COMPARISON OF FOUR TYPES OF INDUSTRIAL ROBOTS

Richard Martin Tekel'

Faculty of Mechanical Engineering, Brno University of Technology
Institute of Automation and Computer Science
Technicka 2896/2, Brno 616 69, Czech Republic
xptekel00@vutbr.cz

Abstract: *The paper defined key attributes and advantages and disadvatages of four type of industrial robots followed by their comparison*

Keywords: *6-axis robot, SCARA robot, Delta robot, 3-axis linear robot*

1 Introduction

The field of robotics is relatively new, with the term robot being introduced in 1920s by Karel Capek [6]. The development of devices which can replace man-power in tedious tasks or bad working conditions took a quick adoption. In the late 2010s (thus in less than 100 years), there were more than 400 000 robots bought; according to International Federation of Robotics. There are many companies which focus on the development of robotic solutions, such as KUKA, FANUC, ABB, Staubli, Kawasaki, Universal Robots, Yamaha, Doosan, etc.. Also, there are various types of robot constructions, leading to segmentation of the industry by robot type. The paper compares four different types of robots widely used in the industry. They are ordered based on the number of movement axes. Thus, 3-axis linear robots, SCARA and Delta robots (4 axes of movement) and 6-axis robot. Each paragraph discussed the key advantages and disadvatages of the construction as well as the deployment in the various industries. Building on the analysis, the paper compares the four types of robots with each other and sets recommendations for their use.

2 Robot Type Technical Specifications

The following section discussed the advantages and disadvatages of each robot type individually. It draws from literature review of original equipment manufacturers (OEMs), analyses and public case studies. Due to the large number of OEMs, the author narrowed down the scope and picked representatives for each robot type group.

2.1 3-axis Linear Robot

This robot type consist of 3 linear axis joined together with a gripper being able to move various loads. This construction is very simple and allows for customization as per customer specification, only limitation being the load transferred by the robot. The speeds can usually reach up to several meters per second using two axis simultaneously. The representative company for this robot type is Wittmann Battenfeld.

Figure 1: Example of 3-axis robot Wittmann Battenfeld

Advantages: Manipulators offer transfer of loads up to lower hundreds of kilograms [9]. THe compact size of linear guides makes the robot very suitable to narrow or limited workspace like injection moulding machines as the movements of the robot are not anyhow affected (due to purely linear movements of each axis). The sky is the limit for these robots in terms of flexibility and customization. Many additions like additional servo axes (in 3 directions), or customizable lengths of linear guides can be added / modified, which can easily double their workspace or allow to perform more complex movements.

Disadvantages: The manipulators have usually quite weak controller combined with their own programming language, which creates limitation to the program length to several thousand lines. Also the software support does not allow for virtual programming, thus it is tedious work to clean the programmed code by the robot. PLC runs cyclically and is not time-triggered, thus the fine-tuning is an important process which requires a lot of observations.

	Payload	Fixed X-axis	Movable X-axis	Single Y-axis	Telescopic Y-axis	Z-stroke	X-stroke	Y-stroke
	[kg]					[mm]	[mm]	[mm]
W808	3	yes	–	yes	–	1,250-2,000	440	600-1,000
W818	6	yes	–	yes	–	1,250-2,500	420-620	800-1,200
W818T	6	yes	–	–	yes	1,250-2,500	390-590	800-1,000
W821	12	–	yes	yes	–	1,250-4,000	350-550	800-1,400
W822	15	–	yes	yes	–	1,250-4,000	350-550	1,000-1,400
W823	12	–	yes	–	yes	1,250-4,000	350-550	800-1,400
W828	12	yes	–	yes	–	1,500-3,000	905-1,105	1,200-1,400
W831	12	–	yes	yes	–	2,000-5,000	800	1,000-1,400
W832 pro	30	–	yes	yes	–	2,000-6,000	500-900	1,200-1,600
W833 pro	20	–	yes	–	yes	2,000-7,000	500-900	1,200-1,800
W842 pro	30	–	yes	yes	–	2,500-9,000	1,200-1,400	1,400-1,600
W843 pro	30	–	yes	–	yes	2,500-9,000	1,200-1,400	1,600-2,600
W853 pro	40	–	yes	–	yes	2,500-9,000	1,200-1,500	2,000-2,600
W863 pro	60	–	yes	–	yes	3,000-9,000	1,200-2,000	2,400-3,000
W873	110	–	yes	–	yes	5,000-9,000	2,000	2,800-3,600
W883	130	–	yes	–	yes	5,000-9,000	2,000-3,000	2,800-3,600
W821 UHS	3	–	yes	yes	–	1,500-2,500	500	800-1,200
W832 UHS	7	–	yes	yes	–	2,000-4,000	500-900	1,200-1,600
W833 UHS	5	–	yes	–	yes	2,000-4,000	500	1,200-1,400

Figure 2: Overview of standard configurations - Wittmann Battenfeld

2.2 SCARA Robot

SCARA robot stands for Selective Compliance Assembly Robot Arms [7]. The robot has 4-axis of movement, three of which are rotary and one linear. The robot was specifically designed for fast a precise pick and place applications. The workspace of a robot is a cylinder, three rotary joints making circular movement almost 360 degrees, while stroke height defined by a linear joint allows to reach different heights.

Figure 3: Staubli TS2-80

Advantages: The advantage of SCARA robot lies in its design built for a specific purpose - high quantity of precise not complex movements. It is a choice to go with pick-and-place applications or simple assembly, piling etc.. [7]. The programming of SCARA is in general quite straight-forward, providing both simulation and programming as well as teach pendant programming. The construction is and simplicity of movement results in very robust and long-lasting design, capable of reaching millions of cycles before failure.

Disadvantages: SCARA robot has a fixed distance and while it is amazing within its design capabilities, there is no customization apart from standard models offered in catalogs. Also the loads possibilities are very limited (which may be also partly due to safety hazards to surroundings as unexpected failure of a higher load with velocities reaching tens km/hour may be fatal). On the other hand, the limited load limits the customization as end-effectors need to be light-weight as well.

2.3 Delta robot

Delta robots or parallel delta robots consist of three linear movements and one rotary movement directly attached to end-effector [3]. It uses parallelograms and levers to transmit linear motions into complex motion. The workspace of the robot is usually cylindrical and thanks to its design, it is capable of sudden and quick movements.

Figure 4: ABB IRB 360 Flexpicker

Advantages: The shape and mechanism makes the robot perfect for sharp sudden movements, thus pick-and-place of lightweight object. The shape of robot allows for no limitation in workspace, thus the cylinder can be reached in any point, be it in the middle or on the edge. The speed of the delta robot was for the long-time unmatched by rotary robots and it is still considered very fast (e.g. several m/s) or cycletimes under half a second [1] with reliable positioning. For pick-and-place application, the design which is hanging from the ceiling is definitely an advantage as there is no limitation in the workspace.

Disadvantages: The design became obsolete as the patent expired and cheaper but unreliable options arose. Secondly, current technologies allow other robot type to compete with delta robots and as the scalability is higher for other types, delta robots become less favourable option. Delta robots offer very limited workspace options and load weight options and thus are applicable mostly in niche markets.

2.4 6-axis robot

Lastly, 6-axis robots and the representative for this robot type KUKA [5]. The 6-axis robots in general consist of 6 rotary joints allowing the movement in 6 axis of freedom, cumulatively providing approximately spherical workspace. Robots come in defined sizes with very limited customization of dimensions. However, because of the breadth of defined sizes, there are robots providing loads up to 1300kg or workspace up to radius 3900mm.

Advantages: 6-axis robot have accurate movement, with very broad range of possible movement (or paths, by which the same point can be reached). This is the main differentiator, which is combined with user-friendly

and virtual programming software, giving access to virtual testing and optimizations. Also, many other equipment can be added to the robotic head like force sensors, linear guides providing 7th axis of movement, feeders for welding, painting etc.. The wide variety of tools also represent the range of applications for these robots which is certainly an advantage of the design. Industry applications range from automotive industry to various precise assembly operations or replacement of human operators in many sectors.

Disadvantages: One of the main disadvantages is complexity of movements and singular positions of a robot, which makes it very slow at certain positions. Complexity of movement creates uncertainty of whether the robot can reach specific point or not. Thus, for decisions, usually an aid from an experienced person or paid service is needed. Second disadvantage coming from a design is that, if some place is hardly reached by human operator, there is a fair chance that it will be hard for 6-axis robot as well. Thus, the robot suitability for narrow or small spaces is limited. While the robot can be considered fast enough, it is slower than the other types of robots discussed in this paper, therefore it is considered as another disadvantage.

Figure 5: small AGILUS and largest TITAN - KUKA robots

3 Comparison of robots

If we consider workspace as a primary attribute, 3 axis robots offer better flexibility and wider workspace combinations compared to all other robot types [8]. Pricewise, high-end 3-axis robots can be compared to the 6-axis robots. Low-end 3-axis robots can be significantly cheaper [10]. SCARA robots are generally cheaper than 6-axis robots, although high-end SCARA like Staubli can be more expensive [2]. Price of Delta robots vary, but they used to be more expensive than SCARAs.
If we add second attribute of permissible load, 6-axis robots are the most competitive robots, followed by 3-axis robots, SCARA and the last would be Delta robot. In terms of part stability during movement and respective need for tighter gripping, probably the most favourable would be 3-axis robots (as the calculations are more straightforward) and in less directions than 6-axis robots. Both SCARA and Delta robots use fast speeds to deliver fastest possible cycle times, thus those should be less favourable (which is overcame by low transported weight for both SCARA and Delta type of robot).
On the other hand, when considering speed and niche markets requiring fastest possible cycle times (with low weight), the SCARA would be the winner, followed by Delta robot. There would be a dispute between 3-axis and 6-axis robots. Final criterium would be the ease of programming, where the 6-axis robots have much more user-friendly and smoother environment for programming, and while SCARA and Delta robots are supported within the software, they would be equal. However, the 3 axis robot offer much less flexibility when it comes to the programming.

Coming to the final judgement, 3-axis robots are suitable for mid to high loads being transferred in single to double digit second cycle times [4][9] due to their rigid construction and high construction flexibility. Furthermore, it may be argued that due to customization, it can be used for more complex operations as well, due to the addition of more servo-axis.
6-axis robots are suitable for complex movements with almost any load or applications of fine movement and the ability to reuse the technology makes the hefty price tag more affordable.
SCARA robots are a great pick for quick and reliable pick-and-place applications or simple movement assemblies/operations. These robots are innovating at a high pace and are very competitive with Delta robots, maybe even more competitive than Deltas [2].
Delta robots are legacy system which has its niche in packaging and pharmaceuticals for the quickiest pick-and-place cycle-times and simple assembly operations.

4 Conclusion

This paper discussed four types of industrial robots, containing: 3-axis robots, 6-axis robots, SCARA robots and Delta robots. Through the catalog check and other literature review it was concluded, that each of them has their unique capabilities and applications in different operations and for different needs. There is an overlap between SCARA and Delta robots (while SCARA seems to become superior to Deltas over time) as well as 3-axis and 6-axis robots. Ultimately, the user has to decide what suits their needs more. The biggest drawback of 3-axis robots is the lack of user-friendly programming while 6-axis robots are more expensive and require more skills to operate and design the movements.

References

[1] ABB. *IRB 360 Flexpicker*. https://new.abb.com/products/robotics/industrial-robots/irb-360, 2021.

[2] Bonev, I. *The DIfference between Cartesian, Six-axis and SCARA robots*. https://coro.etsmtl.ca/blog/?p=55, 2012.

[3] Bonev, I. *Delta Parallel Robot — the Story of Success*. https://www.parallemic.org/Reviews/Review002.html: :text=Th 2021.

[4] Cybernetic Technologies. *When are Six Axis Robots a Better Choice than Three Axis Gantry Robots?* https://automation.cybernetik.com/2020/03/20/when-are-six-axis-robots-a-better-choice-than-three-axis-gantry-robots/, 2020.

[5] KUKA. *Industrial robots of firm KUKA*. https://www.kuka.com/en-be/products/robotics-systems/industrial-robots, 2021.

[6] McMorris, B. *A Timeline History of Robotics*. https://futura-automation.com/2019/05/15/a-history-timeline-of-industrial-robotics/, 2020.

[7] STAUBLI. *Our SCARA Industrial Robots*. https://www.staubli.com/en/robotics/product-range/industrial-robots/4-axis-scara-robots/, 2021.

[8] Vaughn, R. *The DIfference between Cartesian, Six-axis and SCARA robots*. https://www.machinedesign.com/mechanical-motion-systems/article/21831692/the-difference-between-cartesian-sixaxis-and-scara-robots, 2013.

[9] Wittmann Battenfeld. *Robots and Automation Systems*. https://www.wittmann-group.com/sites/default/files/2020-10/cnc-robots$_e nglish_2$020 − 10$_l owres.pdf$, 2020.

[10] Wittmann Battenfeld. *Robots and Automation Systems*. https://www.wittmann-group.com/sites/default/files/2020-10/primus$_e nglish_2$020 − 10$_l owres.pdf$, 2020.