Determination of the robot location in a workcell of a flexible production line

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Abstract. Location of components of a manufacturing cell is apparently an easy task but even during the constructing of a manufacturing cell, in which is planned a production of one, simple component it is necessary, among others, to check access to all required points. The robot in a manufacturing cell must handle both machine tools located in a manufacturing cell and parts store (input and output one). It handles also transport equipment and auxiliary stands. Sometimes, during the design phase, the changes of robot location are necessary due to the limitation of access to its required working positions. Often succeeding changes of a manufacturing cell configuration are realized. They occur at the stages of visualization and simulation of robot program functioning. In special cases, it is even necessary to replace the planned robot with a robot of greater range or of a different configuration type. This article presents and describes the parameters and components which should be taken into consideration during designing robotised manufacturing cells. The main idea bases on application of advanced engineering programs to adding the designing process. Using this approach it could be possible to present the designing process of an exemplar flexible manufacturing cell intended to manufacture two similar components. The proposed model of such designed manufacturing cell could be easily extended to the manufacturing cell model in which it is possible to produce components belonging the one technological group of chosen similarity level. In particular, during the design process, one should take into consideration components which limit the ability of robot foundation. It is also important to show the method of determining the best location of robot foundation. The presented design method could also support the designing process of other robotised manufacturing cells.

1. Introduction
Robotic manufacturing lines are increasingly replacing traditional workplace [11,12] In the case of the concept of ergonomics. If the platform is built with the principles of ergonomics worker does not get tired, it has easy access to all the necessary parts at his workplace. Workplace built without these principles are impractical and difficult to work worker can cause accidents. [15,16]

So it is with the robot to place the robot in the correct position will provide security jobs, providing access to all necessary positions [13, 14]. Now, the slot configuration is based on the experience of the designer. It often happens that in the course of the program is needed to generate reconfiguration manufacturing cell. In this case, it is necessary to start working again. When selecting the position of the robot is not possible sometimes modified the position or more positions. This is very dangerous
because it can cause a collision. So it is with the robot to place the robot in the correct position will provide security jobs, providing access to all necessary positions [6, 7]. Now, the slot configuration is based on the experience of the designer. It often happens that in the course of the program is needed to generate reconfiguration manufacturing cell. In this case, it is needed to start working again. When selecting the position of the robot is not possible sometimes modified the position or more positions. This is very dangerous because it can cause a collision.

For starters we need to remember that the robot does not set a point, but it is set in position (point has 3 coordinates, and the position has 6 coordinates) [4, 5]. Even if all the points of the robot work space available, it does not mean that all position in the workspace are available.

2. The search points robot assembly
Let we analyse where the robot can be installed if they are known only the operating position of the wrist. For example will show the difference between the position of the robot and the point of the robot workspace. Figure 1 shows the model of the robot from the robot wrist turned differently. Marked with the letter A workspace, marked with the letter B space in which the robot wrist can have direction as on the model.

If we add equation (1) spaces reachable in each specific position of the robot wrist as a result we will have the entire workspace.

\[ A = B_1 \lor B_2 \lor B_3 \lor \ldots \lor B_n \]  

where: A – robot workspace; B_1 … B_n – each space reachable in specific position of the robot wrist.

Workspace robot is presented everywhere because only depend on the construction of the robot and the rotation angles of the robot joints [8, 9].

The space in which the robot can be in any direction of the robot wrist is a conjunction equation (3) spaces reachable in each specific position of the robot wrist

\[ C = B_1 \land B_2 \land B_3 \land \ldots \land B_n \]  

where: C – points reachable in any direction; B_1 … B_n – each space reachable in specific position of the robot wrist.
Figure 2. Points reachable in any direction.

Figure 2 shows what is the difference between workspace robot and space in which the wrist can be in any direction.

We choose any k position in Cartesian coordinates. In the traditional approach, we checked if our point is located in the workspace. But we will do otherwise, it will be fixed wrist and look for where it can stand a robot [10].

Figure 3. Possible place of the foundation of the wrist robot horizontally at the point k

In figure 3 the place of foundation robot the space labeled β.

The more complicated it is to find a place for the robot, which is expected to reach more position. Such an example is shown in figure 4. The space labeled γ, is the place for the robot. Easy to notice that the larger workspace robot, the more space to place the robot. Construction of a large workspace are more expensive and are usually smaller capacity. This method can be used to find the smallest robot that execute this task. When the distance between the points k₁ ... kₙ increases the space in which the robot can be installed decreases.

\[ \gamma = \beta_1 \land \beta_2 \land \beta_3 \land \ldots \land \beta_n \]  \hspace{1cm} (3)

where: \( \gamma \) – place of installation robot to execution of all tasks; \( \beta_1 \ldots \beta_n \) – Place of installation robot to execution of 1 ... n tasks.
3. Place of installation of other components in the workspace
We need to know which direction the wrist is good for another component workspace. Figure 5 shows an example for placing another piece of the workspace. In figure 6 we can use when we know the desired direction of the wrist.

![Figure 5](image1.png)  
**Figure 5.** Place of installation of other components in the workspace.

![Figure 6](image2.png)  
**Figure 6.** Final view of workspace.

Marked with the letter D is the place (part), in which the robot performs its task in positions k1, k2, k3. It happens that this part makes it difficult to reach the position [1].
In a case shown on the figure 7 it is not possible to find a place from which all points are reachable. In this case, you can slightly modify the direction of the wrist and if it is unsuccessful, it is necessary to change the robot model or adding a second robot.

Then it is needed to further reduce the space foundation work. Such an analysis is more complicated and will be described by the authors in later articles [2, 3].

4. Conclusions
The proposed method searches the foundation point of the robot is not yet complete requires an analysis of collision. It will be further developed for the analysis of collisions in two cases: robot carries the part to the place of assembly and lines that flow components are surrounded by a robot.

The presented method will make it easier to find the right foundation robot when its task is to reach a few positions. Use of this method will make it easier to find a place of foundation robot not by trial and error but more knowingly.

In more complex cell ought to be remember not only for proper flow of information especially when there are many components.
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