IPEC 2023
International Production Environmental Community
Energy | Supply Chain & Logistics | Human-centered Production

Future Design of Human-Centered Collaborative Assembly Workstations for the Improvement of Operators' Ergonomics and Production Efficiency

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Smart Mini Factory
Laboratory for Industry 4.0
unibz

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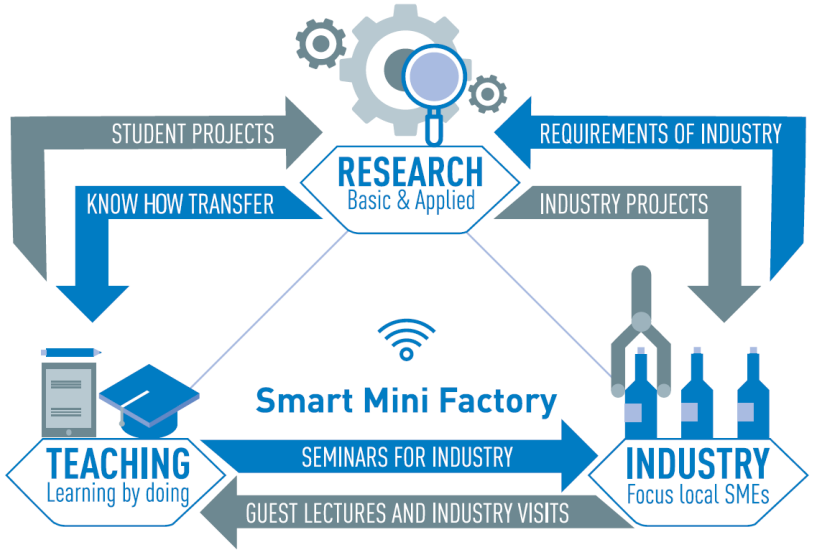
The SMF lab

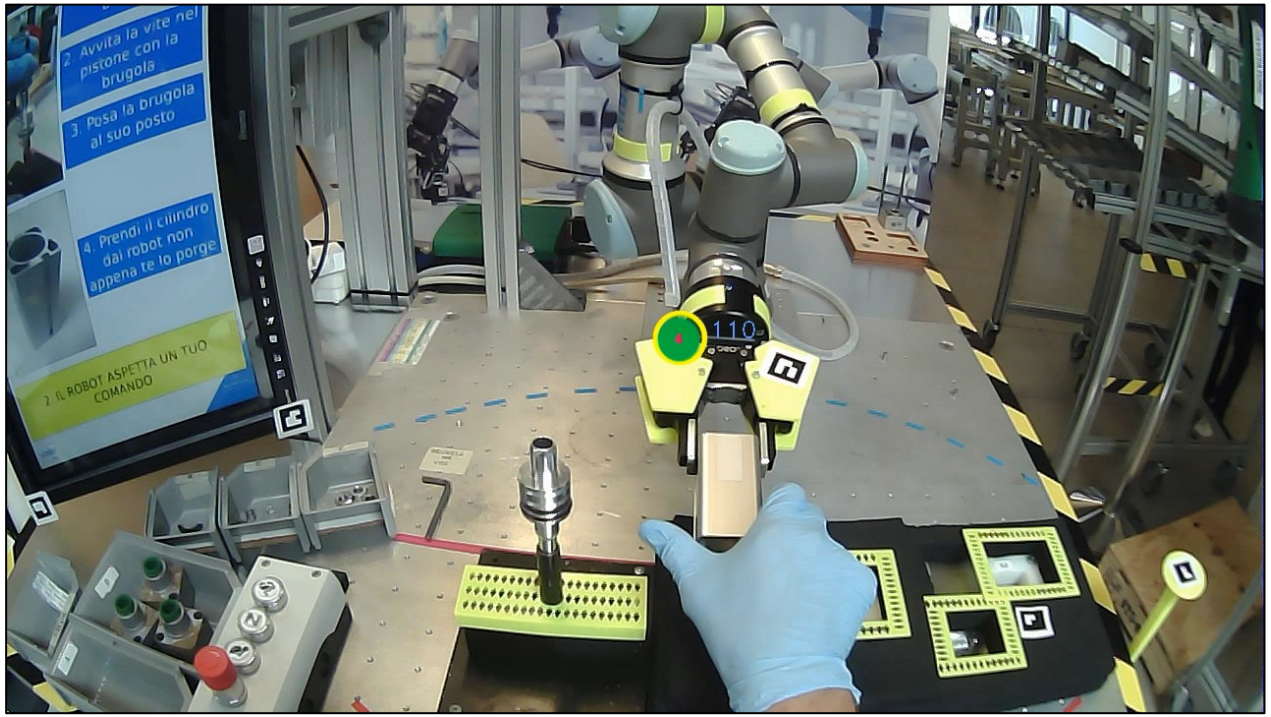
The vision of the lab

- The Smart Mini Factory laboratory is a learning factory focused on the study and simulation of advanced technologies and production methods in the context of Industry 4.0 (especially for SMEs);
- The aim of the laboratory is to create a platform where researchers, students and industry meet to enable the transfer of knowledge from research to industry.
- Main topics are hybrid production/assembly systems, human-centred and assisted production as well as robotics and mechatronics for industrial automation;



A new paradigm of HMI

The current concept of industrial collaborative robot



A collaborative robot (cobot) is:

- a particular type of industrial robot,
- able of performing production tasks in collaboration with operators,
- which allow a safe and physical human-robot interaction (HRI) in a shared and fenceless workspace,
- which has specific SW and HW features that differentiate it from traditional industrial robots.

Source: Smart Mini Factory (unibz)

A new paradigm of HMI

The current concepts of industrial HRI

It is possible to analyze current industrial HRIs by considering different concepts:

Operative concept

"*Collaborative industrial robots as those able to perform tasks in collaboration with workers in industrial settings*".

(International Federation of Robotics (IFR))

Spatial concept

"*A collaborative workspace is the space where the robot system and a human can perform tasks concurrently during production operations*".

(International Standardization Organization (ISO))

Safety concept

"(Physical) Contacts which can cause a limited and momentary pain (similar to that one perceivable in daily activities) are generally permitted".

(Scientific literature)

According to the current situation, collaborative applications design:

(i) (Mainly) prevent mechanical hazards (e.g. contacts);

(ii) Refers to defined and controlled workspaces;

(iii) Consider the robotic system as a production "tool" instead of a human's "companion".

There is a "limited" technological concept of industrial HRI:

A collaborative robotic system is considered as a machine that ("simply") allows a safe interaction with humans in a production context.

Key features for future HRI design

A vision for advanced and intelligent collaborative robotics

To overcome these limitations, two design principles are proposed to drive the design of (future) intelligent and anthropocentric collaborative systems:

Principle #1

An industrial collaborative robot is any kind of cognitive robotic system that is sharing a work experience with humans in industrial settings.

Principle #2

Functional and non-functional human-robot interactions must not cause psychophysical discomfort, harms or injuries to human's wellbeing, health and safety due to direct and indirect operations of the collaborative robotic system;

Key features for future HRI design

Consider different kind industrial robotic systems according to the process

The "robotic system" is the overall mechatronic system composed of the robot arm, end-effector, and integrated sensors/devices/equipment to support its working activities and human interactions.

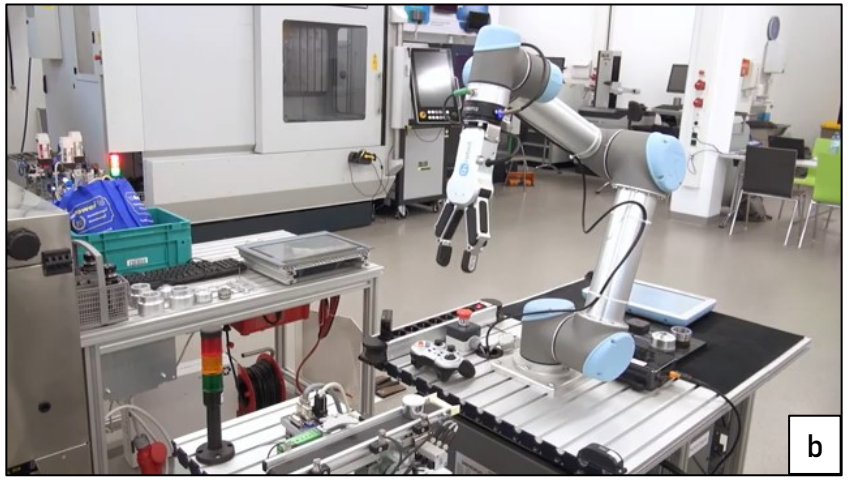
Possible robotic systems for industrial HRI are:

- traditional non-collaborative industrial robots that have been properly modified to interact with humans;
- cobots that have been designed and fabricated as inherently safe machines;
- mobile and collaborative industrial robotic systems;
- humanoid robots for industrial applications.

Already present in factories

Being to be used in factories

Will arrive in factories



(a) Human-Robot-Interaction – Huma Robot Interaction (https://www.youtube.com/watch?v=Qyr5qswTsqQ) (Creative Commons License)
(b) gsteinbauer - Construction of Mobile Robots 2020/2021 (https://www.youtube.com/watch?v=HFYO0KwgbYo&t=160s) (Creative Commons License)
(c) HI TEK ROBOTICS - 9 Most Advance AI Humanoid Robots|HI TEK ROBOTICS (https://www.youtube.com/watch?v=UIVCU7QNwnA) (Creative Commons License)

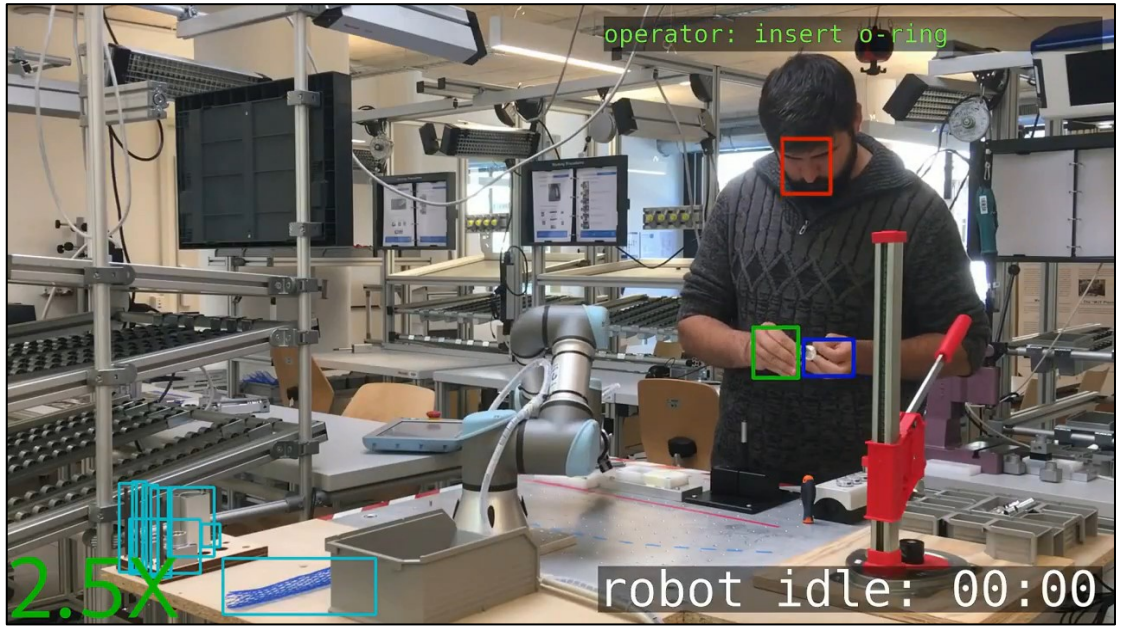
Key features for future HRI design

Make machines cognitive industrial robotic systems

A system using human-like representations and processes will enable better collaboration with people.

This means that:

- The robotic system should be considered as more than just a device able to move and handle objects: It is a component of the human cognitive process;
- Cognitive robots are robotic systems with the capacity to plan solutions for complex goals and to reactively adapt such plans according to unexpected changes in their structured/unstructured environments;
- As a consequence, cognitive robotics aims to make the interaction of the machine with humans as simple, intuitive and natural as possible.



To enable a better awareness of the robotic system, a camera-based monitoring device is used to track the operator and inform the robot about the tasks the human is performing.

Source: Smart Mini Factory (unibz)

Key features for future HRI design

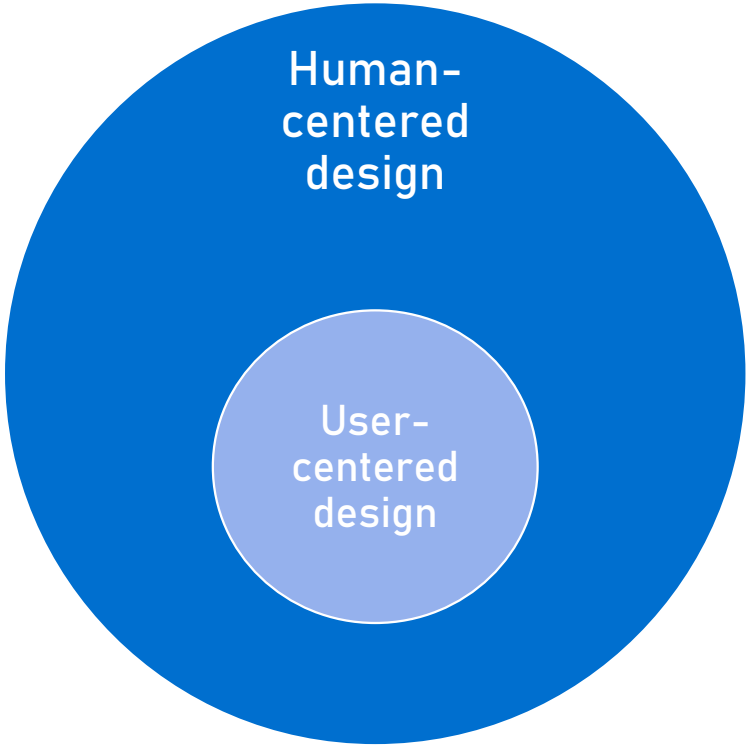
Change the application design from User-centered to Human-centered

Design production systems that adapt the humans (and not vice-versa):

- The robotic system must adapt its behavior (e.g. actions) according to all users needs, wants, diversities;
- The system must support the social inclusion of vulnerable workers (e.g. people with disabilities or special needs).

Shifting the design of the system/application from “User-centric” to “Human-centric”:

- “User-centered design” focuses on the predicted user groups of the end-product (e.g. the operator working with the robotic system),
- “Human-centered design” aims at including all humans as possible users. The design process must include all possible users, and not just a specific target (e.g. programmers, maintenance workers, etc.);



Key features for future HRI design

Implement the concept of assistance system in production

The main function of the robotic system is supporting workers in reducing the effort associated to physical and/or cognitive activities.

This means that:

- The worker should choose which of the available activities to perform based on his/her needs or preferences by considering the production sequence and constraints. The robotic system will act accordingly;
- The robot system should act (and be perceived) as a "third hand" or even as "companion";
- Production efficiency and productivity must be considered as secondary/parallel goals with respect to the reduction of biomechanical or cognitive workloads.

This in an example of a collaborative robotic workstation for wire harnesses assembly that has been designed starting from a manual process to deduce work-related biomechanical overloads.

Source: Palomba, I., Gualtieri, L., Rojas, R., Rauch, E., Vidoni, R., & Ghedin, A. (2021). Mechatronic Re-Design of a Manual Assembly Workstation into a Collaborative One for Wire Harness Assemblies. *Robotics*, *10*(1), 43.

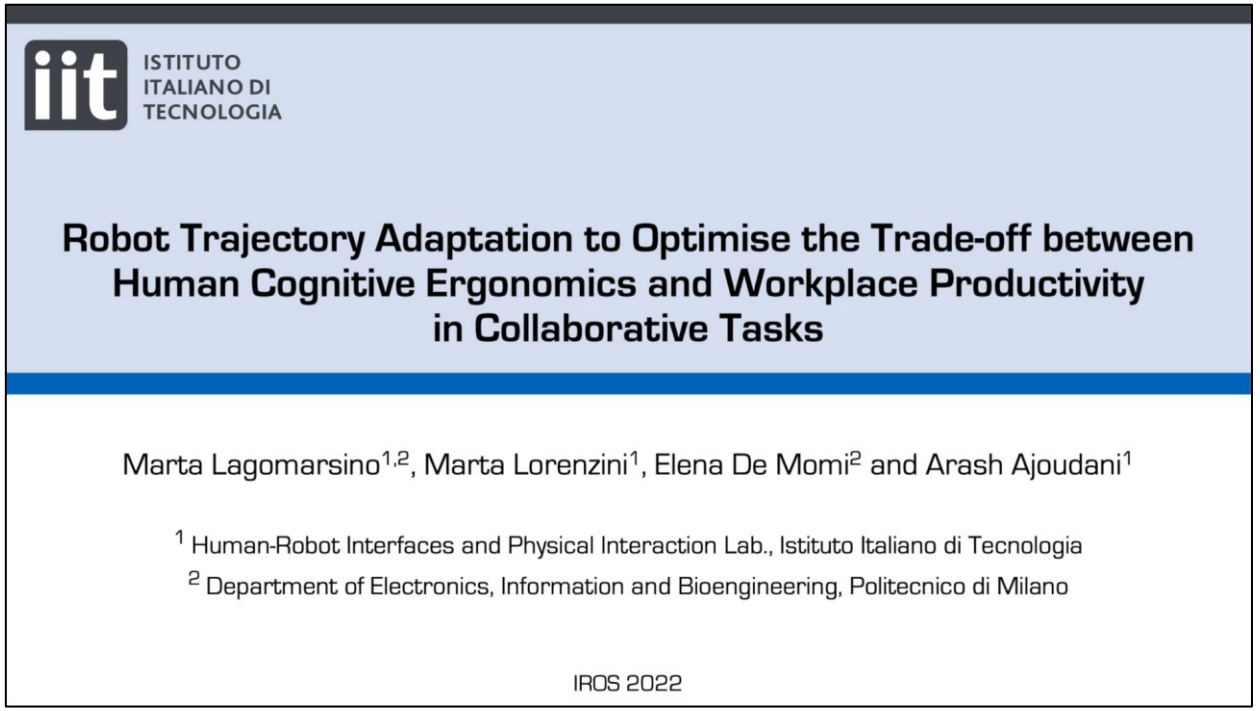
Key features for future HRI design

Design adaptive behavior of robotic systems

The robotic system must rearrange its operations instantaneously, independently and according to the continuous workers requirements.

That means that the adaptive behavior should be:

- automatic = working by itself with little or no direct human control;
- seamless = smooth and continuous, without any sudden changes, interruption, or difficulty;
- dynamic = continuously changing or developing according to the evolution of the situations;
- quasi-real time = processed so that feedback is virtually immediately available to the human.



This is an example of a collaborative robotic system that is able to change the execution of its activities (in terms of trajectory type and task time) according to the human moniotred cognitive workload.

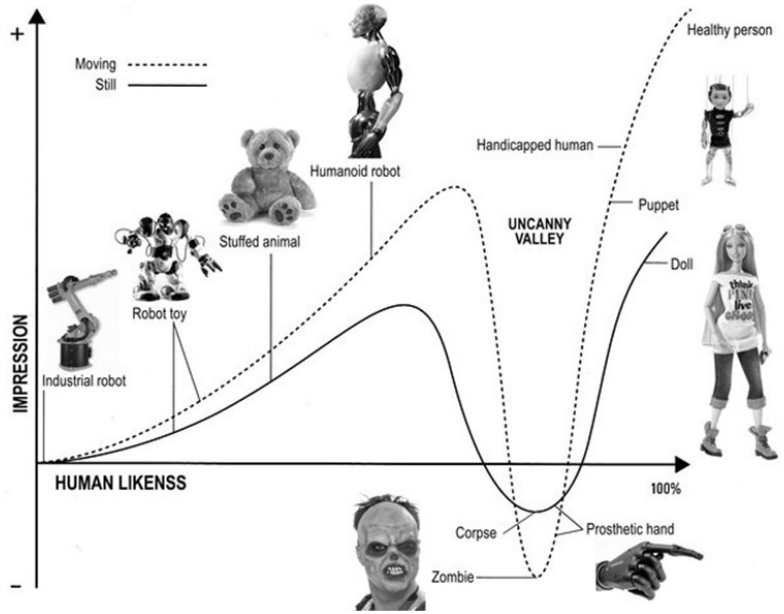
Source: IIT - Robot Trajectory Adaptation to Optimise the Trade-off between Human Cognitive Ergonomics (https://www.youtube.com/watch?v=ZZ8OXijARqU)

Key features for future HRI design

Prevent any kind of human's psychophysical discomfort, harms or injuries

It is necessary to consider human's psychophysical discomfort, harms or injuries by applying a proactive approach for the safeguard of users' health and safety in advanced HRIs.

- Do not just focus on safety: Prevent unpleasant, unergonomic (physical and cognitive), and hazardous situations (protect workers from tangible and intangible damages) by consider functional and non-functional HRIs;
- Consider nominal, as well as unwanted, unexpected, occasional physical and non-physical interactions between the users and the robotic system.



Source: Kędzierski, J., Kaczmarek, P., Dziergwa, M., & Tchoń, K. (2015). Design for a robotic companion. International journal of humanoid robotics, 12(01), 1550007.

Conclusion

- To sum up, the next generation of collaborative and cognitive robots for industrial applications will be:
  - physical and/or cognitive assistant systems (able to implement the “companion concept”)
  - that autonomously, dynamically and instantaneously adapt the behavior according to
  - (i) all user’s needs, wants and diversities, and
  - (ii) changes in structured or unstructured shared working environments
  - by implementing an anthropocentric approach and respecting the ethics principle and human’s rights during the whole operative lifecycle.

- This requires the overcoming of different sociotechnical barriers:
  - Technical challenges, e.g. the development of solutions for reliable human’s intention detection, solutions for dynamic production tasks rescheduling, human-robot shared mental models, solutions for fine manipulation, etc.;
  - Organizational challenges, e.g. the development of new tools for psychophysical risk assessment and management, the management of human-robot teams in production processes, the application of roboethics principles during the whole design, etc.

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Thank you for your attention!

Online Survey on Design Guidelines for Human-Robot Interaction in Industry:

https://unibopsice.eu.qualtrics.com/jfe/form/SV_b0ZPXSr8KYCQeSG

Contacts:

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