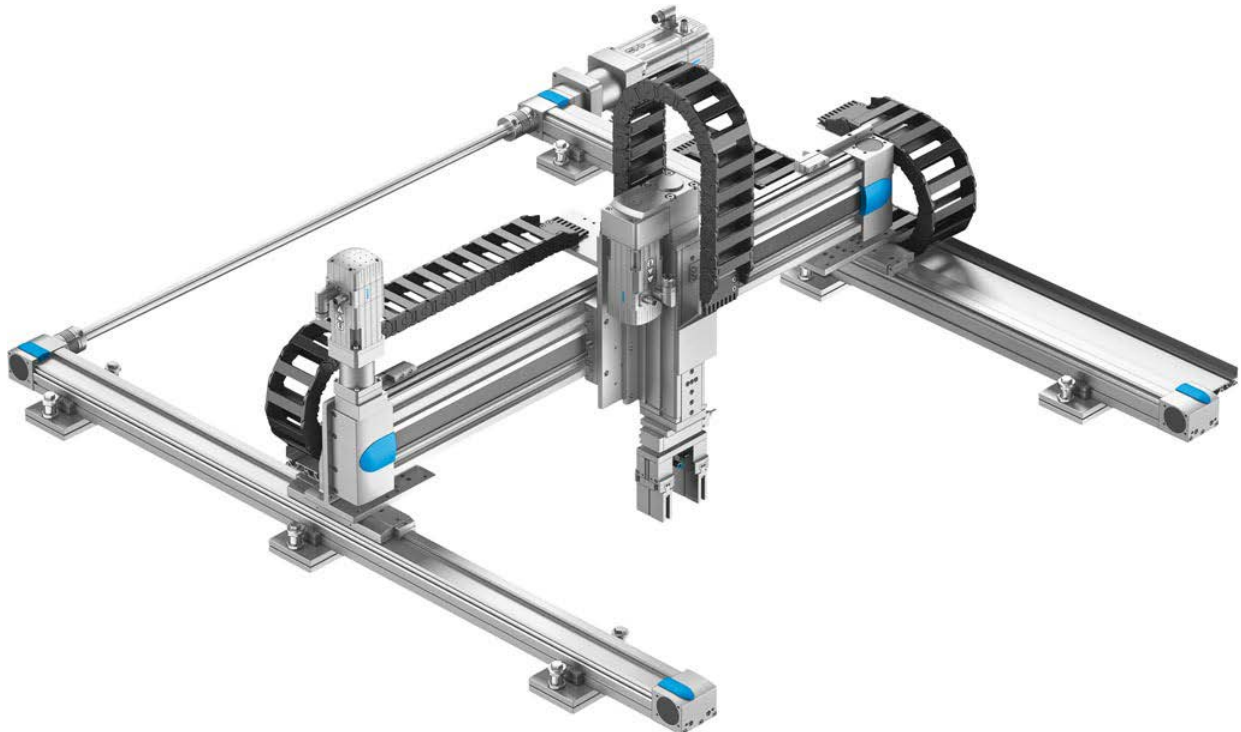


White paper

Cartesian handling systems – a technical comparison with conventional robots



Why is it worthwhile to use Cartesian handling systems?

The trend in conventional assembly and handling solutions is moving from robots to energy-efficient and cost-optimised systems. And no wonder: conventional robot solutions are too large-scale for many applications and frequently offer more functions and degrees of freedom than are actually required.

Energy-efficient and cost-optimised 2D and 3D systems – whether in a technology mix with electrical and pneumatic components or components that are purely pneumatic, purely electrical or servopneumatic – can be adapted more easily and efficiently to linear and rotational applications.

Optimisations in mechanical systems, procurement, programming and installation space can be exploited more effectively.

This white paper contains information on:

- Cartesian handling systems in an overview
- Functional differences between the various systems
- Key factors and selection aids for selecting a handling system

Overview of Cartesian handling systems

The DIN standards classify Cartesian handling systems as industrial robots, the same classification as conventional robots with 4-6 axes (articulated arm): “An industrial robot is an automatically controlled, reprogrammable, [...] multipurpose manipulator, programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications” (DIN EN ISO 8373).

The segmentation of such systems varies depending on the functionality, flexibility and the dynamic response of the system.

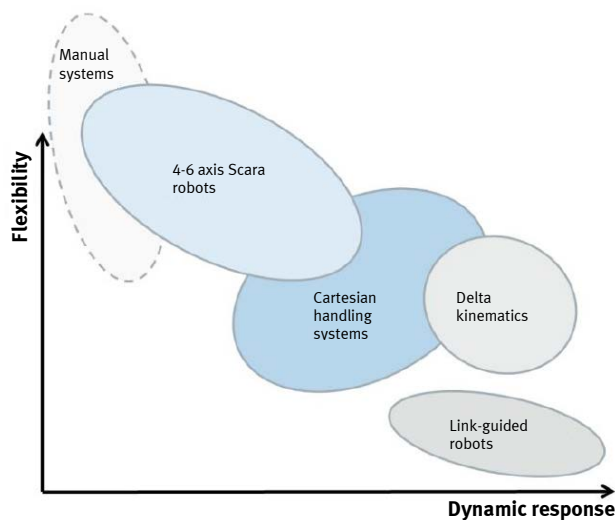


Figure 1: Overview of industrial robots

Cartesian handling systems and conventional robots with 4-6 axes (articulated arm) have a relatively large overlap in terms of flexibility and dynamic response but differ when it comes to their mechanical system. Depending on the application, Cartesian handling systems are controlled either by a simple PLC (which a user may already have) for point-to-point movements or by a complex control system with robotics functionality, such as for path movement.

The 4-6 axis robots always require a complex robot control system.

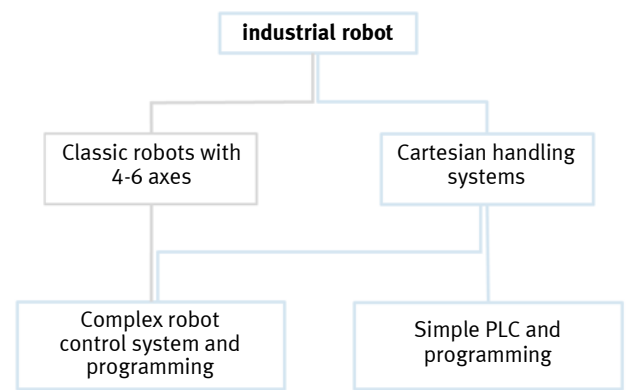


Figure 2: Relationships between robots and control systems

Moreover, Cartesian handling systems require less space for movement and lend themselves more easily to customised and modular adaptation to application conditions. The work space can be adapted easily by changing the axis lengths.

The kinematics are thus configured to suit the requirements of the application – in contrast to conventional robots where the application peripherals must be adapted to suit the mechanical and kinematic system of the robot.

The mechanical system of a Cartesian handling system is therefore part of the total solution and must be integrated into the complete system.

Customised, modular and economical

In contrast to standardised solutions with 4-6 axis robots from the catalogue, Cartesian handling systems can be customised in a modular fashion to suit the application (see Figure 4).

These systems require virtually none of the compromises often found with conventional robots. With a conventional robot, parts of the application must be adapted to the requirements and capabilities of the robot.

The shift towards standardisation and the use of mass-produced components makes the Cartesian customised solution economically attractive as well when compared with conventional robots.

Electric, pneumatic, combinations

With Cartesian handling systems, different drive technologies can be combined. The right pneumatic, servopneumatic and electric drives for the application are selected for each axis in order to achieve optimum movement in terms of efficiency, dynamic response, and function.

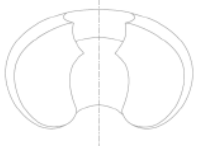
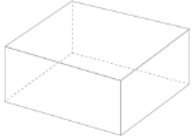
	Dynamic response	Mechanical system	Programming	Working space
Conventional robots	Medium (/High)	4-6 axes (articulated arm)	Complex programming for every movement	 Kidney-shaped/circular
Cartesian handling system	High	Multi-axis systems, axes linked vertically or horizontally	Simple and quick programming for point-to-point movements or complex programming e.g. for path movement (depending on the application)	 Rectangular/block-shaped

Figure 3: The most important features compared

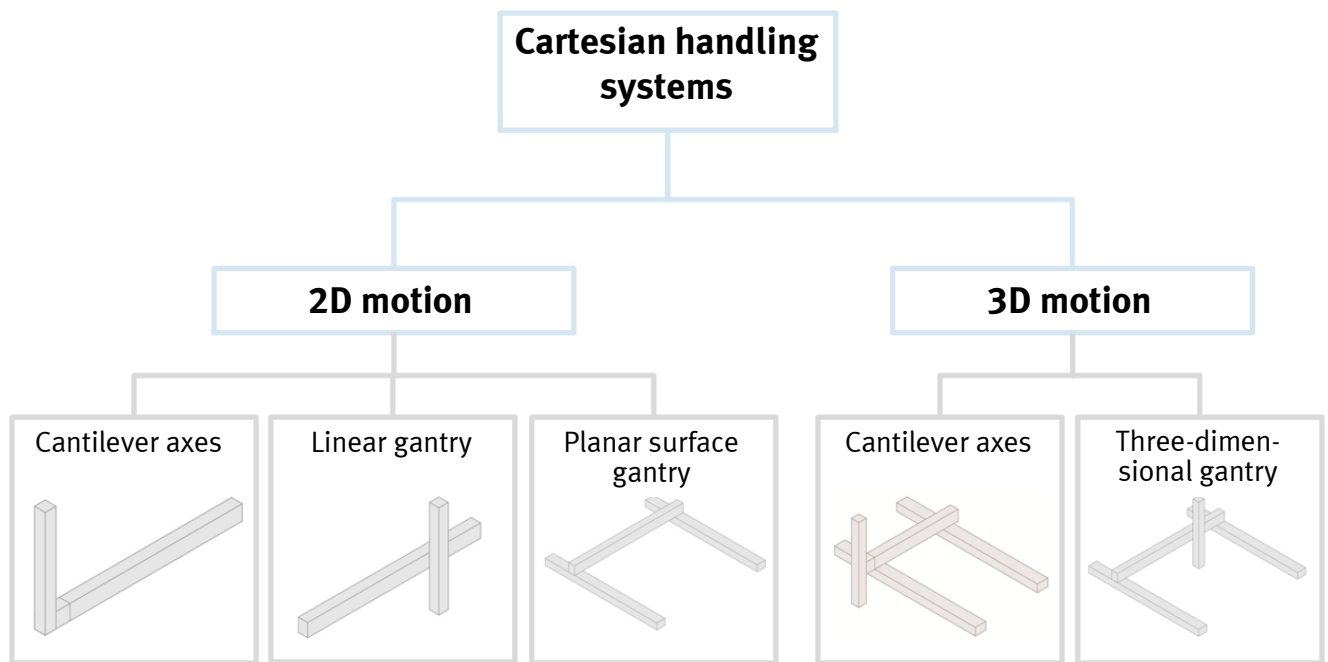


Figure 4: Overview of Cartesian handling systems

Cartesian handling systems as serial kinematics have main axes for straight-line motion and auxiliary axes e.g. for rotation. The system acts simultaneously as guide, support and drive and must be integrated into the application's complete system regardless of the handling system structure.

Mechanical structure of Cartesian handling systems

The following section describes Cartesian handling systems in their standard mounting position. However, all systems can be installed in any position in the space. This allows the mechanical system to be adapted ideally to the conditions of the application.

Two-dimensional handling systems

These Cartesian handling systems are divided into the categories of cantilevers and linear gantries with their

movement in the vertical plane, and planar surface gantries with their movement in the horizontal plane.

A 2D cantilever consists of a horizontal axis (Y) with a vertical drive (Z) mounted on the front of it.

A linear gantry is a horizontal axis (Y) secured at both ends, left and right. A vertical axis (Z) is mounted on a slide between the two end points of the axis. Linear gantries are usually slim, with a rectangular vertical working space.

A planar surface gantry consists of two parallel axes (X) linked by an axis (Y) perpendicular to the direction of movement. Planar surface gantries can cover a significantly larger working space than robot systems with delta kinematics or SCARA with their circular/kidney-shaped working spaces.

In addition to the conventional configuration with individual axes, linear gantries and planar surface gantries also take the form of complete systems with a fixed mechanical combination with a rotating toothed belt as the driving component. The low effective load makes them suitable for high capacities (picks/min) with corresponding dynamic response.

Three-dimensional handling systems

These Cartesian handling systems are divided into the categories of cantilevers and three-dimensional gantries with movements on both planes.

3D cantilevers are two axes (X) mounted in parallel plus a cantilever axis (Y) perpendicular to the direction of movement, with a vertical axis (Z) mounted on the front of it.

Three-dimensional gantries consist of two parallel axes (X) linked by an axis (Y) perpendicular to the direction of movement. A vertical axis (Z) is mounted on this perpendicular axis.

Note:

With planar surface, linear and three-dimensional gantries, the force is applied between the two points of support of the horizontal axes.

The horizontal axis on the cantilever acts as a lever due to the load suspended on its end.

Programming

The degree of programming required depends on the function: if the system only needs to move to individual points, quick and simple PLC programming is sufficient. If path movement is necessary, such as when applying adhesive, PLC control is no longer sufficient. In such cases, conventional robot programming is required for Cartesian handling systems too.

The control environment for Cartesian handling systems offers a large range of possible alternatives when compared with conventional robots.

Whereas conventional robots always require use of the manufacturer's specific control system, any PLC can be used for Cartesian handling systems, in the version with the best range of functions for the application's requirements and complexity.

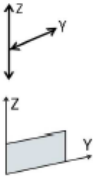
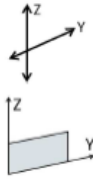
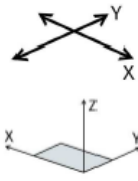
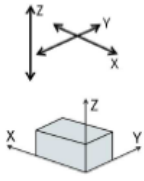
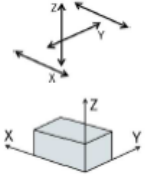
This means customer specifications can be adhered to and a uniform control platform can be implemented, including a uniform programming language and program structure.

With conventional robots, complex programming is required. Consequently a lot of work is needed to use 4-6 axis systems for mechanical tasks. For example, all six axes always need to be moved at the same time for straight-line travel. It is also difficult and time-consuming to program "right arm to left arm". Cartesian handling systems offer excellent alternatives here.

Energy efficiency

The foundations for energy-efficient handling are laid even when selecting the system. If the application requires long dwell times in certain positions, all axes on conventional robots are subject to closed-loop control and must continuously compensate for weight force. With Cartesian handling systems, it is usually only the vertical Z axis which needs to apply force continuously. This force is required to hold the effective load in the desired position against gravitational force. This can be achieved very efficiently using pneumatic drives, as these do not consume energy in their holding phases. A further advantage of pneumatic Z axes is their low dead weight, which means that smaller sizes can be used for the mechanical components of X and Y axes and their electric motor. The reduced effective load leads to a reduction in energy consumption. The typical strengths of electric axes come to the fore especially in the case of long paths and high cycle rates. Therefore they are often a very efficient alternative for X and Y axes.

Selection aid

	Cantilever (2D)	Linear gantry (2D)	Planar surface gantry	Cantilever (3D)	Three-dimensional gantry
Working space					
Shape of working space	Rectangular, vertical	Rectangular, vertical	Rectangular, horizontal (3D gantry can be created by adding Z axis)	Block-shaped	Block-shaped
Utilization of working space	Handling unit and working space adjacent	Handling unit and working space superposed	Handling unit and working space superposed	Handling unit and working space adjacent	Handling unit and working space superposed
Range of application	Pick and place functions for small to medium loads e.g. on rotary indexing tables or assembly-line workstations	Pick and place functions for small to large loads e.g. on assembly-line workstations	Positioning on horizontal plane for small to large loads (e.g. with external Z motion for dosing)	Pick and place functions for small to medium loads e.g. palleting	Pick and place functions for small to medium loads e.g. palleting
Max. usual stroke length (Festo) [mm]	Y: 400 Z: 400	Y: 8500 Z: 2000	X: 8500 Y: 2000	X: 5000 Y: 800 Z: 400	X: 8500 Y: 2000 Z: 2000
Mechanical design	A horizontal axis with a vertical drive at the front	Horizontal axis, mountings on left and right, vertical drive on slide between two mounting points	Two linked parallel axes with one axis at right angles to direction of motion	Two parallel axes plus one axis at right angles to direction of motion, the front of which is equipped with a vertical drive	Two parallel axes plus one axis at right angles to direction of motion, the front of which is equipped with a vertical axis

Application examples for Cartesian handling systems

2D cantilever

Pick & Place system consisting of two yoke drives.

- High mechanical rigidity and sturdy design
- Pneumatic and electrical components combined
- Electrical for positioning
- Pneumatic for lower weight and energy efficiency
- Precision in movement and positioning
- Very space-saving



Linear gantry

With >90 picks/min this linear gantry is especially suitable for highly dynamic Pick & Place applications e.g. in the packaging industry.

- Parallel kinematic principle with two stationary motors, rotating toothed belt and low effective load
- Compact and slim design
- Flexible handling with free movement in the vertical plane even when installation space is limited



Planar surface gantry

This planar surface gantry can approach any position within its working space.

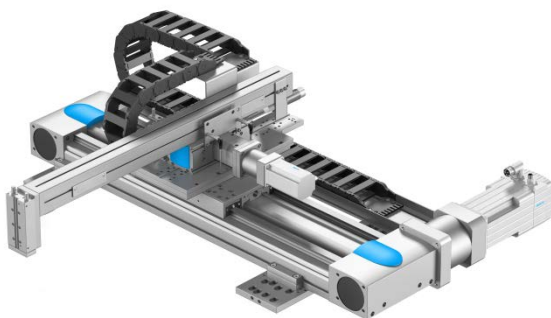
- 3 toothed belt axes as a planar surface gantry with rotating toothed belt for horizontal movement and positioning of the optional Z-axis.
- The parallel kinematic drive concept ensures low effective loads.
- The small version with just 155 x 110 mm is frequently used in the electronics industry or in laboratory applications for positioning trays/laboratory microplates.
- The large version is used for tasks such as the handling of solar wafers with a max. working space of 1800 x 2500 mm.



3D cantilever

The 3D cantilever with a heavy-duty axis linking two guides in one mechanical system.

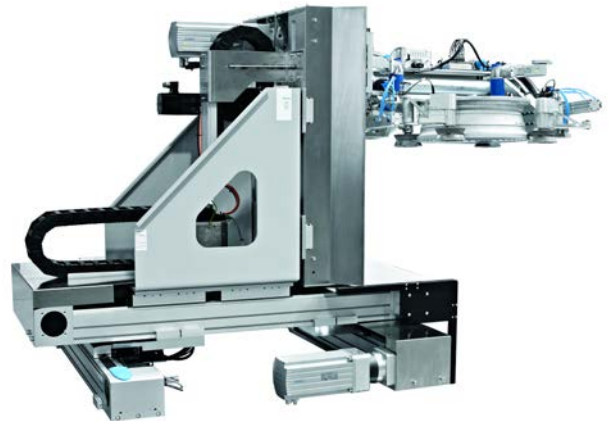
- Maximum rigidity and load capacity of the drives due to aluminium profile which absorbs very high torques and forces
- With recirculating ball bearing guide and with toothed-belt or spindle drive with 2 parallel guides.



Three-dimensional gantry

Very compact three-dimensional gantry for heavy loads, e.g. for X-ray examination of aluminium wheel rims. Precise examination of each rim in exactly the same position is required because tiny air pockets or foreign bodies in the cast aluminium can cause the wheels to break.

- Additional requirement: carefully engineered dynamic response for high process speed even in confined spaces.
- Six axes connected in parallel ensure maximum dynamic response and rigidity



Summary: what are the practical benefits of Cartesian handling systems?

In many cases it is more efficient and economical to use Cartesian handling systems instead of conventional robot systems.

For a large range of applications, it is possible to design an ideal Cartesian handling system.

- The systems are configured for the requirements of the application in terms of optimum paths and dynamic response, and are adapted to the load.
- Their mechanical structure makes them easy to program: for example, only one axis needs to be activated for vertical movements.
- Their optimal mechanical adaptation makes them energy efficient, e.g. by switching off the energy supply when at rest.
- Cartesian handling systems are space-optimised for the application.
- Standard, mass-produced components allow Cartesian handling systems to be an attractively priced alternative to conventional industrial robots.

And last but not least: with Cartesian handling systems, the kinematics are defined by the application and its peripherals, not the other way around.

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