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INTERFACE DESIGN FOR A SERIAL MANIPULATOR USING A VIRTUAL SIMULATION II. PROGRAM APPLICATIONS

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Abstract. This paper represents the second part of a study which focuses on the trajectory analysis of a serial manipulator, configured using the Denavit-Hartenberg method. The paper presents the applications of the MATLAB virtual simulation program, which constitutes the subject of the first part of the research. The simulation covers a large range of serial industrial robots since the program applies to any type of joints (rotational, prismatic) or possible combinations of joints. The object under analysis is configured through a user interface, where the input data consists of the Denavit-Hartenberg values for each constituting joint.

Key words: manipulator serial; Denavit-Hartenberg; trajectory; MATLAB.

1. Introduction

The entrance of robots in the industrial activities on a wide scale allowed not only a significant increase of economic efficiency but at the same time a fast adjustment to the changing of dimensions of products manufactured using the same technological machinery. The design of industrial robots structures of flexible assembly lines implies the necessity of virtual simulations

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that facilitate the optimal selection of the dimension of constituting elements and of the functional parameters, based on the results obtained from the positional analysis.

Two types of fundamental problems are characteristic to robotic kinematics:

- the forward kinematic problem;
- the inverse kinematics problem.

In the case of the forward kinematic problem the geometric characteristics of the robot, the variation laws of the different kinematic relative parameters are presumed known. The objective is determining the absolute kinematic parameters corresponding to the characteristic point (point P from Fig. 1).

In the case of the inverse kinematic problem the geometric characteristics of the robot and the variation laws of the different kinematic absolute parameters are presumed known. The objective is determining the relative kinematic parameters of the robot.

This study handles a particularization of the forward kinematic problem, the forward problem of positions (forward geometric model), where the geometric characteristics of the robot and the variation laws of the generalized coordinates are known; the target is determining the variation laws of the absolute positions of the characteristic point.

The paper presents the applications of the MATLAB program `manip_new` that realizes the positional analysis of serial industrial manipulators. The simulation applies for serial robots consisting of open kinematic chains, where their constituting elements are linked together through active kinematic joints of the fifth class, rotational or prismatic.

The positional analysis performed by the `manip_new` program allows the computation of trajectory of a serial manipulator, based on the coordinates of the constituting active joints, using the Denavit-Hartenberg parameters (Craig, 2013; Handra-Luca *et al.*, 1996).

2. Applications Using the Virtual Simulation `manip_new`

2.1. General Description and Input Parameters

The application considers a serial robot with three degrees of freedom, more specifically three kinematic rotational joints, Fig. 1. Every constituting element of the manipulator has an associated axis system, following the method described in (Craig, 2013). A detailed description of the methodology of setting the reference systems of the elements and the corresponding conventions are presented in (Popescu *et al.*, 1994). Fig. 1, from which the Denavit-Hartenberg parameters emerge, is constructed following the methods mentioned above.

The Denavit-Hartenberg input parameters are described in Table 1. In column a_{i-1} the length of the elements were given particular values, the other parameter values resulted from the chosen robot architecture.

The program determines the joint coordinates based on the imposed steps. If the position of the P point is required, a fifth system of coordinates is needed $\{x_4, y_4, z_4\}$.

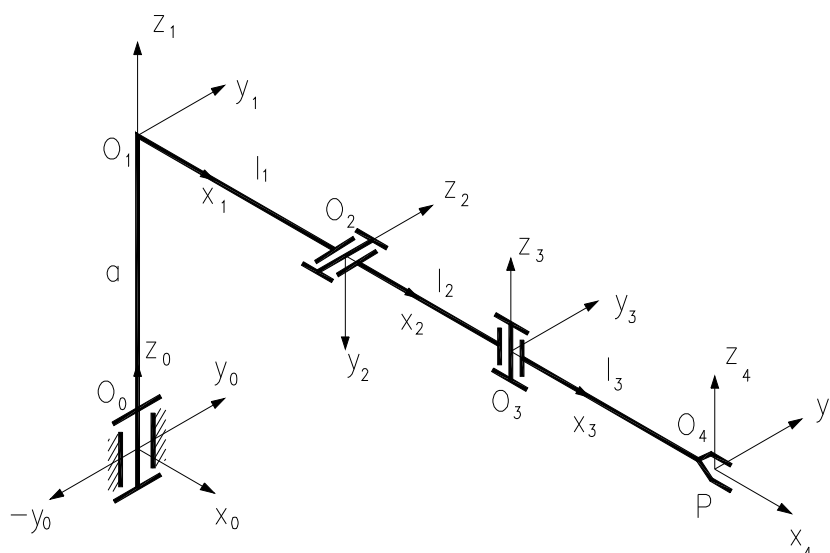


Fig. 1 – Serial manipulator with 3 degrees of freedom (Doroftei, 2002).

Table 1
Denavit-Hartenberg Input Parameters for Joint $i, i = 1,4$

Joint number	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	$a=8$	0
2	-90	$l_1=5$	0	0
3	90	$l_2=8$	0	0
4	0	$l_3=3$	0	0

The user inserts the input parameters from Table 1 using the window shown in Fig. 2, button “Initializare” (Initialization). Button “Urmatoarea” (Next) allows configuration of each joint in particular.

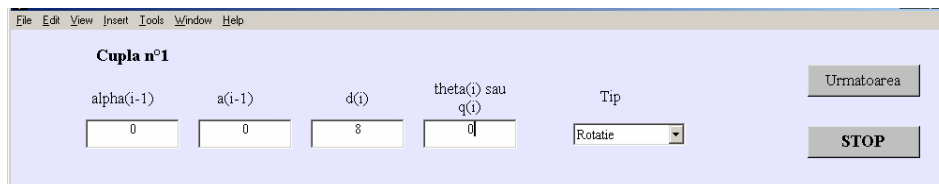


Fig. 2 – Initialization form for first joint.

The animation feature shows the trajectory of the manipulator. Additional input parameters are necessary for each joint: the start and stop angle and the number of steps, see Table 2.

Table 2
Animation Input Parameters for Joint i , $i = 1,4$

Joint number	Start angle	Stop angle	Number of steps
1	-90	180	270
2	-90	90	270
3	0	270	270
4	0	270	270

Considering the input values of the geometric characteristics of the serial manipulator, Fig. 3 illustrates the initial position of the robot.

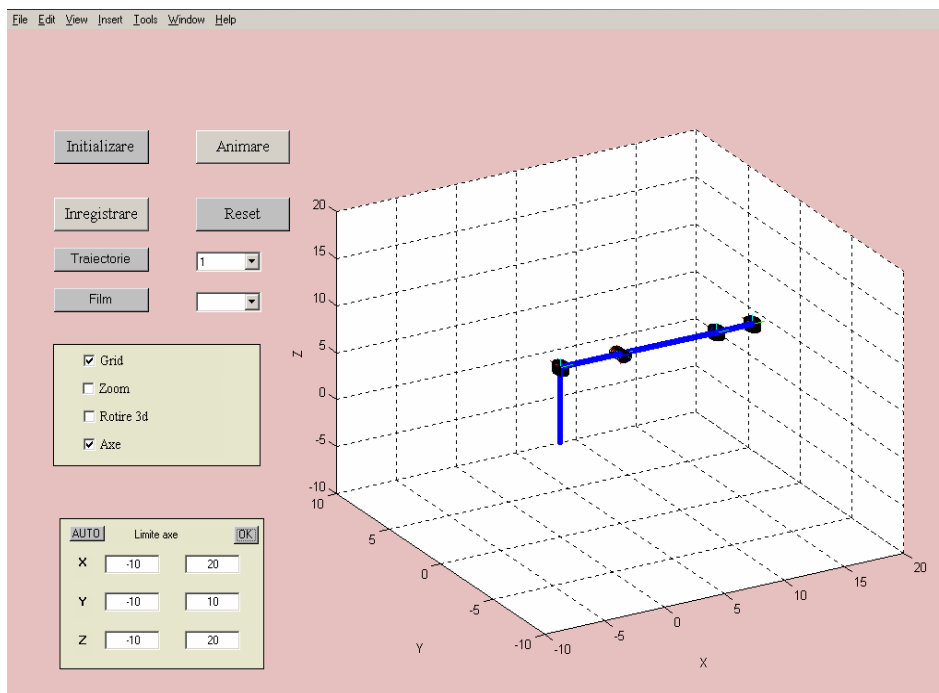


Fig. 3 – Initial position of serial manipulator.

2.2. Results

An example of a resulting animation is shown in Fig. 4.

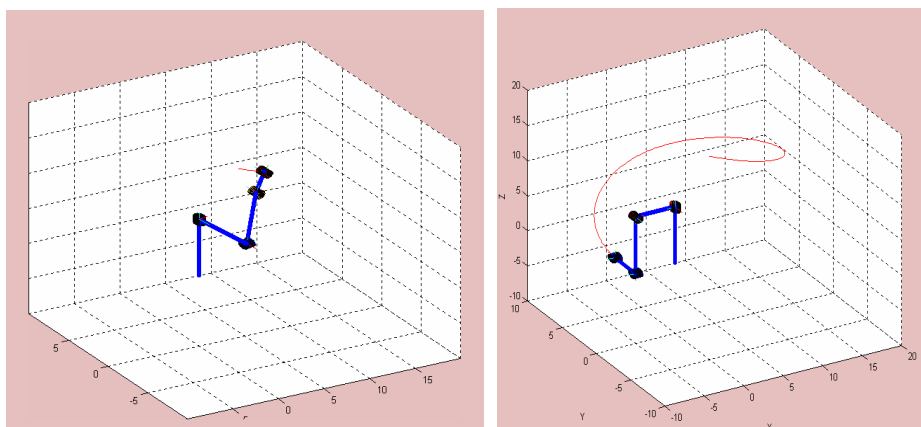


Fig. 4 – Trajectory animation of serial manipulator – different moments.

In Fig. 5 an extract of the history data of the computed coordinates for the first joint based on the given steps is shown. The program stores information for all joints.

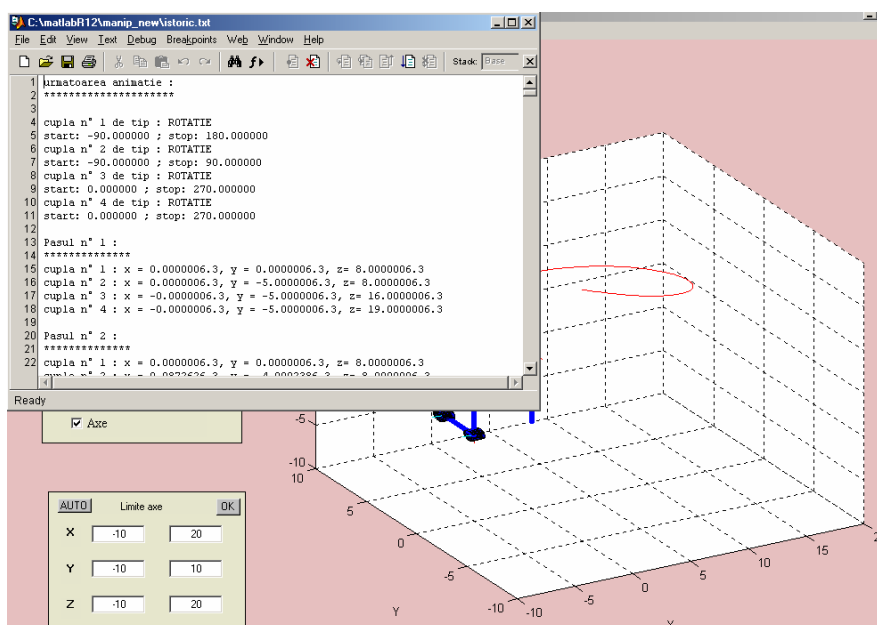


Fig. 5 – Extract from the history data, using button “Inregistrare” (Record).

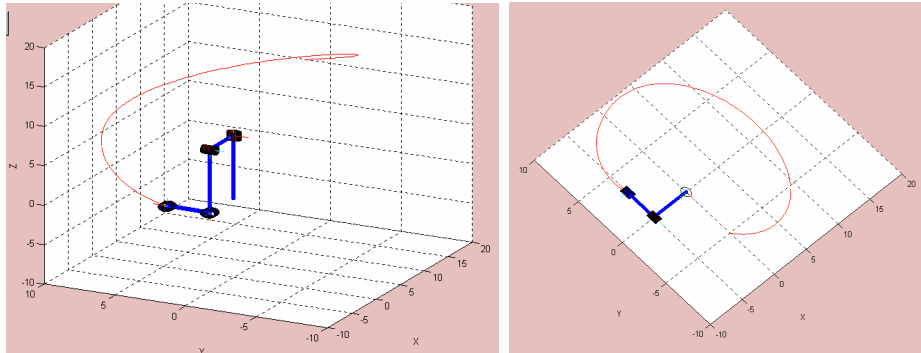


Fig. 6 – Trajectory from different points of view.

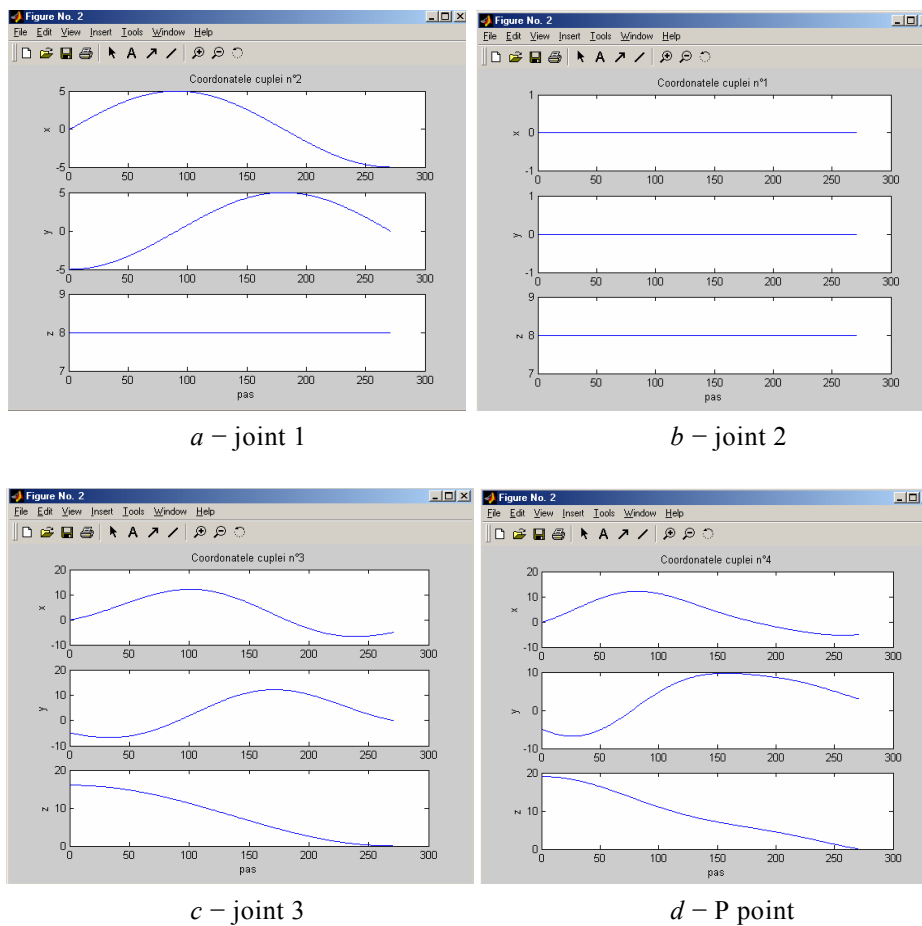


Fig. 7 – Coordinates for three joints and P point.

4. Conclusions

1. In the context of the forward kinematics problem, the program handles the forward position problem (the forward geometric model), where the geometrical characteristics of the robot and the variation laws of the generalized coordinates are known; the goal being to determine the variation laws of the absolute position of the characteristic point.

2. The present paper presents the application of a program developed in MATLAB that allows robot trajectory analysis, based on Denavit-Hartenberg input parameters.

3. The application focuses on a serial robot with three degrees of freedom, more specifically three kinematic rotational joints.

4. The resulting trajectories of each joint are graphically represented in output windows.

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SIMULAREA VIRTUALĂ A MIȘCĂRII UNUI MANIPULATOR SERIAL

II. Aplicație a programului

(Rezumat)

Această lucrare reprezintă partea a doua a studiului în care a fost propus un program destinat analizei poziționale a oricărui tip de manipulator serial indiferent de configurația acestuia, program dezvoltat pe baza utilizării metodei Denavit-Hartenberg. Articolul descrie aplicații ale utilizării acestui program de simulare virtuală în MATLAB. În exemplul prezentat s-a considerat un robot manipulator cu 3 cuple cinematice de rotație, Fig. 1 (Doroftei, 2002). Fiecărui element i se atașează sistemele de axe corespunzătoare după metoda Craig (Craig, 2013).

Simularea virtuală permite trasarea 3D a traiectoriei punctului caracteristic totodată realizându-se și animația mișcării; sunt prezentate capturi din diverse direcții, sunt reprezentate grafic traiectoriile cuplelor, precum și traiectoria punctului P, în funcție de pași considerați. Programul permite consultarea unui istoric al mișcării.

Simularea virtuală prezentată poate fi utilizată de exemplu în scop educațional.