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POSITION PAPER

Collaborative Robots

HOW ROBOTS WORK ALONGSIDE HUMANS

IFR International Federation of Robotics

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IN BRIEF

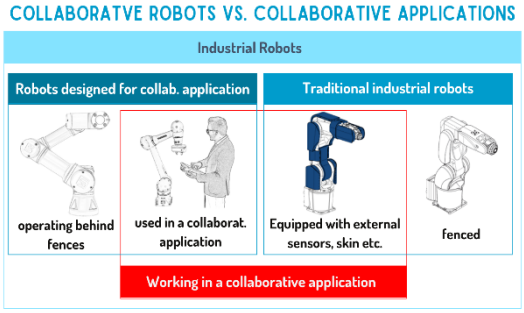
What is a Collaborative robot?

Intro

Cobots or collaborative industrial robots are robots with power and force limiting functions designed to perform tasks in collaboration with workers in industrial sectors. Collaborative applications contrast with **traditional industrial** robot applications in which robots are isolated from human contact **behind fences** or other protective barriers.

Definition

The International Organization for Standards (ISO) does not provide an individual definition for collaborative robots but only for collaborative operations. Safety requirements for such operations are described in ISO 10218-1 and ISO 10218-2, with additional guidance for collaborative robot applications provided in ISO TS 15066.



Both robots designed for collaborative use and traditional industrial robots equipped with external safety features can be employed in collaborative applications. Picture source: IFR.

Types of Cobots

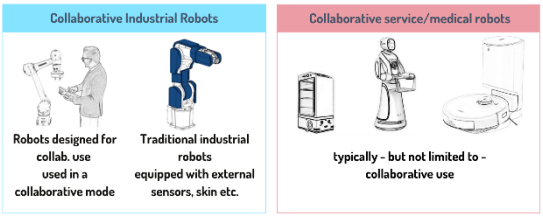
The International Federation of Robotics considers two types of robots designed for collaborative use:

Group one covers robots designed for collaborative use that comply with the International Organization for Standards norm ISO 10218-1. This specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots.

Group two covers robots designed for collaborative use that do not satisfy the requirements of ISO 10218-1. These robots follow different safety standards, for example national or in-house standards.

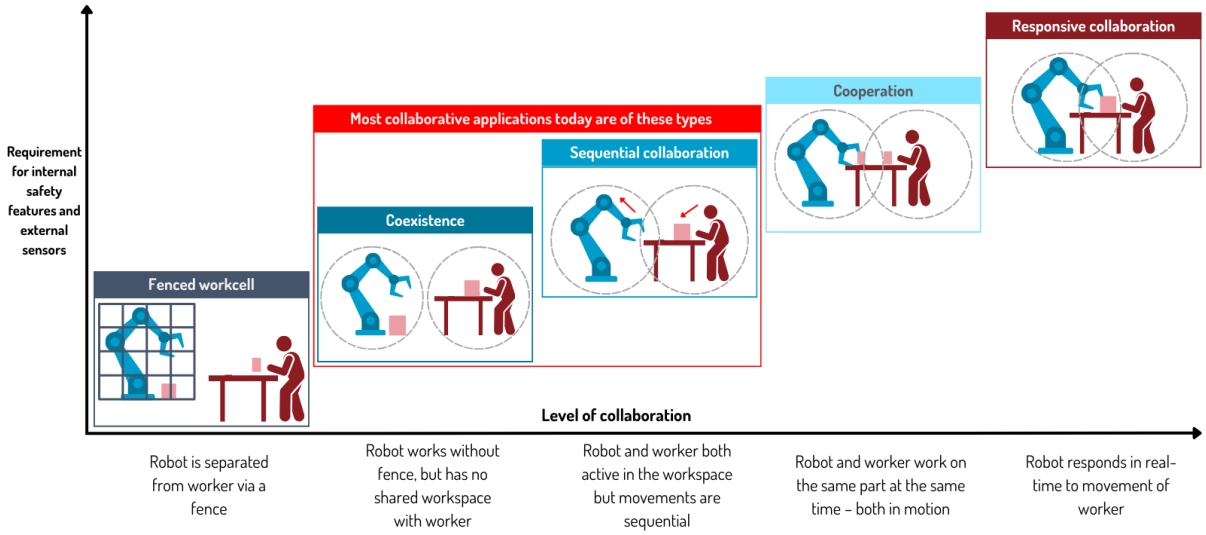
Cobots are robots designed to perform tasks in collaboration with workers in industrial sectors. Picture source: Universal Robots.

Service robots for domestic use (e.g. floor cleaning robots) or professional use (e.g. robots built for transportation of cargo) or mobile robots (AGV´s or AMR´s) are not included in the common understanding of a cobot.



While most service robots are designed to be used in collaborative mode, the term "cobots" typically refers to collaborative industrial robots. Picture source: IFR.

TYPES OF COLLABORATION WITH INDUSTRIAL ROBOTS



The IFR classifies 4 levels of cooperation with industrial robots (circles mark the respective workspaces of human and robot application). Picture source: IFR.

4 Levels of collaboration

The IFR classifies four levels of collaboration between industrial robots and human workers:

1. Coexistence: Human and robot work alongside each other without a fence, but with no shared workspace.
2. Sequential Collaboration: Human and robot are active in shared workspace, but their motions are sequential; they do not work on a part at the same time.
3. Cooperation: Robot and human work on the same part at the same time, with both in motion.
4. Responsive Collaboration: The robot responds in real-time to movement of the human worker.

Today, IFR members find that a substantial share of cobots is still not used for human-robot-collaboration. Most common cobot applications are shared workspace applications where robot and employee work alongside each other, completing tasks independently or sequentially (Co-existence or sequential). They perform jobs that are either tedious or unergonomic – from lifting heavy parts to performing repetitive tasks such as tightening screws.

Experts predict **in 5 years' time** a step towards true co-operation: Robot and employee work at the same time together – both in motion will be commonplace.

Examples of applications in which the robot responds in real-time to the motion of a worker are likely to appear on a larger scale in **10 years' time**. This level is the most technically challenging.

EXECUTIVE SUMMARY

Quick entry into automation

Cobots offer a quick entry into automation. They are easy to program; some are programmable by hand guiding – called "lead-though teach" – or through tablet interfaces. Cobots most often require no additional safety measures to implement on the factory floor. This allows fenceless operation directly integrated into existing production areas. They can adapt flexibly by using Plug & Play technologies for example. This is especially attractive for companies which do not have engineering experts, for companies with smaller production batches and in industries where production needs are constantly changing.

Cobots vs. traditional industrial robots

Cobots typically have some trade-offs compared to traditional industrial robots. This is due to their design and purpose to safely work alongside humans: Cobots are currently not applicable e.g. for processes that require high payloads and high speeds. Their lightweight design supports easy relocation and simplified integration into mobile robot platforms. Cobots are used in many setups where a direct human-robot interaction is not required. Traditional industrial robots can be an alternative in those cases. However, cobots have additional safety functions and capabilities that are useful for many applications.

In cases where human intervention is needed, industrial robots that are equipped with external safety measures can provide good solutions without compromising velocity and payload. The safety measures include e.g. laser scanners, locking safety gates or safety mats.

Main customer industries for cobots

Manufacturing industries have been early adopters of cobot technology. This includes automotive, electronics, aerospace, consumer goods, pharmaceuticals, logistics and warehousing. Due to a cobot's ease of use, we typically see industries that require low volume high mix production. This can include welding, machine tending, bin picking and end of line palletizing.

Cobots can work side-by-side with humans in many applications, e.g. closing a CNC machine. Picture Source: OMRON.

Trends driving cobot development

The shortage of skilled workers will drive the development of automated solutions and will re-establish manufacturing infrastructure closer to the consumers. New applications are developed for cobots, continuously expanding their potential fields of use – from simple handling, through welding, to painting, dispensing and assembly.

Cobot manufacturers are developing machine learning systems so that cobots can "learn". This modular technology and learning approach leads to opening further doors to expand what a cobot can do while unattended. In future, new sensors, vision technologies and artificial intelligence (AI) will allow robots to respond in real-time to changes in their environment and thus work safely – and more responsively - alongside human workers.

Cobot market

Cobots accounted for 10.5% of the total 541,302 industrial robots installed in 2022. IFR's statistics show: collaborative robots will complement – not replace – investments in traditional industrial robots which operate at much faster speeds and will therefore remain important for improving productivity in response to tight product margins.

DEEP DIVE

Why Do Companies Use Cobots?

Like industrial robots in general cobots can help improve productivity, product quality and consistency by executing tasks with a high level of precision and accuracy. They are less prone to errors or variations compared to human workers, leading to fewer defects and higher customer satisfaction.

Cobots can be used to automate parts of a production line with minimal changes to the rest of the line. The easy-to-program technology can encourage first time users to get started with robotic automation.

For some companies, collaborative robots provide an economically-viable entry-point to robotic automation, particularly with “easy to program” cobots. Companies that have not yet automated production processes may use a cobot as a low barrier starting point.

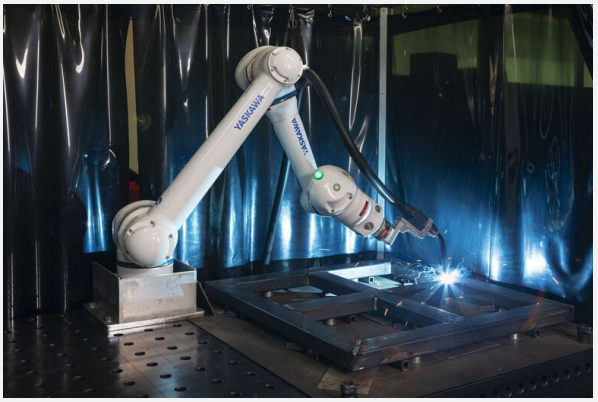
Cobots can work alongside human workers augmenting their capabilities. They enable individuals to collaborate on complex tasks that are difficult to fully automate. Cobots help to handle repetitive tasks or heavy lifting, for example, allowing human workers to focus on more complex or creative aspects of their jobs.

The capability of flexible manufacturing is greatly enhanced by Cobots. They allow for movable workstations that can be deployed when it's needed and moved elsewhere quickly.

CASE STUDY

Using welding cobots to ramp up production of sky loungers

Stöckl Maschinen und Gerätebau in Germany needed to fulfill a large-scale order for pivot mounts used in Holztec-Leitner’s relaxation loungers, prompting the company to automate its welding process. They adopted Yaskawa's cobot welding cell, which combines a collaborative robot with a simple interface for professional welding functions. This cobot was chosen for its compact size, ease of use, and ability to work without a safety fence, facilitating safe, efficient, and flexible welding operations. The application involved sequential cooperation, where the robot operates in industrial mode as soon as the safety curtains are closed, but can be hand-guided for programming and parts can be fed manually by the worker.



Picture Source: Yaskawa

https://ifr.org/case-studies/welding-cobot-in-use-at-stoeckl-maschinen-und-geraetebau

Adequate safety precautions need to be considered when required by the application itself, e.g. in welding. Picture Source: Universal Robots.

Safety

Like any other piece of industrial machinery, collaborative robot applications must be safe. Compliance with ISO 10218-2 for collaborative applications is required.

However, a safe cobot does not guarantee a safe collaborative application in practice. An application in which a cobot wields a sharp tool is unsafe no matter how slowly the cobot operates. A risk assessment of the intended application by the user is obligatory to comply with ISO 10218-2 and workplace health and safety requirements. The risk assessment covers the entire application, including the robot, end-effector, tools, workpieces, other machines plus equipment and components in the workplace.

Tradeoffs and limitations of cobots

Cobots and traditional industrial robots each have their own advantages.

Companies often opt for cobots to combine human labor with automation. This approach can leverage the strengths of both humans and machines, allowing for greater flexibility while still improving efficiency and productivity.

While cobots can achieve a high level of accuracy and repeatability, they may not be as precise as traditional industrial robots, especially for tasks that require extremely tight tolerances.

Alternatives to cobots

While traditional industrial robots and cobots serve different purposes, they can sometimes be alternatives depending on the specific application. For tasks with high production volumes and minimal need for human interaction, traditional industrial robots are an alternative to consider.

There exist several options to outfit industrial robots with safety devices when processes require human intervention. These include dedicated sensors using skin like haptic sensors on traditional robots, force feedback control for manipulators as well as laser or radar scanners, emergency stop buttons, and physical barriers. In each case, the robot may perform normal highspeed operation until the safety area is breached by a human.

CASE STUDY

Robots for assembly at container refrigeration factory

Carrier Transicold faced a challenge at their Singapore factory where human intervention was required in limited space, making traditional safety fences impractical.

They installed the T-Skin on a FANUC robot. This robot solution could work alongside human workers in confined spaces without extensive fencing, still able to handle the heavy refrigerator doors.

The deployment was implemented in half a day with minimized disruption of the operations, resulting in over 8,000 annualized hours of productivity gain. Automation initiatives led to a 3% increase in manufacturing efficiency, improved inventory tracking, and enhanced quality control.

Robot mounting refrigerator doors. Picture Source: Touché Solutions

https://ifr.org/case-studies/carrier-transicold-begins-using-robots-at-global-container-refrigeration-factory

CASE STUDY

Reducing footprint with precise and cost-effective collaborative solution

Picture Source: OnRobot

Cleaning products manufacturer Sano aimed to optimize their palletizing operations, traditionally done manually, but faced issues like labor shortages and space constraints.

The solution was to implement two collaborative palletizing stations using Fanuc cobots equipped with OnRobot grippers, chosen for their efficiency, compact footprint, and ease of integration. Cobots were ideal due to their ability to work safely alongside human workers without requiring large, fenced-off areas, thereby maximizing space utilization.

This setup allowed sequential collaboration, where cobots and humans perform tasks in succession within the same workspace, leading to significant operational improvements and a quick return on investment of less than 1.5 years.

https://ifr.org/case-studies/reducing-footprint-with-innovative-precise-and-cost-effective-collaborative-solution

CASE STUDY

Leak detection for refrigerator production line

Household appliances manufacturer Electrolux aimed to enhance productivity and quality control and reduce repetitive manual tasks by automating the manual testing of gas leaks and electrical systems in their refrigerator production line in Brazil. ABB provided YuMi and GoFa cobots, resulting in a 68% productivity boost and 100% reliability in testing. Cobots were chosen for their precision, safety, and ease of programming, allowing operators to manage and deploy them independently. This application is an example for coexistence without a shared workspace, where the operator is around, but not involved in the process.

Picture Source: ABB

https://ifr.org/case-studies/abbs-collaborative-robots-boost-productivity-by-68-on-electroluxs-refrigerator-production-line

CASE STUDY

Quality assurance for coffee grinder

Gronbach, high-end supplier of consumer goods, aimed to ensure the durability and precision of their new coffee grinder through rigorous quality control tests. They used KUKA's LBR iisy cobot conducting 55,000 grinding and weighing cycles to simulate ten years of usage. The cobot was chosen for its precision, repeatability, and ease of programming and for its ability to operate safely alongside humans without needing a large footprint, providing a cost-effective and reliable solution for quality control. This application exemplifies coexistence without a shared workspace, where the cobot performs tasks independently within the same environment as human workers.

Picture Source: KUKA

https://ifr.org/case-studies/lbr-iisy-cobot-in-quality-assurance

Main customer applications

Cobots are commonly used for pick-and-place operations, where they can efficiently move objects from one location to another with accuracy and speed.

They are also utilized in packaging processes to automate tasks including product packaging, case packing, labeling, and palletizing. They can handle a variety of packaging materials and shapes, making them versatile solutions for packaging operations.

Moreover, cobots are deployed for assembly processes and machine tending tasks, where they assist in loading and unloading parts from CNC machines, injection molding machines, or other automated equipment.

Cobots are used for quality inspection and testing tasks, where they can perform visual inspection, dimensional measurement, and defect detection with high accuracy and repeatability.

A recent market development is the increase of cobot welding applications, driven by a shortage of skilled welders.

More intelligent and efficient cobots are helping address demands for sustainability, through smaller operational footprints, and are quickly adapting to a high mix/low volume product portfolio. This now also includes cobots for painting and dispensing (glueing).

Palletizing cobot. Picture Source: Yaskawa.

Main customer industries

Collaborative robots are used across a variety of industries: The manufacturing industry, notably in automotive and electronics, heavily relies on cobots for welding, precise assembly tasks and quality control. Logistics and warehousing benefit from the growth of e-commerce and the increasing demand for efficient logistics operations. Cobots are being deployed for tasks like order fulfillment, inventory management, palletizing, and sorting. The food and beverage industry is adopting cobots to improve efficiency and hygiene. Cobots with food-grade materials and designs are specifically tailored to meet the stringent requirements of this industry. Pharmaceutical manufacturers are using cobots for tasks such as batch processing, packaging, and handling of sensitive materials.

CASE STUDY

Collaborative assembly application for lighting solutions

Lighting solutions provider Fagerhult Belysning sought to improve productivity and ergonomics in their assembly processes. They integrated three cobots from Yaskawa to automate tasks such as plug/conduit entry assembly, panel fastening, screw driving units, and terminal block placement. The cobots were chosen for their ability to operate in both full-speed industrial mode and a safe collaborative mode using safety scanners, allowing them to work closely with human operators without the need for fences. This application led to a production of over 240 units daily, reduced repetitive manual tasks, and retained in-house programming expertise for future automation projects.

Picture Source: Yaskawa

https://ifr.org/case-studies/collaborative-assembly-application-with-hc10

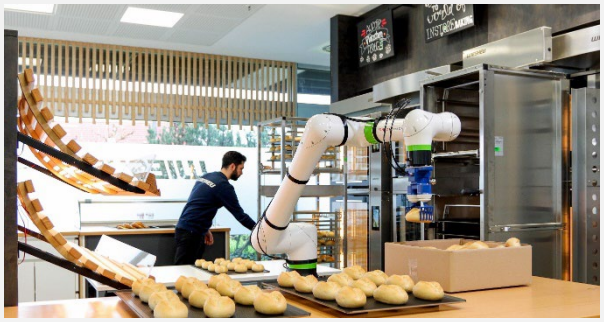
CASE STUDY

Cobots in the bakery

Robot manufacturer FANUC, baking oven manufacturer WIESHEU and retail specialist Wanzl have jointly developed the automatic system. The robot is designed to relieve supermarket and discount store employees from repetitive tasks, introduce higher levels of reliability into the baking process and reduce food waste.

The system involves a robot performing important work steps, such as loading the baking tray, inserting and removing the tray from the oven, and stocking the displays.

Introducing robots into the bakery environment benefits employees in many ways, including through more attractive working hours. In the case of “Bakisto”, the cobot starts baking on its own early in the morning, allowing employees to sleep longer.



Picture Source: Fanuc.

https://go4robotics.com/robots-in-the-bakery/

CASE STUDY

Cobots revolutionizing the painting process

Brandt A/S, a Danish powder coating specialist, sought to improve the accuracy and consistency of its manual painting processes. To address this, they integrated two UR10 cobots with Nordbo Robotics' Mimic technology, enabling the cobots to replicate human movements for precise touch-up tasks. The cobots now work alongside operators, improving product quality and freeing employees for more complex work. This solution allowed for seamless automation with minimal operator training, enhancing productivity. The collaboration level is sequential, with the cobots and workers alternating tasks in the shared workspace.

Picture Source: Universal Robots

https://ifr.org/case-studies/ur10-robots-revolutionize-the-painting-process

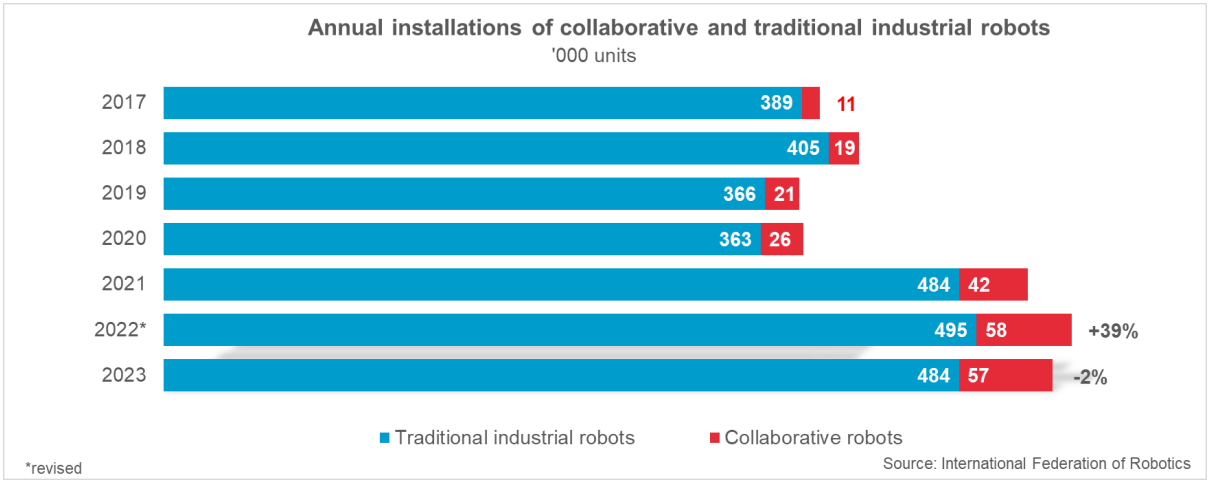
CASE STUDY

Cobots boost production on welding and on machine tending

Metal fabricator Raymath A/S faced the challenge of automating a high-mix, low-volume manufacturing process, especially for complex metal inert gas (MIG) and tungsten inert gas welding (TIG) welding tasks. The company adopted UR10e cobots with THG Automation’s welding systems, enabling precise, flexible welding for varied part geometries. This solution allowed Raymath to improve productivity, with cobots handling twice the welding speed and achieving 4x productivity while requiring fewer operators. The cobots work in sequential collaboration with operators, alternating between welding tasks and manual intervention. The ease of programming and flexibility in handling diverse parts justified the use of cobots for this high-precision, custom welding process.

Picture Source: Universal Robots

https://ifr.org/case-studies/cobots-boost-production-on-welding-and-machine-tending



Annual new installations of robots designed for collaborative used compared traditional industrial robots. Source: World Robotics 2024.

Cobot market

When the IFR collaborative robot statistics[1] started in 2017, collaborative robots had a market share of just 2.8%. Since then, the available product portfolio in the market has been continuously expanding. In 2022 the number of newly deployed collaborative robots grew above average by 39% to 57,966 units, representing a market share of 10.5%.

In 2023, there has been a contraction of the cobot market - for the first time since the start of IFR's cobot statistics. The number of newly deployed cobots declined by 2% to 57,040 units, but still keeping its share of 10.5% of the total industrial robot market.

The share of companies that use robots is still rather small, especially among SMEs. Cobots offer solutions for this customer segment where a traditional industrial robot might be oversized for their needs. Many cobot applications have lower requirements in terms of robot programming and training, precision, payload, and service life. This has the potential for lower costs of ownership.

Additional effort is needed to spread knowledge - especially among SMEs - to reap the benefits of robotic automation. The IFR's new campaign Go4Robotics (https://go4robotics.com/) offers vendor-neutral first orientation help for companies new to robotic automation.

Future trends and technological drivers

Digital technologies such as IoT and Cloud computing play a crucial role in enabling and enhancing the capabilities of cobots:

Cobots are increasingly equipped with advanced sensing technologies such as 3D vision systems, depth cameras, and lidar sensors. These sensors enable cobots to perceive and understand their environment, allowing them to interact with objects and humans more intelligently and safely.

Easy to program technology. Picture Source: Onrobot.

[1] *IFR´s Statistical Department has narrowed the definition of a oobot and offers the following distinction from traditional industrial robots: A collaborative industrial robot is an industrial robot that is designed in compliance with ISO 10218-1 and intended for collaborative use.*

The trend of using Artificial Intelligence and machine learning keeps growing. Cobot manufacturers are developing generative AI-driven interfaces which allow users to program robots more intuitively by using natural language instead of code. The impact of AI on the use of cobots is multifaceted. AI algorithms can enable cobots to learn from human demonstrations and adapt to new tasks. Another example is predictive AI analyzing robot performance data to identify the future state of equipment.

Cobot welding application. Picture Source: Yaskawa

New competitors are entering the market with a specific focus on collaborative robots. Mobile manipulators offer new use cases that could expand the demand for collaborative robots substantially. These mobile manipulators combine the mobility of robotic platforms (AMR´s) with the dexterity of manipulator arms. They are automating material handling tasks across industries.

Mobile manipulator palletizing products. Picture Source: Neura Robotics.

APPENDIX

Online-Links

- ISO/TS 15066:2016(en) - Robots and robotic devices — Collaborative robots https://www.iso.org/obp/ui/en/#iso:std:iso:ts:15066:ed-1:v1:en
- ISO 10218-1:2011(en) - Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots https://www.iso.org/obp/ui/en/#iso:std:iso:10218:-1:ed-2:v1:en
- ISO 10218-2:2011(en) - Robots and robotic devices — Safety requirements for industrial robots — Part 2: Robot systems and integration https://www.iso.org/obp/ui/en/#iso:std:iso:10218:-2:ed-1:v1:en
- World Robotics 2023 – Industrial Robots https://worldrobotics.org/
- IFR Position Paper „Next Generation Skills“, Nov. 2023 https://ifr.org/ifr-press-releases/news/next-generation-skills
- Go4Robotics campaign of IFR: https://go4robotics.com/

Case studies

Case studies showing the real-world application of robots designed for collaborative operation are regularly published on the IFR website:

https://ifr.org/case-studies/case-studies-collaborative-robots/

Case studies mentioned in this paper are listed below:

- **Using welding cobots to ramp up production of sky loungers** https://ifr.org/case-studies/welding-cobot-in-use-at-stoeckl-maschinen-und-geraetebau

- **Robots for assembly at container refrigeration factory** https://ifr.org/case-studies/carrier-transicold-begins-using-robots-at-global-container-refrigeration-factory
- **Reducing footprint with precise and cost-effective collaborative solution** https://ifr.org/case-studies/reducing-footprint-with-innovative-precise-and-cost-effective-collaborative-solution
- **Leak detection for refrigerator production line** https://ifr.org/case-studies/abbs-collaborative-robots-boost-productivity-by-68-on-electroluxs-refrigerator-production-line
- **LBR iisy cobot in quality assurance** https://ifr.org/case-studies/lbr-iisy-cobot-in-quality-assurance
- **35% cost reduction while maintaining work safety and high-quality output** https://ifr.org/case-studies/35-cost-reduction-while-maintaining-work-safety-and-high-quality-output
- **Collaborative assembly application for lighting solutions** https://ifr.org/case-studies/collaborative-assembly-application-with-hc10
- **Cobots in the bakery** https://go4robotics.com/robots-in-the-bakery/
- **Cobots revolutionizing the painting process** https://ifr.org/case-studies/ur10-robots-revolutionize-the-painting-process
- **Cobots boost production on welding and on machine tending** https://ifr.org/case-studies/cobots-boost-production-on-welding-and-machine-tending

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