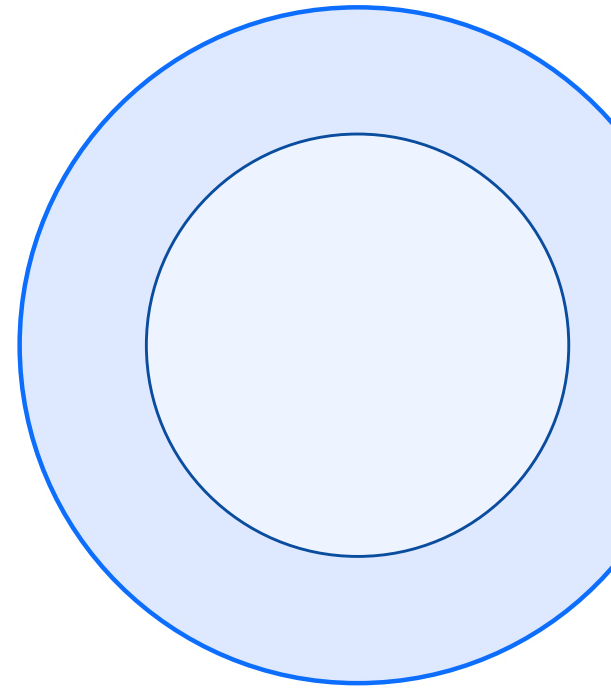


Robotics in the Smart Factory

Industry 4.0

Michael Blum und Ida Bausch | 12.05.2026



Learning Goals

- 1 The significance of robotics in industry and the smart factory
- 2 How industrial robots are structured and how they move
- 3 The different types of robots and their applications
- 4 How networked robots collaborate and optimize processes (IoRT)
- 5 How cobots enable safe human-robot collaboration
- 6 How safety standards protect humans working alongside robots
- 7 How robotics enables flexible Lot Size 1 production

Introduction & Development

What is an Industrial Robot?

ISO 8373:2021: "An automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be fixed or mobile for use in industrial automation applications."

- First industrial robots: 1960s
- Modeled after the human arm
- Goals: rationalization + consistent quality
- Central to smart factories & Industry 4.0



Top Robot Markets

1st CN China

2nd KR South Korea

3rd JP Japan

4th us USA

5th DE Germany

Fundamentals: Robot Structure



Main axes (A1–A3): Macro positioning ·
Secondary axes (A4–A6): Fine wrist orientation

The Six-Axis Articulated Robot

Modeled on the human arm — most widely used robot type in industry.

Base Frame

Stable foundation

Robot Arm

Main axes A1–A3

Wrist / Central Hand

Fine axes A4–A6

Robot Controller

Coordinates all axes

Weight Compensation

Supports precision

Mounting Flange

Connects end effectors

Axes & Degrees of Freedom

Main Axes (A1–A3)

- Also called 'large axes'
- Positioning the end effector
- Define the robot's workspace
- Linear or rotational (macro-movements)

Secondary Axes (A4–A6)

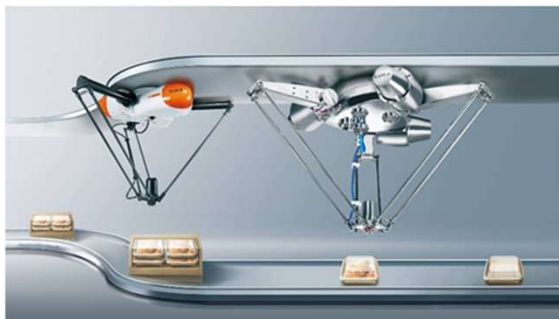
- Also called 'wrist axes'
- Fine positioning and orientation
- Almost always rotational
- Precise movement in the gripping area

< 6 DoF: Globally degenerate — limited range

6 DoF: Standard — full 3D positioning

> 6 DoF: Redundant — avoids obstacles

Types of Industrial Robots



Articulated

6 DoF

Welding, painting, assembly — most versatile

Gantry

3–4 DoF

Machine loading, large component assembly

Palletizing

4 DoF

Stacking pallets/boxes at high cycle speed

SCARA

4 DoF

Small parts, PCB assembly, pick-and-place

Delta

3–4 DoF

High-speed packaging, food & pharma

Mobile Platforms

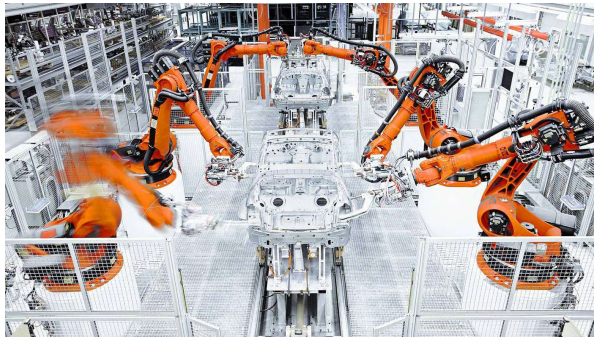
Variable

Intralogistics, warehouse transport

Industrial Applications

95%+

Automation level in automotive
body-shop areas



Key Tasks Performed by Robots:

Welding

Painting

Palletizing

Machine Loading

Deburring & Gluing

Measurement & Inspection

Assembly

Material Transport

Industries: Automotive · Electronics · Consumer Goods · Chemical · Food · Metal

Humanoid Robots

Tesla Optimus

Height:	~173 cm
Weight:	55–60 kg
Walk Speed:	Up to 8 km/h
Payload:	9–68 kg
Actuators:	40 electric
Brain:	Tesla FSD Chip + Neural Networks

Advantages

- Flexible — fits existing human workflows
- Relieves humans from dangerous/monotonous tasks
- Combines AI, sensors & humanoid design

Disadvantages & Limitations

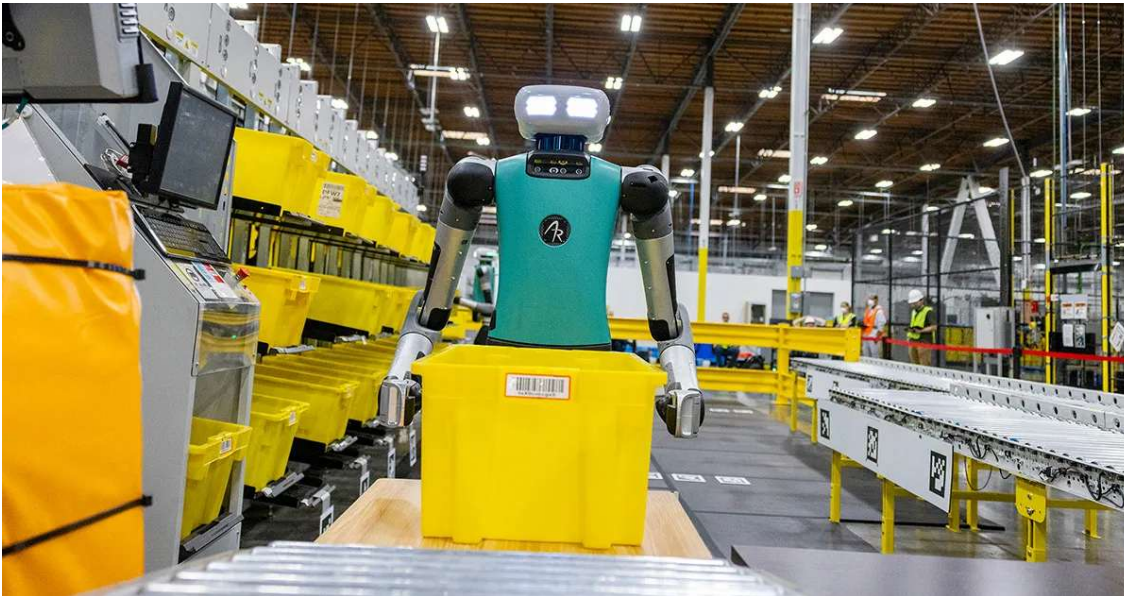
- High cost and technical complexity
- Full autonomy not yet achieved
- Technology still emerging


Pioneer: Mercedes testing 'Apollo' robot in Hungary for assembly, intralogistics & human collaboration.

Mercedes-Benz' neuer humanoider
Arbeitsroboter Apollo

Internet of Robotic Things (IoRT)

IoRT = IoT + Robots that not only exchange data but actively act in their environment.



 Amazon Fulfillment Centers: shorter walking distances, faster order processing, flexible product handling.

Local & Distributed

Process optimization across the entire factory floor

Robot-to-Robot

Machines share data and learn from each other's errors

Amazon Example

QR code navigation, infrared sensors, Wi-Fi coordination

Wireless Mesh

Data exchange among robots, sensors & smart spaces

Collaborative Robots (Cobots)



Leading cobot vendors: Universal Robots (UR) · KUKA · FANUC CRX ·
ABB YuMi · Franka Emika

What makes cobots different?



No Safety Fence

Force and speed limits allow direct contact without guards



Easy Programming

Teach-by-demonstration: guide the arm by hand



Flexible Deployment

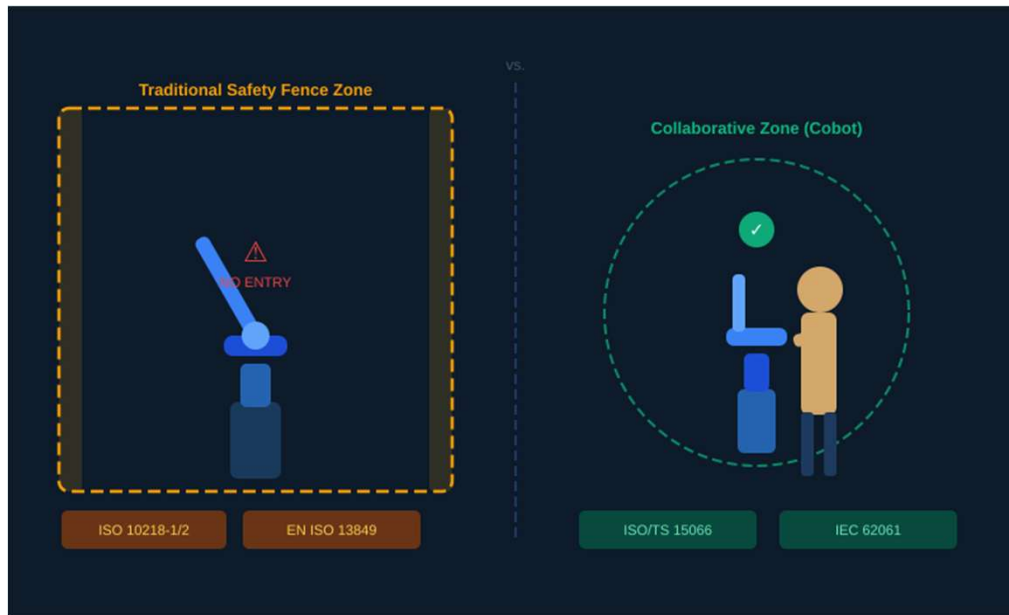
Rapidly repositioned for new tasks — no fixed workstation

True Collaboration

Cobots represent the fastest-growing segment of industrial robotics — global cobot market expected to exceed \$10B by 2030.

What are Cobots (Collaborative Robots)?

Robot Safety & Standards



Collaborative Safety Modes (ISO/TS 15066):

Safety-rated monitored stop

Hand guiding

Speed & separation

Power & force limiting

Key Standards

ISO 10218-1/2

Requirements for industrial robot design and integration in cells

ISO/TS 15066

Collaborative robots — power & force limits, speed & separation

EN ISO 13849

Safety-related control system performance level (PL a–e)

IEC 62061

Functional safety for machinery — SIL classification

Multi-Robot Systems (MRS)

Higher Efficiency

Distributed task execution reduces bottlenecks and idle time.

Extended Functionality

Different robot types combine their specializations.

Fault Tolerance

Redundancy allows work to continue if one robot fails.

Collaborative Learning

Robots share data and learn from each other's errors.

Key Challenges: Coordination · Interference · Cost · Robustness

Batch Size 1 in Industry 4.0

Lot Size 1: Manufacturing each product as a unique single unit — individual customer requirements met without sacrificing efficiency.

Flexible Robotics

Fast single-piece production · No long changeover · Cobots for collaboration

IoRT Integration

Real-time data sharing · Autonomous adaptation · Bottleneck prevention

Autonomous AGV/AMR

On-demand material flow · No human intervention · Minimizes waiting time

Together: Economical · Flexible · Individualized production in the Smart Factory

Summary

- 1 Robots are central to smart factories — enabling automation of precise, repeatable, and flexible tasks.
- 2 Six robot types (articulated, gantry, palletizing, SCARA, delta, mobile) cover all industrial needs.
- 3 Cobots enable direct human-robot collaboration without safety fences — the fastest-growing robot segment.
- 4 Safety standards (ISO 10218, ISO/TS 15066) define how robots and humans can safely share workspaces.
- 5 IoRT enables networked robot teams that exchange data, learn from each other, and adapt in real time.
- 6 Robotics + IoRT + autonomous transport make economical Lot Size 1 production in Industry 4.0 possible.