Positioning a robot in a robotic cell in Tecnomatix

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Abstract. The life cycle of the product is shortening more and more. Therefore, it is necessary to rebuild the line, the time intended for reconstruction is shorter and the requirements set for the line are greater. This is the reason for changing the way the line is designed. Earlier, the design of the line was based mainly on the designer's experience and intuition. This method was very labour-intensive and required many corrections both at the construction and commissioning stages. This method was very labour-intensive and required many corrections both at the construction and commissioning stages. Sometimes the robot did not reach the points of the trajectory of movement. In this case, it was necessary to move the robot to another place or even replace the robot with another one. This, of course, increases costs and extends construction time. The next stage is programming the robots and other elements of the production line. Even at this stage there are errors that need to be corrected.

1. Introduction
Programs for offline programming, especially with visualization, avoid many errors at the stage of designing the production line [11, 14, 16]. These programs allow you to check the reachability of points and collisions of the robot's movement. This allows you to check the correctness of the selected trajectory of the movement and the written program. Sometimes it happens that during programming, it is necessary to change the position or even the robot.

By entering into the program the possibility of determining all points of the robot's foundation based on the points to be achieved by the robot. The theoretical assumptions necessary to implement the tool are presented in the previous article. Such a tool can be extended with additional options that allow to choose a better robot placement.

The software available for offline robot programming [8, 9] is becoming more and more complex and the virtual world is close to reality. Programs of this type have many tools related to robot motion programming. Geometric modelling more difficult than in CAD programs [2, 6], only primitives are available. It is possible to build the geometry of the elements of a cell or production line, but it is very labour-intensive and long-lasting.

Fortunately, these programs can import standard CAD formats [12, 13]. It is useful that these programs work with CAD programs. It is easier to make a model in a CAD program and make all necessary corrections. The preparation of documentation is also easier in CAD program.

Figure 1 shows an example cell consisting of several robots [3]. These robots manipulate an element with large dimensions.
It is easy to notice the dimensions of the element are larger than the robot's workspace. If the points are not close to each other, just distributed over the entire length, proper planning of the robot's position to reach each point is difficult.

In the traditional design of the cell, it is necessary to verify the availability of all points. In most cases, this is difficult because the robot's working space is a spatial complex body presented in the form of two flat drawings.

Sometimes it may happen that the position of the robot is wrong and it does not reach certain points in the right orientation. In this case, there are two options: the first is to modify the orientation, the second is to move the robot to a different position. Both options require additional work, especially when the problem was detected at the end of work.

2. Modelling
During the robot cell modelling [4], its position was asymmetrically selected. When choosing the first point (the farthest from the robot) and determining its orientation window will show as in figure 2.

![Figure 2. Failure to reach the point by the robot a) information window b) the properties window.](image)
In the window figure 2b, it is possible to move the robot to the position from which the robot will reach the point. This is an experimental method and in more difficult cases it may be difficult to determine the robot's position.

It is a good idea to know in what space there it can be putted a robot. For this reason, it is necessary to familiarize yourself with the documentation of the robot and especially with the working space of figure 3.

![Table showing robot variants and dimensions](image1)

![Diagram of robot's working space and dimensions](image2)

**Figure 3.** The robot's working space and its dimensions.

![Diagram of robot's working space 3D](image3)

**Figure 4.** The robot's working space 3D.
Using the documentation from figure 3, it is possible to build a workspace model in the CAD program [10] Fig. 4. This space can be transferred to the Tecnomatix program. By inserting space into the cell, it is possible to check the robot's range. This method allows to check if the points are in the workspace. It does not allow finding a space in which a robot can be placed.

**Figure 5.** The space in which a robot should stand to reach a point.

**Figure 6.** The space in which a robot should stand to reach one of two points.

**Figure 7.** The space in which a robot should stand to reach two points.

To find the space in which the robot was used a different method. In this method, the vector connecting the robot base to the wrist was reversed. Determining the workspace is like searching for the end of this vector. If the robot's workspace is attached at a point and then moved symmetrically
through this point. Determining the workspace is like searching for the end of this vector. If the robot's workspace is attached at a point and then moved symmetrically through this point then the space will be created, the place where the robot can stand. It remains to move the space by the inverse vector to the vector connecting the robot wrist with the tool's TCP point. The tool can change its position because the tool may have its pneumatic drive, electric, piezoelectric [5, 15], so that the choice is an important TCP. The tool can be used for welding, welding, 3D printing [7].

It is easy to see that the robot in figure 5 is outside the space determined by this method. Figure 5 confirms the message shown in figure 2a. Now it is visible and everyone can see how to check how far you have to move the robot to reach the point.

This method can be repeated for all points to which the robot has to reach. As an example in figure 8, the space for two points is presented. To make the next space, the same steps were taken as in the case of the first one. It is also possible to copy the first space and to properly shift the copy from point to point. The spaces thus obtained will be used for further analysis.

The next step is to find the space from which the robot will reach each of the points. It is easy in this method because it is sufficient to use one of the basic Boolean functions.

Figure 9 shows the result of a logical operation of two solids. A robot placed in this space with a mounted tool will reach both points.

The space obtained in this way can be used to select the location of the robot.

![Figure 8](image1.png)  ![Figure 9](image2.png)

**Figure 8.** The space in which a robot should stand to reach one of two points.

**Figure 9.** The space in which a robot should stand to reach two points.

If the height of the base under the robot is known, it is easy to find the plane on which the robot should be. This plane is obtained by cutting the body at the correct height. A part of this plane is located under the workpiece.

It is necessary to delete this fragment, it can be done now or it could be done earlier. Now just cut out the part of the plane under the workpiece. It is important to remember the cut with the offset so that the robot does not collide with the workpiece.

At an earlier stage, the contour of the workpiece can be cut from the solid. It is also necessary to remember to keep the offset and the basis under the robot, in this way.
3. Conclusions
This is a very easy way to find the right place to place the robot. It speeds up and facilitates searching. If the robot is too small to reach all points it will be detected without having to move the robot many times. It is possible to correct the orientation of points, thus changing the shape of the plane.
At a later stage it will be possible to divide the space into zones with different properties, eg: energy consumption [1].

4. References
[1] Banas W, Cwikla G, Foit K et al. 2017 Experimental determination of dynamic parameters of an industrial robot. IOP Conf. Ser.: Mater. Sci. Eng. 227, 012012
[2] Banas W, Cwikla G, Foit K et al. 2017 Modelling of industrial robot in LabView Robotics. IOP Conf. Ser.: Mater. Sci. Eng. 227, 012012
[3] Hryniewicz P, Banas W, Foit K et al. 2017 Modelling cooperation of industrial robots as multi-agent systems. IOP Conf. Ser.: Mater. Sci. Eng. 227, 012061
[4] Banas W, Gwiazda A, Monica Z et al. 2016 Analysis of the position of robotic cell components and its impact on energy consumption by robot. IOP Conf. Ser.: Mater. Sci. Eng. 145, 052017
[5] Buchacz A, Płaczeck M, Wróbel A 2014 Modelling and analysis of systems with cylindrical piezoelectric transducers, Mechanika 20 (1) 87-91
[6] Dymarek A, Dzitkowski T 2016 Inverse task of vibration active reduction of Mechanical Systems. Mathematical Problems in Engineering. (2016) 3191807.
[7] Ćwikła G, Grabowik C, Kalinowski K, Paprocka I and Ociepka P 2017 The influence of printing parameters on selected mechanical properties of FDM/FFF 3D-printed parts. IOP Conf. Ser.: Mater. Sci. Eng. 227, 012033
[8] Golda G and Kampa A 2017 Manipulation and handling processes off-line programming with use of K-Roset. IOP Conf. Ser.: Mater. Sci. Eng. 227, 012050
[9] Golda G, Kampa A and Paprocka I 2016 Modelling and simulation of manufacturing line improvement. Int. J. Comput. Eng. Res. 6, iss. 10, 26-31
[10] Grabowik C, Kalinowski K, Kempa W 2015 A method of computer aided design with self-generative models in NX Siemens environment IOP Conf. Ser.: Mater. Sci. Eng. 95, 012123
[11] Krenczyk D, Skolud B and Olender M 2017 The production route selection algorithm in virtual manufacturing networks IOP Conf. Ser.: Mater. Sci. Eng. 227
[12] Ociepka P and Herbuś K 2016 Application of the CBR method for adding the technological process designing IOP Conf. Series: Materials Science and Engineering 145 022030
[13] Ociepka P and Herbuś K 2016 Application of CBR method for adding the process of cutting tools and parameters selection IOP Conf. Series: Materials Science and Engineering 145 022029
[14] Olender M and Krenczyk D 2017 Practical example of game theory application for production route selection IOP Conf. Ser.: Mater. Sci. Eng. 227
[15] Płaczeck M, Buchacz A, Wróbel A 2015 Use of piezoelectric foils as tools for structural health monitoring of freight cars during exploitation, Eksploatacja i Niezawodność-Maintenance and reliability 17 (3) 443-449
[16] Skołud B, Krenczyk D, Kalinowski K, Ćwikła G and Grabowik C 2017 Integration of manufacturing functions for SME. Holonic based approach. [in] [ed.: Janusz Kacprzyk] Advances in Intelligent Systems and Computing 527, Springer, 464-473