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THE PATH PLANNING OF INDUSTRIAL ROBOTS USING POLYNOMIAL INTERPOLATION, WITH APPLICATIONS TO FANUC LR-Mate 100iB

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Abstract: *The objective of this paper is to describe the path planning of industrial robots, using polynomial interpolation functions, applied on the robot Fanuc LR-Mate 100iB, implemented in a demonstrative technological process. In the presented paper the (4-3-4) method is used, implemented into a MATLAB function. This function is called from the script file FANUC_planning.m for each joint and each phase the technological process is divided in. In order to determine the polynomial coefficients, the analyzed phase is divided also into an initial segment, a final segment and at least one intermediate segment. After solving a system of minimum seven equations with the same number of unknowns, the time variation polynomial functions yield, for coordinates, velocities and accelerations from each of the robot joints.* ***Key words:*** *serial robot, path planning, (4-3-4) method, interpolation, MATLAB.*

1. INTRODUCTION

Path planning of industrial robots is an important process which must be regarded, both in the stage of design-modelling-simulation of the robot and in the stage of implementing the robot in a technological process. The path planning is generally achieved using the polynomial interpolation functions, established on each component of the generalized variables vector or of the operational variables vector. The robot path or trajectory represents, therefore, the union of all the polynomial functions of time which describe its motion, expressed either in the configuration space or in the Cartesian space.

There are more methods of planning the path of a robot, of which we could mention: (4-3-4) method [3], [5-(4-3-4)-5] method, (3n) method with restrictions, (3n) method without restrictions [7], (3-4-5) method, (4-5-6-7) method [1] etc.

In the presented paper the (4-3-4) method is used, implemented into a MATLAB function *inter434()*. This function is called from the script file *FANUC_planning.m* for each joint and each phase the technological process is divided in.

The input parameters of the function are represented by the number of segments, the joint identifier, the joint stroke given by the minimum and maximum positions, the zero position, the relative displacements vector, the absolute time vector, the initial and final conditions for velocities and accelerations and a time increment. The output parameters of the functions are: the vectors describing the evolution of the generalized coordinates, velocities and accelerations on each of the three segments and the vector of time corresponding to their sampling. The variation graphs with respect to time are eventually generated, for the generalized coordinates, velocities and accelerations corresponding to each segment, in normalized time, and to the entire phase, in real time. The overcome of stroke, maximum velocities and maximum accelerations imposed on each joint is checked and in the case when these events are produced, specific measures for their correction will be taken.

2. THE (4-3-4) METHOD FOR PATH PLANNING

The path of the end-effector of any robot is determined by the initial and the final position of the motion, which establish the first and the last trajectory segment (end segments). In order

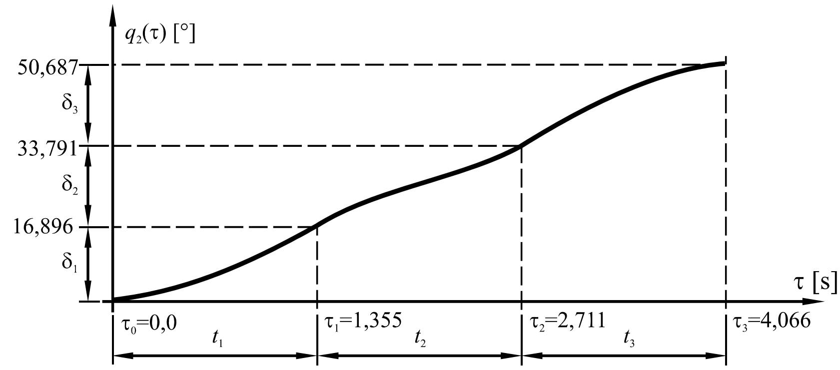

Fig. 1. The 1st phase of the work cycle for the 2nd joint of Fanuc LR-Mate 100iB

to avoid collisions with the external obstacles, a finite set of intermediary points, defining the intermediary segments, is added.

The path is generated using polynomial interpolation functions, whose degree depends on the constraints imposed by the technological process where the robot is implemented in. In the case of the trajectories of the (4-3-4) kind, the end segments are interpolated by 4th degrees polynomials, while the intermediary segments are interpolated by 3rd degrees polynomials (cubic spline functions) [3], [6], [7].

By differentiating the polynomials with respect to time, the polynomials describing the generalized velocities and accelerations from the robot's joints yield. In order to illustrate the method, Fig. 1 depicts the division of the first phase of the work cycle of Fanuc LR-Mate 100iB [5], corresponding to the 2nd joint.

According to the (4-3-4) method, the first segment is interpolated by 4th degree polynomials of time. By differentiating the generalized coordinate function with respect to time, a 3rd degree polynomial will be established, expressing the time variation of the generalized velocity. By differentiating again the velocity function, the obtained 2nd degree time function will express the generalized acceleration. In the following expressions, $j=\overline{1,m}$ will be the joint index, where m is the number of degrees of freedom of the robot and $i=\overline{1,n}$ will be the path segment index, where n is the number of segments the trajectory is divided in. The following notations will also be used:

- $t=\dfrac{\tau-\tau_{i-1}}{t_i}$ the normalized time, having values in the [0, 1] interval;
- $h_{ji}(t)$ the trajectory interpolation normalized polynomial for the joint j, segment i;
- $v_{ji}(t)$ the velocity interpolation normalized polynomial for the joint j, segment i;
- $a_{ji}(t)$ the acceleration interpolation normalized polynomial for the joint j, segment i;
- a_{jik} the polynomial coefficient for the joint j, segment i, and k^{th} order term from the normalized polynomial function ($k=\overline{0,4}$ for 4th order polynomials etc.).

The interpolation functions for the generalized coordinates, velocities and accelerations for *the first path segment* are the following [6], [7]:

$$\begin{aligned}
&h_{j1}(t)=q_{j1}(t)=a_{j14}t^4+a_{j13}t^3+a_{j12}t^2+a_{j11}t+a_{j10}\\
&v_{j1}(t)=\frac{\dot{q}_{j1}(t)}{t_1}=\frac{1}{t_1}(4a_{j14}t^3+3a_{j13}t^2+2a_{j12}t+a_{j11})\\
&a_{j1}(t)=\frac{\ddot{q}_{j1}(t)}{t_1^2}=\frac{1}{t_1^2}(12a_{j14}t^2+6a_{j13}t+2a_{j12}).
\end{aligned}\tag{1}$$

The following restrictions are useful for determining some of the polynomial coefficients:

- at $t = 0$ (τ_0) – initial point:

$$\begin{aligned}
&h_{j1}(0)=q_{j0};\\
&v_{j1}(0)=v_{j1}=\dot{q}_{j0};\quad a_{j1}(0)=a_{j1}=\ddot{q}_{j0},
\end{aligned}\tag{2}$$

resulting the following polynomial coefficients:

$$a_{j10}=q_{j0};\quad a_{j11}=\dot{q}_{j0}t_1;\quad a_{j12}=\ddot{q}_{j0}\frac{t_1^2}{2}.\tag{3}$$

- at $t = 1$ (τ_1) – segment end:

$$\begin{aligned}
&h_{j1}(1)=q_{j1};\quad \delta_{j1}=q_{j1}-q_{j0};\\
&v_{j1}(1)=v_{j2}(0);\quad a_{j1}(1)=a_{j2}(0).
\end{aligned}\tag{4}$$

The unknown coefficients from (1) are: a_{j13}, a_{j14}. *The last segment* is interpolated again by a 4th degree polynomial and for an easier determination of coefficients, the following substitution will help:

$$\bar{t} = t - 1; \quad \bar{t} \in [-1, 0]. \tag{5}$$

The polynomial functions will be, consequently:

$$\begin{aligned} h_{jn}(\bar{t}) &= q_{jn}(\bar{t}) = a_{jn4}\bar{t}^4 + a_{jn3}\bar{t}^3 + a_{jn2}\bar{t}^2 + a_{jn1}\bar{t} + a_{jn0} \\ v_{jn}(\bar{t}) &= \frac{\dot{q}_{jn}(\bar{t})}{t_n} = \frac{1}{t_n}(4a_{jn4}\bar{t}^3 + 3a_{jn3}\bar{t}^2 + 2a_{jn2}\bar{t} + a_{jn1}) \\ a_{jn}(\bar{t}) &= \frac{\ddot{q}_{jn}(\bar{t})}{t_n^2} = \frac{1}{t_n^2}(12a_{jn4}\bar{t}^2 + 6a_{jn3}\bar{t} + 2a_{jn2}), \end{aligned} \tag{6}$$

The following restrictions can be applied:

- at $\bar{t} = 0$ (τ_n) – endpoint:

$$\begin{aligned} &h_{jn}(0) = q_{jn}; \\ &v_{jn}(0) = v_{jn} = \dot{q}_{jn}; \quad a_{jn}(0) = a_{jn} = \ddot{q}_{jn}, \end{aligned} \tag{7}$$

resulting the following polynomial coefficients:

$$a_{jn0} = q_{jn}; \quad a_{jn1} = \dot{q}_{jn}t_n; \quad a_{jn2} = \ddot{q}_{jn}\frac{t_n^2}{2}. \tag{8}$$

- at $\bar{t}$ = -1 (τ_{n-1}) – segment beginning:

$$\begin{aligned} &h_{jn}(-1) = q_{j,n-1}; \quad \delta_{jn} = q_{jn} - q_{j,n-1}; \\ &v_{j,n-1}(1) = v_{jn}(-1); \quad a_{j,n-1}(1) = a_{jn}(-1). \end{aligned} \tag{9}$$

The remaining unknown coefficients are: a_{jn3}, a_{jn4}. For the *intermediary segments*, $i = \overline{2, n-1}$, the interpolation functions are:

$$\begin{aligned} h_{ji}(t) &= q_{ji}(t) = a_{ji3}t^3 + a_{ji2}t^2 + a_{ji1}t + a_{ji0} \\ v_{ji}(t) &= \frac{\dot{q}_{ji}(t)}{t_i} = \frac{1}{t_i}(3a_{ji3}t^2 + 2a_{ji2}t + a_{ji1}) \\ a_{ji}(t) &= \frac{\ddot{q}_{ji}(t)}{t_i^2} = \frac{1}{t_i^2}(6a_{ji3}t + 2a_{ji2}). \end{aligned} \tag{10}$$

The restrictive conditions can be written as:

- at $t = 0$ (τ_{i-1}) – segment beginning:

$$\begin{aligned} &h_{ji}(0) = q_{j,i-1} \;\Rightarrow\; a_{ji0} = q_{j,i-1} \\ &\frac{1}{t_i}a_{ji1} = \frac{\dot{q}_{ji}(0)}{t_i} = v_{j,i-1}(1) = v_{ji}(0) \\ &\frac{2}{t_i^2}a_{ji2} = \frac{\ddot{q}_{ji}(0)}{t_i^2} = a_{j,i-1}(1) = a_{ji}(0) \end{aligned} \tag{11}$$

- at $t = 1$ (τ_i) – segment end:

$$\begin{aligned} &h_{ji}(1) = q_{ji}; \quad \delta_{ji} = q_{ji} - q_{j,i-1} \\ &\frac{1}{t_i}a_{ji1} + \frac{2}{t_i}a_{ji2} + \frac{3}{t_i}a_{ji3} = \frac{\dot{q}_{ji}(1)}{t_i} = v_{ji}(1) \\ &\frac{2}{t_i^2}a_{ji2} + \frac{6}{t_i^2}a_{ji3} = \frac{\ddot{q}_{ji}(1)}{t_i^2} = a_{ji}(1). \end{aligned} \tag{12}$$

The overall undetermined coefficients from (1, 6, 10) are: $a_{j13}, a_{j14}, a_{jn3}, a_{jn4}, a_{ji1}, a_{ji2}, a_{ji3}$, $i = \overline{2, n-1}$.

If there are more intermediary coefficients, at the moment τ_i, $i = \overline{2, n-2}$ the following continuity conditions will be set up:

$$v_{ji}(1) = v_{j,i+1}(0); \quad a_{ji}(1) = a_{j,i+1}(0). \tag{13}$$

By the union of the restrictive conditions, using the directly determined coefficients the following system of 4+3(*n*–2) linear and homogeneous equations can be written as:

$$\begin{aligned} &a_{j13} + a_{j14} = \delta_{j2} - \ddot{q}_{j0}\frac{t_1^2}{2} - \dot{q}_{j0}t_1 \\ &\frac{3}{t_1}a_{j13} + \frac{4}{t_1}a_{j14} - \frac{1}{t_2}a_{j21} = -\ddot{q}_{j0}t_1 - \dot{q}_{j0} \\ &\frac{6}{t_1^2}a_{j13} + \frac{12}{t_1^2}a_{j14} - \frac{2}{t_2^2}a_{j22} = -\ddot{q}_{j0} \\ &\text{-----------------} \\ &\left.\begin{aligned} &a_{ji1} + a_{ji2} + a_{ji3} = \delta_{ji} \\ &\frac{1}{t_i}a_{ji1} + \frac{2}{t_i}a_{ji2} + \frac{3}{t_i}a_{ji3} - \frac{1}{t_{i+1}}a_{j,i+1,1} = 0 \\ &\frac{2}{t_i^2}a_{ji2} + \frac{6}{t_i^2}a_{ji3} - \frac{2}{t_{i+1}^2}a_{j,i+1,2} = 0 \end{aligned}\right\}, \ \forall i = \overline{2, n-2} \\ &\text{-----------------} \\ &a_{j,n-1,1} + a_{j,n-1,2} + a_{j,n-1,3} = \delta_{j,n-1} \\ &\frac{1}{t_{n-1}}a_{j,n-1,1} + \frac{2}{t_{n-1}}a_{j,n-1,2} + \frac{3}{t_{n-2}}a_{j,n-1,3} - \\ &- \frac{3}{t_n}a_{j,n-1,3} + \frac{4}{t_{n-1}}a_{j,n-1,4} = -\ddot{q}_{jn}t_n + \dot{q}_{jn} \\ &\frac{2}{t_{n-1}^2}a_{j,n-1,2} + \frac{6}{t_{n-1}^2}a_{j,n-1,3} + \frac{6}{t_n^2}a_{jn3} - \frac{12}{t_n^2}a_{jn4} = \ddot{q}_{jn} \\ &a_{jn3} - a_{jn4} = \delta_{jn} + \ddot{q}_{jn}\frac{t_n^2}{2} - \dot{q}_{jn}t_n \end{aligned} \tag{14}$$

The 4+3(*n*-2) unknowns from the system (14) are the polynomial coefficients to be calculated.

By identifying the matrix of the coefficients A_j, the column vector of the unknowns X_j and the free terms column vector B_j, from (14), the following matrix equation can be formulated:

$$A_j \cdot X_j = B_j \, . \qquad (15)$$

By solving the above matrix equation, the coefficients of the interpolation polynomial functions, from the vector $\cdot X_j$, are calculated:

$$X_j = A_j^{-1} \cdot B_j \, . \qquad (16)$$

Using the above presented method, the path planning of any serial robot can be achieved.

3. THE DESCRIPTION OF THE TECHNOLOGICAL PROCESS WITH Fanuc LR-Mate 100iB

Fanuc LR-Mate 100iB [5], is a five-axes serial industrial robot, having only rotation joints (R), whose kinematic diagram is described in [7]. It will be implemented into a technological process for HDD assembly. During its work cycle, the robot will be programmed to start from the nest position, to move above the lid of the HDD, to pick it in the gripper, to transport the lid above the HDD body and to place it on the body in order to fix the lid with screws.

Table 1 represents the absolute and relative time, corresponding to the robot program lines, for the first two phases of the technological process. It is assumes that the robot starts from the nest position, having the gripper open. The first two program lines check that assumption.

Fig.2 presents the first 9 phases of the robot work cycle, where the state of the gripper (DP) is marked with continuous green, corresponding to a closed gripper. The working periods of the joints are represented with continuous red. The gripper closing is denoted by GC and the gripper opening with GO.

Table 1

Absolute time, relative time corresponding to the first two phases of the technological process

Program line	Point/ event	Mo- ment	Abs. time	Rel. time
`1:J P[1] 100% FINE`	P_1	T_0	0,000	0,000
`2: RO[1:OG]=OFF`	GO	T_1	0,000	0,000
`3:J P[4] 100% CNT100`	P_4	T_2	4,066	4,066
`4:L P[3] 100mm/sec FINE`	P_3	T_3	5,366	1,300
`5:L P[2] 100mm/sec FINE`	P_2	T_4	5,600	0,234
`6: RO[1:OG]=ON`	GC	T_5	5,700	0,100
`7:L P[5] 100mm/sec CNT100`	P_5	T_6	6,466	0,766
`8:J P[6] 100% CNT100`	P_6	T_7	7,500	1,034
`9:L P[7] 100mm/sec FINE`	P_7	T_8	8,033	0,533
`10: RO[1:OG] = OFF`	GO	T_9	8,133	0,100

The 1st phase can be described as follows: displacement from din P_1 (nest position) to P_4. Time span of the 1st phase: $T_1 = 0 \div 4{,}066\ s$. The robot starts from configuration P_1, at the time 0.

The overall time for the robot task is 23,833s. The time was measured using the *Avidemux 2.5.4* software [2], on the technologic process movie (the file *Fanuc2cut.avi*).

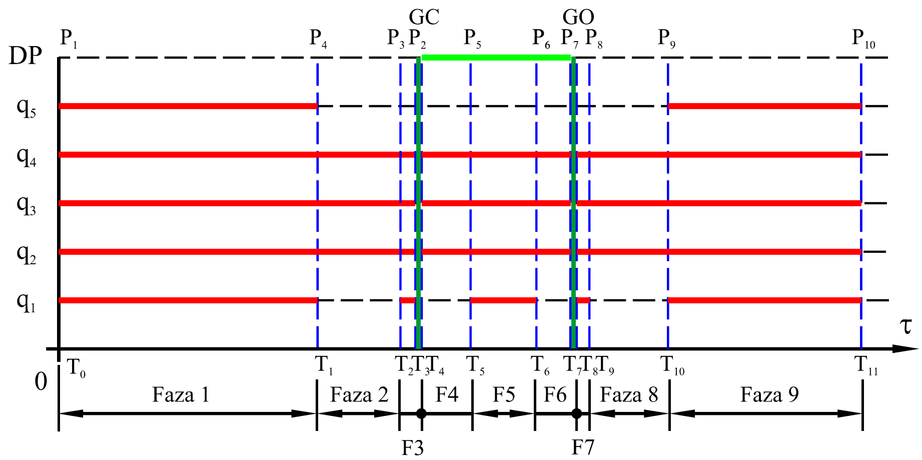

Fig. 2 Operating cyclograme for *Fanuc LR Mate 100iB*, phases 1-9

4. THE PATH PLANNING FOR THE DESCRIBED ROBOT TASK

In order to apply the path planning algorithm, the interpolation polynomials for the joints of the robot, corresponding to the first phase, are determined. As seen in Fig. 2, in this phase all the joints are active. The table 2 provides the generalized coordinates variation for the first seven positions from the robot task.

Table 2

The generalized coordinates variation, corresponding to the positions P[1]-P[7] from the robot task

P[i]	q_1 [°]	q_2 [°]	q_3 [°]	q_4 [°]	q_5 [°]
P[1]	0	0	0	0	0
P[4]	-15,18	50,687	-86,222	86,221	90,106
P[3]	-15,18	77,883	-99,552	99,552	90,106
P[2]	-14,999	77,621	-97,601	97,601	90,106
P[5]	-14,999	61,006	-90,933	90,932	90,106
P[6]	-2,099	60,720	-93,191	93,190	90,106
P[7]	-2,099	72,524	-98,534	98,533	90,106

The 1st phase ($\tau = 0 \div 4{,}066\ s$) is divided in $n = 3$ path segments. For the first joint ($j = 1$), the following conditions are assigned:

• at $\tau_0 = 0$:

$$q_{10} = 0\ ;\quad \dot{q}_{10} = 0\ ;\quad \ddot{q}_{10} = 0 \tag{17}$$

• at $\tau_1 = 1{,}355$ s:

$$q_{11} = -5{,}060°\ ;\ \delta_{11} = q_{11} - q_{10} = -5{,}060°; \quad t_1 = \tau_1 - \tau_0 = 1{,}355\ s \tag{18}$$

• at $\tau_2 = 2{,}711$ s:

$$q_{12} = -10{,}12°;\ \delta_{12} = q_{12} - q_{11} = -5{,}060°; \quad t_2 = \tau_2 - \tau_1 = 1{,}355\ s \tag{19}$$

• at $\tau_3 = 4{,}066$ s:

$$q_{13} = -15{,}180°;\ \dot{q}_{13} = 0\ ;\ \ddot{q}_{13} = 0 \quad \delta_{13} = q_{13} - q_{12} = -5{,}060°;\ t_3 = \tau_3 - \tau_2 = 1{,}355\ s \tag{20}$$

The following coefficients are determined:

$$\begin{gathered} a_{110} = q_{10} = 0;\quad a_{111} = \dot{q}_{10} t_1 = 0; \\ a_{112} = \ddot{q}_{10}\frac{t_1^2}{2} = 0;\ a_{130} = q_{13} = -15{,}180°; \\ a_{131} = 0;\quad a_{132} = 0; \\ a_{120} = q_{11}(1) = -5{,}060°. \end{gathered} \tag{21}$$

The unknowns vector is:

$$X_1 = \begin{bmatrix} a_{113} & a_{114} & a_{121} & a_{122} & a_{123} & a_{133} & a_{134} \end{bmatrix}^{\mathrm{T}} \tag{22}$$

and the free terms vector:

$$B_1 = \begin{bmatrix} \delta_{11} - \frac{1}{2}\ddot{q}_{10}t_1^2 - \dot{q}_{10}t_1 \\ -\ddot{q}_{10}t_1 - \dot{q}_{10} \\ -\ddot{q}_{10} \\ \delta_{12} \\ -\ddot{q}_{13}t_3 + \dot{q}_{13} \\ \ddot{q}_{13} \\ \delta_{13} + \frac{1}{2}\ddot{q}_{13}t_3^2 - \dot{q}_{13}t_3 \end{bmatrix} = \begin{bmatrix} -0{,}0883 \\ 0 \\ 0 \\ -0{,}0883 \\ 0 \\ 0 \\ -0{,}0883 \end{bmatrix}. \tag{23}$$

The unknown coefficients matrix, given by numeric values, is the following:

$$A_1 = \begin{bmatrix} 1{,}0000 & 1{,}0000 & 0 & 0 & 0 & 0 & 0 \\ 2{,}2140 & 2{,}9520 & -0{,}7380 & 0 & 0 & 0 & 0 \\ 3{,}2679 & 6{,}5359 & 0 & -1{,}0893 & 0 & 0 & 0 \\ 0 & 0 & 1{,}000 & 1{,}0000 & 1{,}0000 & 0 & 0 \\ 0 & 0 & 0{,}7380 & 1{,}4760 & 2{,}2140 & -2{,}2140 & 2{,}9520 \\ 0 & 0 & 0 & 1{,}0893 & 3{,}2679 & 3{,}2679 & -6{,}5359 \\ 0 & 0 & 0 & 0 & 0 & 1{,}0000 & -1{,}0000 \end{bmatrix} \tag{24}$$

The unknowns vector is determined with the matrix relation (16), where the inverse of the coefficients matrix, is numerically expressed as:

$$A_1^{-1} = \begin{bmatrix} 2{,}7500 & -0{,}5081 & -0{,}1913 & -0{,}5000 & 0{,}1694 & 0{,}0383 & 0{,}2500 \\ -1{,}7500 & 0{,}5081 & 0{,}1913 & 0{,}5000 & -0{,}1694 & -0{,}0383 & -0{,}2500 \\ 1{,}2500 & -0{,}8469 & 0{,}1913 & 0{,}5000 & -0{,}1694 & -0{,}0383 & -0{,}2500 \\ -2{,}2500 & 1{,}5244 & -0{,}3443 & 1{,}5000 & -0{,}5081 & -0{,}1148 & -0{,}7500 \\ 1{,}0000 & -0{,}6775 & 0{,}1530 & -1{,}0000 & 0{,}6775 & 0{,}1530 & 1{,}0000 \\ 0{,}2500 & -0{,}1694 & 0{,}0383 & -0{,}5000 & 0{,}5081 & -0{,}1913 & 2{,}7500 \\ 0{,}2500 & -0{,}1694 & 0{,}0383 & -0{,}5000 & 0{,}5081 & -0{,}1913 & 1{,}7500 \end{bmatrix} \tag{25}$$

and the unknowns vector is:

$$X_1 = [-0{,}2208;\ 0{,}1325; -0{,}1325; 0{,}1325; -0{,}0883; -0{,}2208; -0{,}1325]. \tag{26}$$

The unknown polynomial coefficients are:

$$\begin{gathered} a_{113} = -0{,}2208 \quad a_{114} = 0{,}1325 \\ a_{121} = -0{,}1325 \quad a_{122} = 0{,}1325 \quad a_{123} = -0{,}0883. \\ a_{133} = -0{,}2208 \quad a_{134} = -0{,}1325 \end{gathered} \tag{27}$$

The 1st segment ($\tau_0 \to \tau_1$) is characterized by:

$$\begin{gathered} h_{11}(t) = q_{11}(t) = 0{,}1325 \cdot t^4 - 0{,}2208 \cdot t^3 \\ v_{11}(t) = \frac{\dot{q}_{11}(t)}{t_1} = 0{,}738 \cdot \left(0{,}53 \cdot t^3 - 0{,}662 \cdot t^2\right) \\ a_{11}(t) = \frac{\ddot{q}_{11}(t)}{t_1^2} = 0{,}544 \cdot \left(1{,}59 \cdot t^2 - 1{,}324 \cdot t\right) \end{gathered} \tag{28}$$

The 2nd segment ($\tau_1 \to \tau_2$) is described by:

$$h_{12}(t) = q_{12}(t) = \text{-}0{,}0883 \cdot t^3 + 0{,}1325 \cdot t^2 \text{ -} 0{,}1325 \cdot t - 5{,}060$$
$$v_{12}(t) = \frac{\dot{q}_{12}(t)}{t_2} = 0{,}738 \cdot (-0{,}2649 \cdot t^2 + 0{,}265 \cdot t \text{ -} 0{,}1325)$$
$$a_{12}(t) = \frac{\ddot{q}_{12}(t)}{t_2^2} = 0{,}544 \cdot (0{,}5298 \cdot t + 0{,}265) \quad (29)$$

The 3rd segment ($\tau_2 \to \tau_3$) has the following polynomial functions:

$$h_{13}(\bar{t}) = q_{13}(\bar{t}) = \text{-}0{,}1325 \cdot \bar{t}^4 \text{ -} 0{,}2208 \cdot \bar{t}^3 - 15{,}180$$
$$v_{13}(\bar{t}) = \frac{\dot{q}_{13}(\bar{t})}{t_3} = 0{,}738 \cdot (-0{,}53 \cdot \bar{t}^3 - 0{,}6624 \cdot \bar{t}^2) \cdot (30)$$
$$a_{13}(\bar{t}) = \frac{\ddot{q}_{13}(\bar{t})}{t_3^2} = 0{,}544 \cdot (-1{,}59 \cdot \bar{t}^2 - 1{,}3248 \cdot \bar{t})$$

Applying the described algorithm, similar results can be obtained for the rest of the joints and for the rest of the phases of the robot task. The functions can be graphically represented, either in normalized time, on each segment or in real time, on the entire phase.

5. CONCLUSION

The implementation of the (4-3-4) method in a MATLAB function is an easy way to determine the polynomial interpolation functions for generalized coordinates, velocities and accelerations when a robot is implemented in a technological process. The resulted functions are useful for analyzing the kinematic and dynamic behavior of the studied robot.

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PLANIFICAREA TRAIECTORIEI ROBOȚILOR INDUSTRIALI, UTILIZÂND INTERPOLAREA POLINOMIALĂ, CU APLICAȚII PE FANUC LR-Mate 100iB

Rezumat: Scopul acestei lucrări este descrierea planificării traiectoriei roboților industriali, utilizând funcțiile polinomiale de interpolare, cu aplicații pe robotul Fanuc LR-Mate 100iB, implementat într-un proces tehnologic demonstrativ. În lucrarea de față se prezintă metoda (4-3-4), implementată într-o funcție MATLAB. Această funcție este apelată din fişierul script *FANUC_planning.m* pentru fiecare cuplă şi fiecare fază în care este descompus procesul tehnologic. Pentru a determina coeficienții polinomiali, faza analizată este divizată într-un segment inițial, un segment final şi cel puțin un segment intermediar. După rezolvarea unui sistem de minimum şapte ecuații cu tot atâtea necunoscute, sunt determinate funcțiile polinomiale de variație în timp a coordonatelor, vitezelor şi accelerațiilor din fiecare cuplă a robotului.

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