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THE DESIGN OF MOVEMENT OF THE ROBOT MODEL IN STRUCTURED ENVIRONMENT USING MSC ADAMS

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Abstract: In this work, the issue of kinematic analysis of the open kinematic chain of an industrial robot is discussed. The aim of the work lies in the kinematic analysis of the robot and the display of kinematic quantities in the work process. Transformation matrices of coordinate systems of individual members are determined for the solution by the matrix method. The direct method of kinematics using the MSC Adams View program is solved. The result is a graphical representation of the kinematic variables of the mechanical system of the end point of the effector and trajectory when moving in its working space.

1 Introduction

The issue of solutions of industrial robots is currently becoming more and more topical, because increasing the level of production and control after exhausting the known possibilities can be done only by automation and artificial intelligence, which will replace much of the necessary human participation in the production process. As in other fields, robotics is characterized by an effort to find general methods for solving entire sets of problems. An industrial robot is a device with multi-position motion units and its own drive and control with a flexible program for automatic operational and inter-operational manipulation of working machines or performing technological tasks. Industrial mobile robot is better solution, because smaller robot with locomotion function can be used instead of big fixed platform industrial robot. Industrial mobile robot can be used also for long distance handling with products in production process.

The paper shows the advantage of computer simulation, which allows you to create a virtual prototype of the device and modify it or create new variants without making the real device. It is possible to study the change in behavior of these different variants of the model. We can also simulate the proposed model in its work cycle. This will show possible collisions of its elements and evaluate various parameters of interest. The result is visualized in their program. It is possible to understand the operation of the model and subsequently verify its effectiveness. We can check the values of various parameters in the respective output views of the simulated model in real time.

2 Model of manipulator

The aim of the paper is the movement of a mobile robot in a structured environment. The robot consists of a handling arm mounted on a mobile chassis. We are interested in the trajectory of the effector endpoint. The generalized coordinates matrix method would be suitably used in the analytical solution of kinematics.

The configuration of the system with respect to the reference configuration is described by the generalized coordinates described q with q_i* (Figure 1). These indicate the motion (rotation or translation) in the individual axes. Configuration of the model with 5 degrees of freedom of movement is shown in Figure 1 [1-5].

The model consists of five members and a base marked 0. The arms of the robot are connected to each other by rotating kinematic pairs. The drives are in the appropriate kinematic pairs. The motion in kinematic pairs is described by generalized coordinates *q*.

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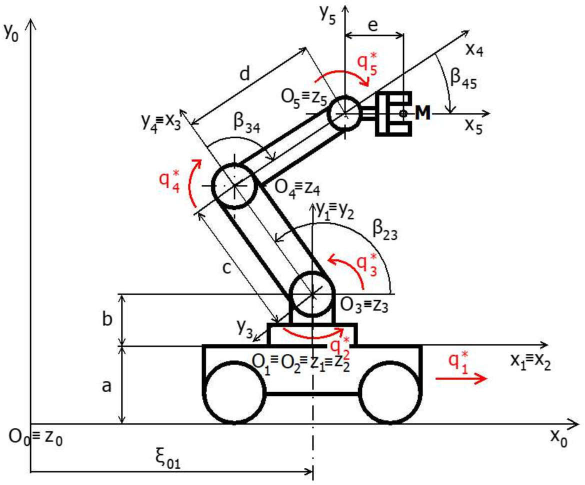

Figure 1 Model of the manipulator

The choice of the coordinate system is very important in order to be able to investigate the movement of the mechanism of the respective industrial robot in space. In this case, we will use a clockwise Cartesian coordinate system. In the matrix method we use translation matrices, which transfer the transformations of one coordinate system to another.

We consider the reference coordinate system $O_0(x_0, y_0, z_0)$ connected with base 0. For each member of the kinematic chain we define its local coordinate system. For nth member it is $O_n(x_n, y_n, z_n)$. The location of an individual member in the global coordinate system is then determined using the local coordinates systems of the other members. The coordinate system $O_1(x_1, y_1, z_1)$ was created by moving the coordinate system along the x_0 axis by ξ_{01} and along the y_0 axis by *a*. Other offsets of coordinate systems are apparent from Figure 1. The relation between the coordinates of the point M in the global and nth local coordinate systems can be expressed by using the transformation matrix notation [1-5] and takes the following form:

$$\bar{r}_{0M} = \boldsymbol{T}_{0n}\bar{r}_{nM} \tag{1}$$

Where $\bar{r}_{0M}$ – is the position vector of point M, $\bar{r}_{nM}$ – is the position vector of point M in the *n*-th local coordinate system.

The matrix $\boldsymbol{T}_{0n}$ in equation (1) then takes the form (2):

$$\boldsymbol{T}_{0n} = \boldsymbol{T}_{01}\boldsymbol{T}_{12}\dots\boldsymbol{T}_{n-1,n} \tag{2}$$

It represents the transformation matrix of the resulting motion. It is given by the product of transformation matrices of elementary motions of individual bodies.

We have chosen the following labelling of transformation matrices of elementary motions: $\boldsymbol{T}_{Z1}(x)$, $\boldsymbol{T}_{Z2}(y)$, $\boldsymbol{T}_{Z3}(z)$ for translation along the axes *x*, *y*, *z* respectively $\boldsymbol{T}_{Z4}(\varphi_x)$, $\boldsymbol{T}_{Z5}(\varphi_y)$, $\boldsymbol{T}_{Z6}(\varphi_z)$ for rotation round the axes *x*, *y*, *z* respectively.

Equation (1) is an effective notation for study of simultaneous motion, especially of spatial mechanisms which in most cases represent industrial robots. It is also suitable for subsequent numerical solution.

There are shown the locations of the generalized coordinates q_1^*, q_2^*, …, q_n^*. The individual generalized coordinates for all model links form the vector of generalized coordinates of the manipulator mechanism. The position of the point M of the end effector is also indicated. The matrix notation described in the previous chapter is applicable in the following problem analysis. It is practical to describe the relative position of the model links using a set of local coordinate systems. The indicated generalized coordinates are defined using these local coordinate systems. They represent the relative rotations or translations in the respective links of the model.

We can describe any shape of a manipulator model using the transformation matrices of elementary motions [5,8]. In our case a set of motion equations is assembled for the model in Figure 1. The assembled set of equations of motion is then solved using numerical methods. Using the rule of homogeneous transformation between two coordinate systems we define a transformation matrix between the nth local coordinate system and the coordinate system of the base 0 in the form (3):

$$\boldsymbol{T}_{0n}(q_1^*,\dots,q_n^*) = \boldsymbol{T}_{01}(q_1^*)\boldsymbol{T}_{12}(q_2^*)\dots\boldsymbol{T}_{n-1,n}(q_n^*) \tag{3}$$

Where:

$$\boldsymbol{T}_{01} = \boldsymbol{T}_{B2}(a)\boldsymbol{T}_{B1}(\xi_{01}) \tag{4}$$

$$\boldsymbol{T}_{12} = \boldsymbol{T}_{B5}(\beta_{12}) \tag{5}$$

$$\boldsymbol{T}_{23} = \boldsymbol{T}_{B2}(b)\boldsymbol{T}_{B6}(\beta_{23}) \tag{6}$$

$$\boldsymbol{T}_{34} = \boldsymbol{T}_{B1}(c)\boldsymbol{T}_{B6}(\beta_{34}) \tag{7}$$

$$\boldsymbol{T}_{45} = \boldsymbol{T}_{B1}(d)\boldsymbol{T}_{B6}(\beta_{45}) \tag{8}$$

Point M position:

$$\bar{r}_{5M} = [e, 0, 0, 1]^T \tag{9}$$

Initial model configuration is described by constant transformation matrices of elementary motions. They set the initial position of the model by applying a constant rotation or translation in the respective link. Transformation matrix of each link with one degree of freedom is given by the product of two matrices, a constant and a variable matrix. Derivatives of transformation matrices of elementary motions can be replaced by a product of the respective transformation matrix and a matrix differential operator as described in more detail in [6-8].

3 Computer simulation

The algorithms for dynamic analysis are used in software for simulation of the dynamics of bound systems [1-4]. One of them is MSC Adams. We used it to design and simulate a mobile service robot as outlined in Figure 1. In Figure 2 is shown the 3D model compilation. Modelling elements and procedures for the creation of bodies and their kinematic bonds were used in the Adams software. After proposing the model the functionality is verified and the simulation is started Figure 2 [8-10].

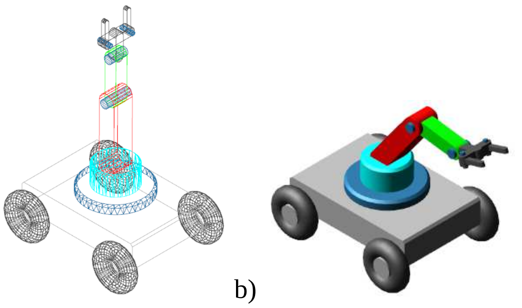

Figure 2 a)-b) Model of the manipulator in MSC Adams/View

The service robot has 5 degrees of freedom of motion. We simulated the model motion in structured environment performing prescribed operations (Figure 3) [11-16].

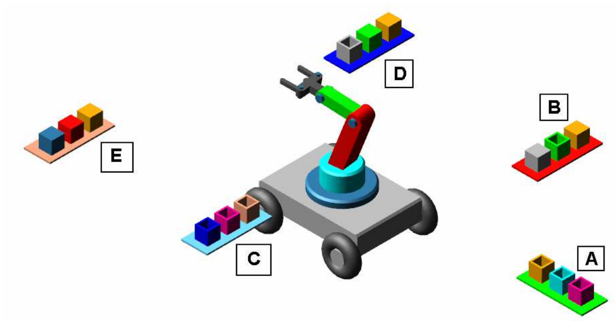

Figure 3 Mobile robot in structured environment with the designation of places A – E to perform the operations

The trajectory in the spatial view of the end effector in structured environment is shown in Figure 4.

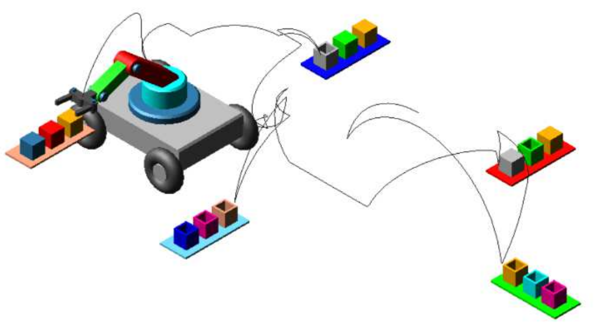

Figure 4 Window of the MSC Adams/View software with trajectory of the end effector in the spatial view

The progression of position (top view) of the end effector are shown in Figure 5.

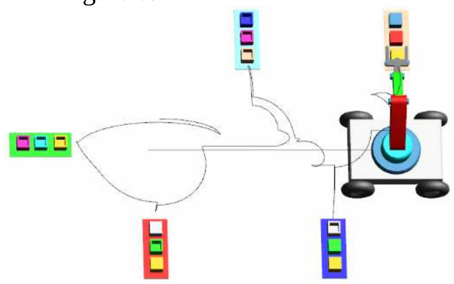

Figure 5 Trajectory of the end effector – top view

Interactive simulation and visualization allows comfortable simulation of the model, model modifications and visualization of results. The graphs of output variables enable viewing the current values of the measured variables in real time during the actual simulation and its visualization (Figure 6).

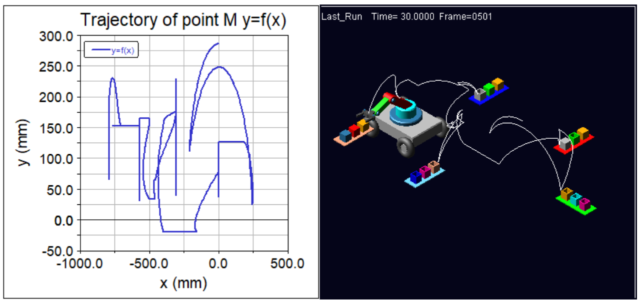

Figure 6 The animation of the simulation and displacement of the end-effector y=f(x)

It is also possible to display the model in its current state and print the results prepared in this way. The postprocessor is an integral part of the computer prototype modeling process and is a very convenient tool for creating, processing, editing and presenting simulation results in the form of graphs [5,8,17]. Simulation output can also be created in AVI format.

4 Resulting kinematic parameters

The resulting graphs are in the following pictures. The values of the calculated variables are displayed in a graphical form with the postprocessor in Figure 7 to Figure 9.

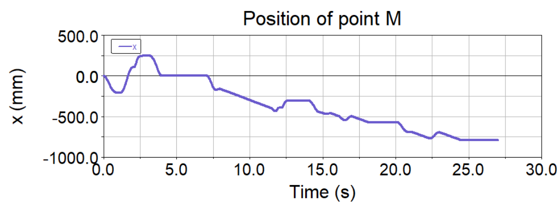

Figure 7 The graph of the x position of point M

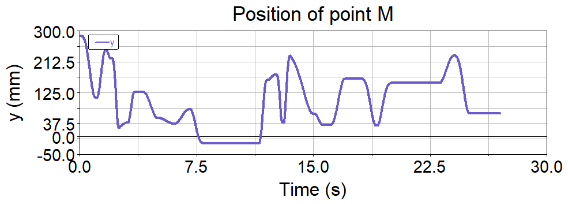

Figure 8 The graph of the y position of point M

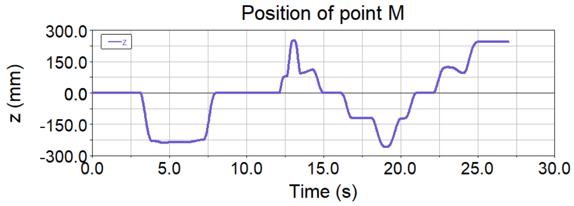

Figure 9 The graph of the z position of point M

The graph of the trajectory of the point M are shown in Figure 10.

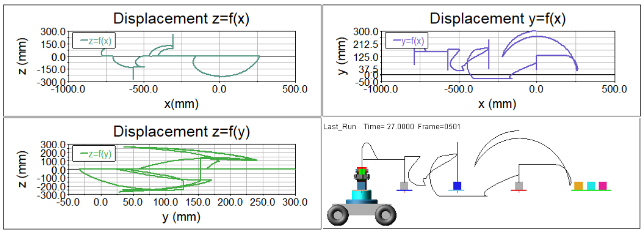

Figure 10 The graph of the trajectory z=f(x), y=f(x), z=f(y) and trajectory front view

The obtained graphs of the actual motion during the motion along the trajectory shown in Figure 10 indicates a suitably designed and functional end-effector position control system.

5 Conclusions

MSC Adams works with a 3D model. The advantage is the possibility to simulate the motion of the prototype model and its control in the program environment and verification of the functionality in the form of 3D visualization. Based on the results obtained from the simulation it is possible to build a real model and design the drives. Based on the results of the simulation it can be stated that the proposed motion in joints is functional during the motion of the manipulator in structured operating environment. Simulation software is a suitable tool for design, saving time and resources. It is also suitable for detailed research and investigation of mechanical systems in practice.

We outlined the process of dynamic analysis of spatial open kinematic chains using the theory of matrices of elementary motions. Movement characteristics of individual kinematic pairs - position, velocity and acceleration at certain time intervals were determined. The benefit of the work is also didactic. Particularly in the field of Applied Mechanics and Mechatronics the presented process offers the possibility of practical application of matrix algorithms for automated generation of mathematical models. These provide the theoretical base for further analysis by existing software and also the possibility to develop more specialized software tools. These procedures are used in software tools which make dynamic analysis and optimization of complex mechanisms more effective.

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