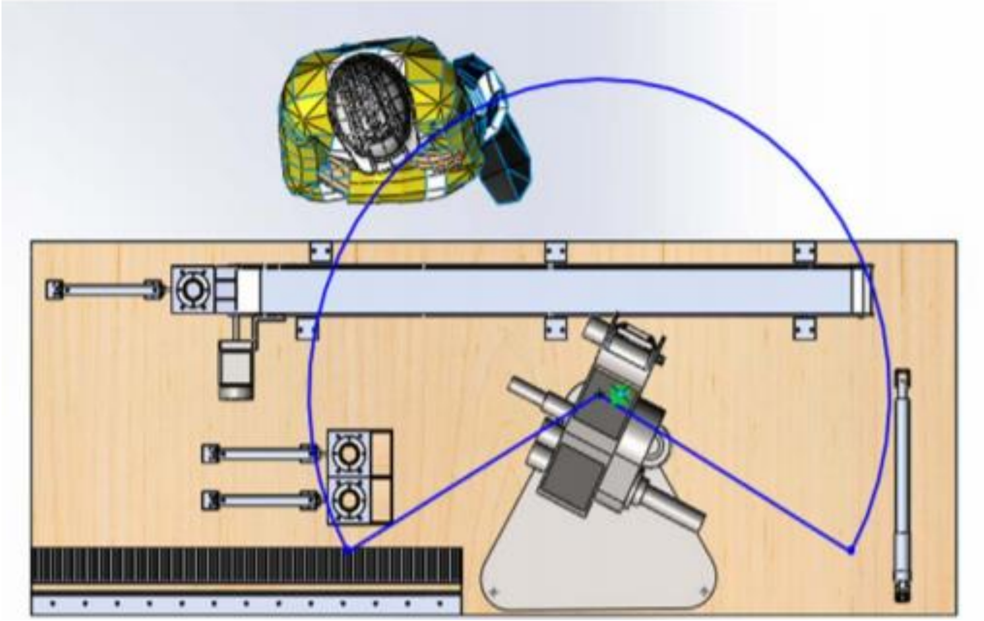
Flexibility of Human-Robot collaboration

A flexible manufacturing system (FMS)



Assembly parts while sharing production activities:

Case study of Meziane et al. (2017)

- Sharing workspace shall allow reducing musculoskeletal disorders when the robot absorbs shock, vibration, heavy load or avoid inadequate posture of the operator
- This hybrid workspace includes a Programmable Logic Controller (PLC), a robot, a conveyor, a distributor and a storage system.

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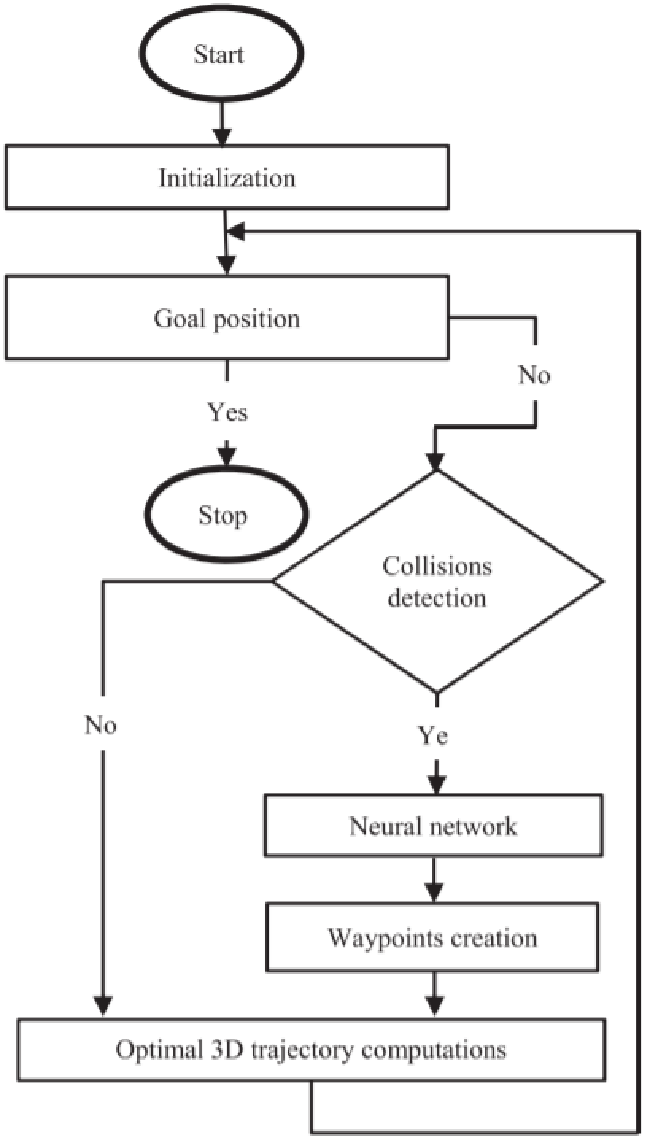
Flexibility of Human-Robot collaboration

Assembly parts while sharing production activities:

Case study of Meziane et al. (2017)

Motion planning using neural network

- Robot motion is performed inside a set of subspaces of this hybrid workspace.
- Each subspace is linked with constraints in order to generate smooth motion and avoid dynamic obstacle (human moving its limbs and components).
- Neural network is applied to generate a waypoint in the intermediate subspaces needed for moving the robot end-effector in a collision free path.



(Meziane et al., 2017)

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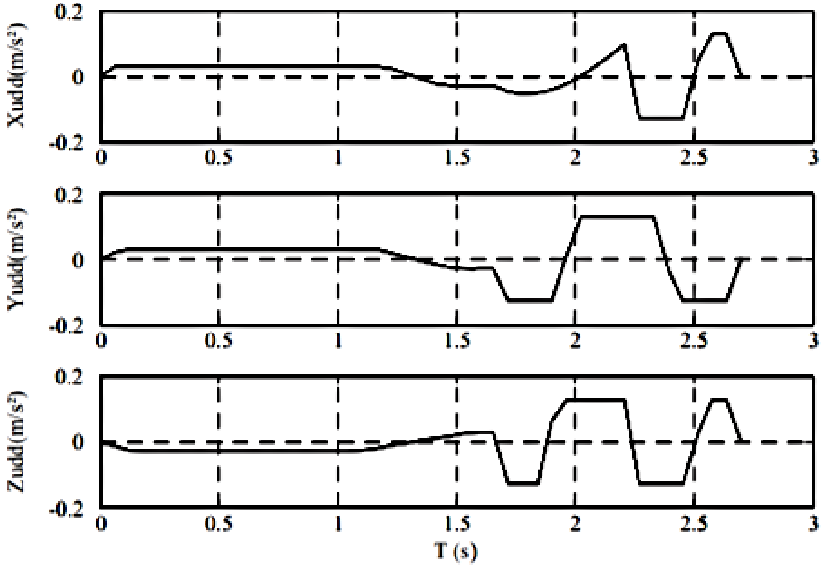
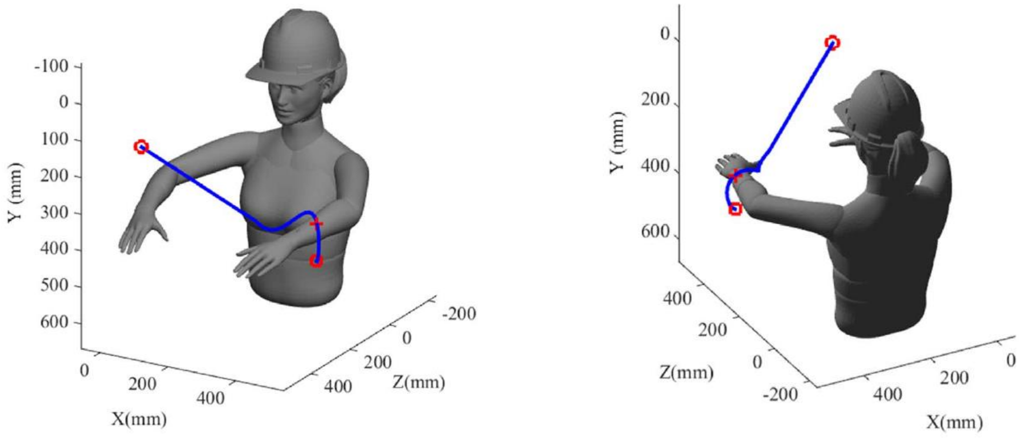
Flexibility of Human-Robot collaboration

Assembly parts while sharing production activities:

Case study of Meziane et al. (2017)

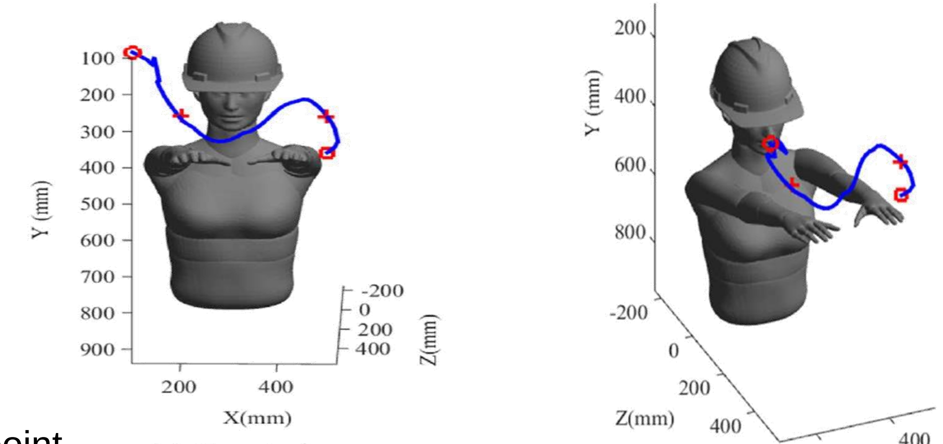


Speed and acceleration of first simulation



(a) Front view (b) Back view

Optimal 3D trajectory with one waypoint.



(a) Front view (b) Side view

Optimal 3D trajectory with two waypoint

(Meziane et al., 2017)

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Human-robot coexistence and interaction in open industrial cells

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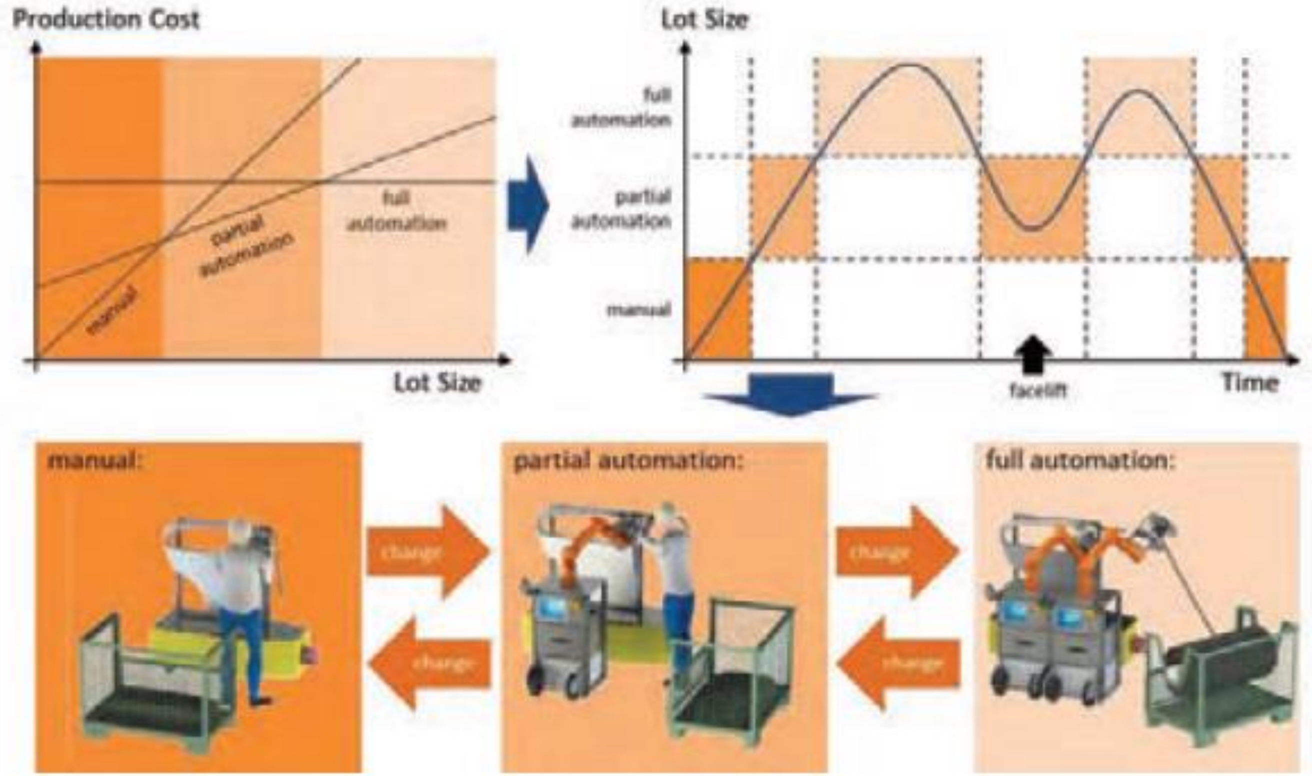
Flexibility of Human-Robot collaboration

Axiomatic design approach for human-robot collaboration in flexibly linked assembly layouts

Case study of Fechter et al. (2017)

Correlation between lot size, production costs and automation level



(Naumann and Fechter, 2015)

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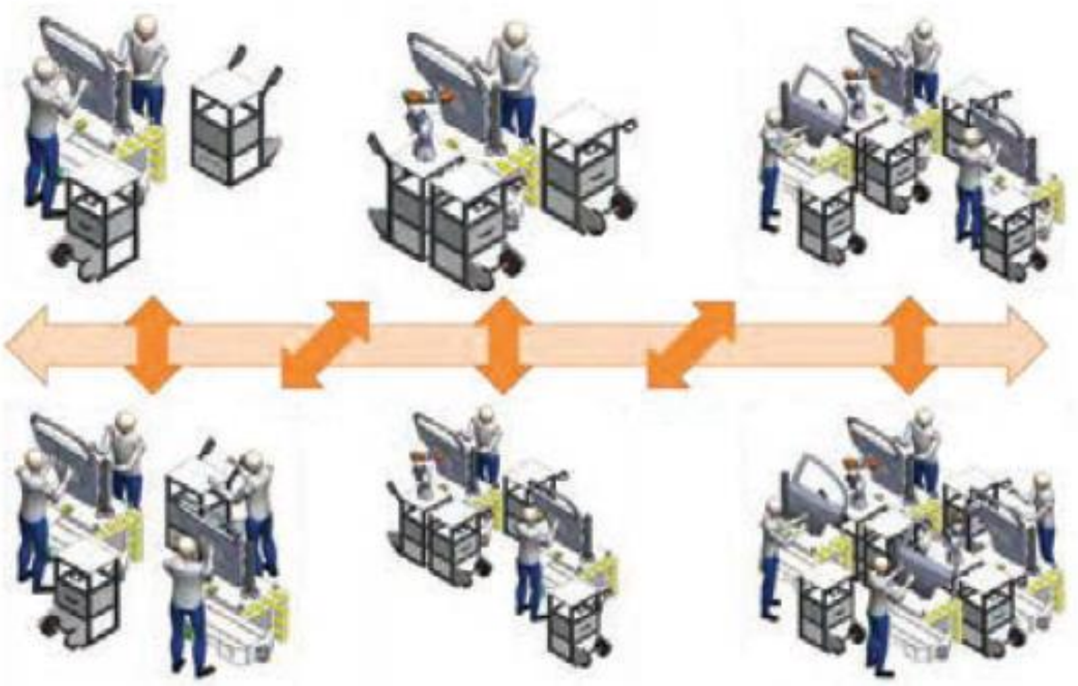
Case study of Fechter et al. (2017)

Flexibly linked assembly modules for human-robot collaboration (ARENA2036)



Assembly of automotive door at ARENA2036

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Flexibility of Human-Robot collaboration

Axiomatic design approach for human-robot collaboration in flexibly linked assembly layouts: Case study of Fechter et al. (2017)

Application of HRC for Assembly of automotive door at ARENA2036

Aspects of the process

- Repetitive workload with impact on product quality
- Manual handling during separation due to bad part characteristics

Consideration of the subsequent economical facts

- Full automation imaginable
- Higher flexibility regarding seen/unseen changes in the assembly flow → expensive machinery
- Reduced hardware cost on handling and tooling
- More process reliability through possible direct rework by operator

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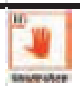
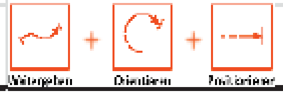
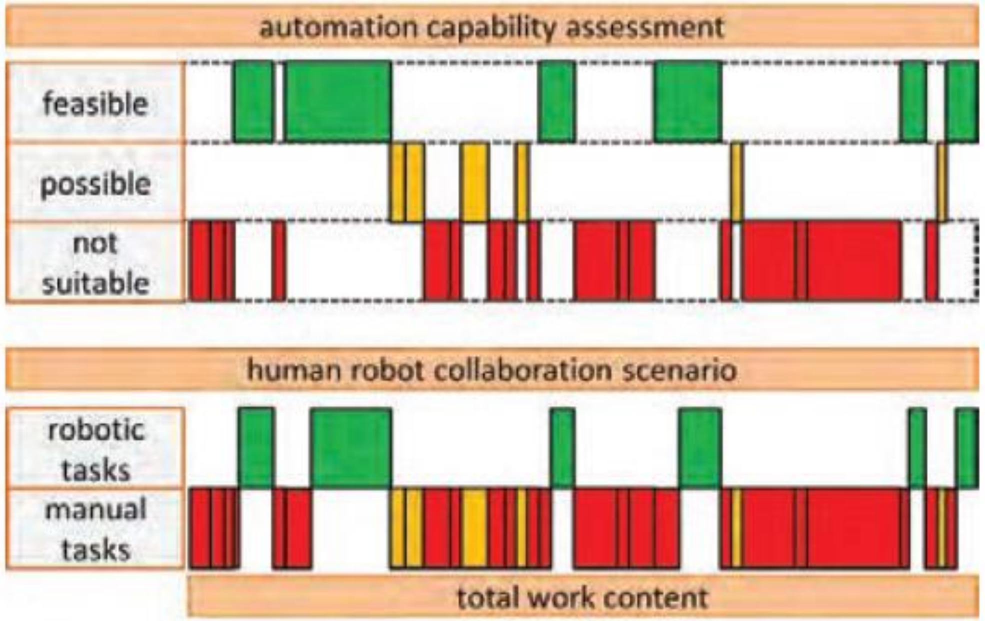
Assembly of automotive door at ARENA2036

Automation assessment

Layer	Assembly Task (FR)	Assembly Job (DP)	Composition
A	Handling	influence spatial arrangement	
B	Buffering	build up stock	
C	Buffer parts	move parts to buffer	

Exemplary task allocation of the ARENA2036 door module assembly



Exemplary task allocation of the ARENA2036 module assembly

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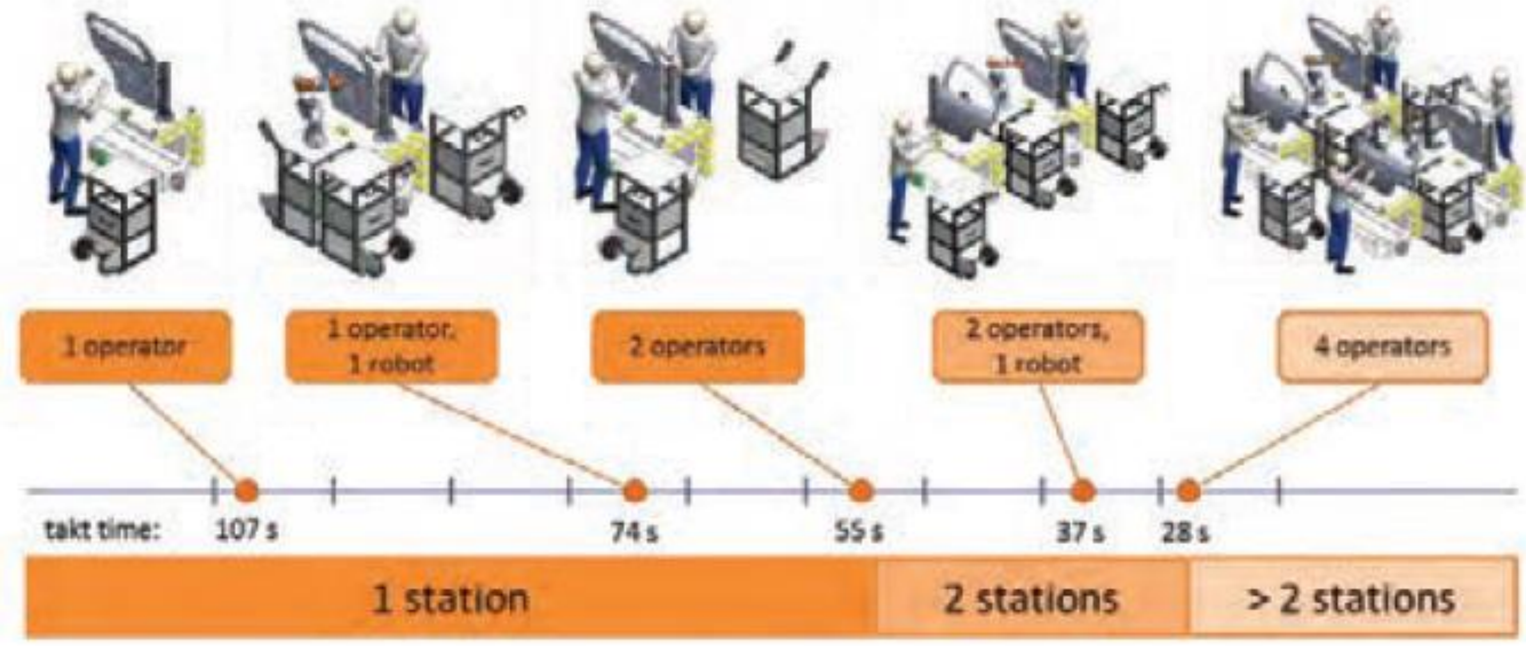
Assembly of automotive door at ARENA2036



Layout examples and corresponding cycle times for door module assembly

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Think to the Future of Human-Robot Interaction?

How Robots Are Learning to Help People

Carnegie Mellon University (https://www.youtube.com/watch?time_continue=94&v=tVHo8wpkdMA&feature=emb_title)

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