Simulation of the robotic transport devices characteristics

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Abstract. Modern development of microelectronics has made it possible to create a variety of compact technical tools that help in all areas of human activity. The scale of production of microelectronic components has enabled the development of many areas of science and technology that were previously engaged in only a few specialists. One of these areas is robotics. The development of robotics solves many problems—from everyday household needs to narrow specialized tasks related to space technologies. However, one of the most relevant applications of robotics is manufacturing. This is primarily due to the fact that the life cycle of any product begins with production. Industrial robots represent a wide class of technical devices which can perform such actions as: Assembly, welding, moving, warehousing, etc. At present, there are already fully robotized production, where man is only an observer, which interferes with work in a pinch. Separately, we should note the possibility of using artificial intelligence technologies in industrial robots, which provide adaptation to various tasks. However, there is a wide range of problems where the use of artificial intelligence is not justified and their solution should be thoroughly studied.

1. Literature review and problem statement
The study of robotic systems is widely considered in applications to various tasks of human activity. At the same time, we consider both the design and manufacture and operation of robotic equipment [1-5].

Separately, we should consider the work devoted to the calculation of optimal parameters for the operation of robotic systems. The parameters of robotic systems were optimized for a wide range of tasks [6-9].

Analyzing the given literature sources, it is found that the problem of speed control of a production robotic transport cart is poorly studied. Therefore, it was decided to optimize the speed of movement of the robotic transport truck in accordance with the emerging production tasks.

A production robotic transport truck is a wheeled vehicle used to move workpieces, parts, and products within the production area. The robotic cart automatically receives the task and moves to the loading point along the specified trajectory. After loading, the cart is moved to the unloading point – processing equipment or warehouse.

Such parameter as the speed of movement of the robotic transport cart directly affects the time of execution of the production plan. Of course, there are production systems in which the transport cart is idle most of the time. But, as noted above, the class of tasks for adapting robotic devices to different production situations is very wide [10]. This is especially true for mass production, which is considered in this paper.
The problem of choosing the maximum speed of moving a transport truck arises, first of all, when designing a transport system. The choice of the maximum speed will determine the cost of production and operation of trucks.

In this article, the production of 3 parts is considered as an example of optimization. Each part has 2 processing operations. Moving between processing stations must be carried out using a robotic transport cart. Currently, in the production system under consideration, the movement of parts and blanks is carried out using an automated cart controlled by a person.

2. Simulation model of the production system
A simulation tool was used to study the production system. The choice of the tool is determined by the ability to collect all the system parameters of interest for research. The created simulation model reproduces all the characteristics of a real production system as accurately as possible. In the created simulation model, the source data is generated according to the most common production programs. The initial data is the number of parts of 3 names. Graphs of the distribution of the number of parts are shown in figure 1.

![Figure 1. Distribution of the number of parts in the production system](image)

In the created simulation model, an experiment was performed to determine the initial parameters of the study. In the experiment, the speed of the robotic production truck was equal to 1 m/s. The speed was chosen based on the speed of the existing transport system. The study tested the correlation between the total number of parts and the final time to complete the production plan. The correlation graph is shown in figure 2.

As you can see from figure 2, the processing time depends on the total number of parts. However, the figure also shows that this relationship is not strictly linear. Therefore, we decided to check the correlation of the number of each part with the total processing time. Table 1 shows the pairwise correlation between the quantity of each specific part and the processing time.

Thus, it was found that the number of parts # 3 has the least effect on the total processing time. The number of parts # 2 has the greatest impact on the processing time. This information does not directly affect the choice of speed of the robotic cart. But the problem of calculating speed cannot be solved in isolation from other problems. Using the degree of correlation, it is found that waiting for tasks on the
cart is best performed by equipment that processes 2 parts. It was implemented in the control algorithm of the robotic cart.

Figure 3 shows the correlation between 2 and 3 parts and the total processing time.

![Graphs showing correlation](image)

**Figure 2.** Correlation between the total number of parts and the final completion time of the production plan.

| Part number | Degree of correlation |
|-------------|-----------------------|
| 1           | 0.679                 |
| 2           | 0.746                 |
| 3           | 0.455                 |

Table 1. Correlation indicators between the quantity of each specific part and the processing time.

From figure 3, we can conclude that part 2 and part 3 are distributed independently of each other, which ensures the reliability of the generated data. Also, figure 3 clearly demonstrates the effect of the number of specific parts on the processing time.

3. **Optimizing the speed of a robotic transport cart**

To solve the optimization problem, we decided to use the experiment planning tool. Planning an experiment involves going through a finite set of options for the speed of a robotic cart. However, given that the amount of input data is limited and a fairly simple production system is being studied, experiment planning is the most successful optimization tool.

However, in order for the results of the presented work to be used in other systems, it is necessary to elaborate on the choice of an experiment planning model.
Figure 3. Correlation between 2 and 3 parts and the total processing time.

In practice, different planning models are used. The polynomial model is one of the most complete solutions to these problems. The task of finding a polynomial model that describes a system or its individual characteristics is to evaluate the type and parameters of a certain function:

\[
\eta = \sum_{i=0}^{m} \sum_{j=0}^{m} b_{ij} x_i x_j + \sum_{i=1}^{m} \sum_{j=1}^{m} b_{ij} x_i^{i_1} x_j^{i_2} ... x_m^{i_m}, \sum i j = d
\]  

(2)

After selecting the planning model, the next task is to plan and conduct an experiment to evaluate the numerical values of the coefficients of the equation (2) used. Since the polynomial contains coefficients to be determined, the experiment plan \( D \) must contain at least various experimental points:
The initial stage of experiment planning is based on the variation of factors at two levels: the lower and upper levels are symmetrically located relative to the main level, $i=1, k$. By writing out combinations of factor levels for each experimental point, a plan $d$ is obtained.

Software methods for conducting experiments have been added to the simulation environment. After conducting experiments on the resulting plan, the dependence of the production plan execution time on the speed of the robotic transport cart was obtained. A resulting table containing the following information is obtained:

- number of parts;
- total processing time;
- distance covered by the robotic cart;
- the time during which the cart was empty.

Figure 4 shows a graph of the dependence of the total processing time of parts on the total number of parts at different values of the speed of movement of the robotic cart.

The optimal speed of the robotic trolley is 3 m/s. This can be clearly seen in Figure 4. The discrepancy in processing time for the number of parts less than 1500 relative to high speeds is in the range of 5-8%. The maximum discrepancy with higher speeds is 11% with the number of parts equal to 1780.
4. Conclusion
As a result of this work, it was possible to determine an important parameter of the production robotic cart—the maximum speed of movement. Determining the maximum travel speed of a robotic cart has a significant impact on the final cost of the implementation project. By limiting the maximum speed, you can also save on the cost and weight of the batteries and other cart components used.

In addition to the main task, the operation algorithm of the transport cart has also been optimized. According to the adjustments made, the robotic cart waits for tasks at the equipment that processes part #2. As a result, the time that the cart passed unloaded decreased by 15%.

Thus, it can be concluded that using the simulation tool, it is possible to set the optimal parameters of a production robotic cart. In the future, this work will save significant material resources.

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