BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXIII No. 2/2011	15 - 18	Seria Tehnică

Research Concerning the Optimized Positional Synthesis of the Lynx 5 Robot System

Dorin Bădoiu

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti 39, Ploieşti
e-mail: badoiu@mail.upg-ploiesti.ro

Abstract

The paper presents a method that permits the calculus of the inverse geometric model of the Lynx 5 robot system when an optimization criterion is adopted. The optimization criterion imposes that the displacements of the motor axes of the robot system for achieving an imposed position of the gripper characteristic point is minimum compared to the zero configuration of the robot (the configuration when all of the robot coordinates are equal to zero). Finally, some simulation results are presented.

Key words: *robot, position, orientation, optimization*

Introduction

In many cases, when the robots are used in different operations of manipulation, their mechanism has more degrees of freedom than necessary to fulfill a task. These robots are redundant in relation to the task to be performed. So, they can perform a task, whilst meeting certain performance criteria, such as: minimum energy consumption, the fulfillment of some conditions for avoiding obstacles or singular configurations of the robot mechanism etc.

In this paper a method that allows the calculus of the inverse geometric model of the Lynx 5 robot system (fig. 1) by considering an optimization criterion is presented. The optimization criterion imposes that the displacements of the motor axes of the robot system for achieving an imposed position of the gripper characteristic point is minimum compared to the zero configuration of the robot (the configuration when all of the robot coordinates are equal to zero).

Theoretical Considerations and Verification Results

In figure 1, the cinematic scheme of the mechanism of the Lynx 5 robot system is presented. The systems of coordinates $(O_i x_i y_i z_i), i = \overline{0,4}$, have been attached to each component module *i*, $i = \overline{0,4}$. The values of the geometric parameters *a, b, c* and *d* are: $a = 79\text{ mm}$; $b = 95.25\text{ mm}$; $c = 95.25\text{ mm}$; $d = 124.3\text{ mm}$.

The rotation matrices ${}^{i}R_{i+1}, i = \overline{0,3}$, corresponding to the relative orientation of the component modules i+1 and i have the following expressions:

$$ {}^{0}R_1 = R(z,q_1) = \begin{bmatrix} c1 & -s1 & 0 \\ s1 & c1 & 0 \\ 0 & 0 & 1 \end{bmatrix}; \quad {}^{i-1}R_i = R(x,q_i) = \begin{bmatrix} ci & -si & 0 \\ si & ci & 0 \\ 0 & 0 & 1 \end{bmatrix}; \; i = \overline{2,4} \tag{1} $$

where:

$$ \begin{cases} si = \sin q_i \\ ci = \cos q_i \end{cases} \; i = \overline{1,4} \tag{2} $$

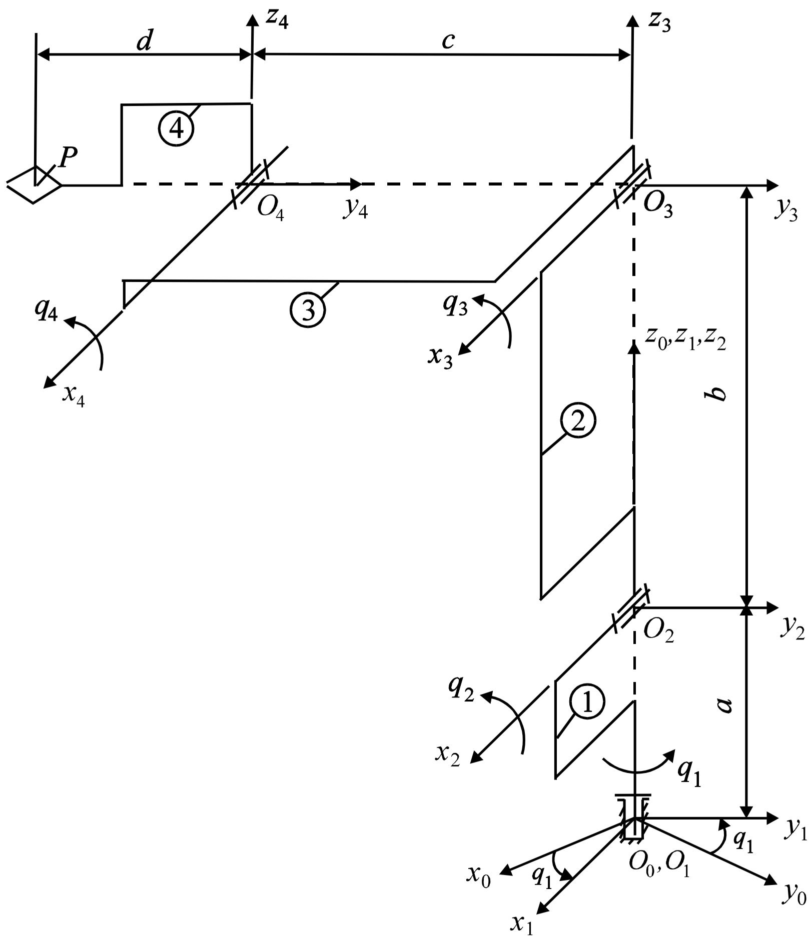

Fig. 1. Lynx 5 robot mechanism

The position of the characteristic point P of the robot gripper (fig. 1) relative to the system of coordinates $(O_0x_0y_0z_0)$ can be determined with the following relation:

$$ {}^{(0)}O_0P = {}^{(0)}O_0O_1 + {}^{0}R_1 \cdot {}^{(1)}O_1O_2 + {}^{0}R_2 \cdot {}^{(2)}O_2O_3 + {}^{0}R_3 \cdot {}^{(3)}O_3O_4 + {}^{0}R_4 \cdot {}^{(4)}O_4P \tag{3} $$

where:

$$ \begin{aligned} &{}^{(0)}O_0O_1 = 0; \; {}^{(1)}O_1O_2 = [0 \;\; 0 \;\; a]^{\mathrm{T}}; \; {}^{(2)}O_2O_3 = [0 \;\; 0 \;\; b]^{\mathrm{T}}; \\ &{}^{(3)}O_3O_4 = [0 \;\; -c \;\; 0]^{\mathrm{T}}; \; {}^{(4)}O_4P = [0 \;\; -d \;\; 0]^{\mathrm{T}} \end{aligned} \tag{4} $$

$$ {}^{0}R_2 = {}^{0}R_1 \cdot {}^{1}R_2 = \begin{bmatrix} c1 & -s1\cdot c2 & s1\cdot s2 \\ s1 & c1\cdot c2 & -c1\cdot s2 \\ 0 & s2 & c2 \end{bmatrix} \tag{5} $$

$$ {}^{0}R_3 = {}^{0}R_2 \cdot {}^{2}R_3 = \begin{bmatrix} c1 & -s1\cdot c23 & s1\cdot s23 \\ s1 & c1\cdot c23 & -c1\cdot s23 \\ 0 & s23 & c23 \end{bmatrix} \tag{6} $$

$$ {}^{0}R_4 = {}^{0}R_3 \cdot {}^{3}R_4 = \begin{bmatrix} c1 & -s1\cdot c234 & s1\cdot s234 \\ s1 & c1\cdot c234 & -c1\cdot s234 \\ 0 & s234 & c234 \end{bmatrix} \tag{7} $$

where:

$$ \begin{cases} s23 = \sin(q_2 + q_3) \\ c23 = \cos(q_2 + q_3) \end{cases} ; \quad \begin{cases} s234 = \sin(q_2 + q_3 + q_4) \\ c234 = \cos(q_2 + q_3 + q_4) \end{cases} \tag{8} $$

After calculations, it results:

$$ {}^{(0)}O_0P = \begin{bmatrix} s1\cdot(s2\cdot b + c23\cdot c + c234\cdot d) \\ -c1\cdot(s2\cdot b + c23\cdot c + c234\cdot d) \\ a + c2\cdot b - s23\cdot c - s234\cdot d \end{bmatrix} \tag{9} $$

By imposing the position of the point *P*, the inverse geometric model of the Lynx 5 robot system will be solved by considering an optimization criterion. The optimization criterion imposes that the displacements of the motor axes of the robot system for achieving an imposed position of the point *P* is minimum compared to the zero configuration of the robot (the configuration when all of the robot coordinates are equal to zero). So, this optimization criterion imposes that the following function must take a minimum value:

$$ F = \frac{1}{2}\cdot\sum_{i=1}^{4} q_i^2 \tag{10} $$

where $q_i, i = \overline{1,4}$, verify the relation (9), when the position of the point *P* is imposed.

By introducing the following function [3]:

$$ L = F + \lambda^T \cdot \left({}^{(0)}OP - \begin{bmatrix} x_P \\ y_P \\ z_P \end{bmatrix} \right) \tag{11} $$

where: x_P, y_P and z_P are the imposed values of the coordinates of the point *P* relative to the fixed system of coordinates $(O_0x_0y_0z_0)$ and $\lambda = [\lambda_1 \quad \lambda_2 \quad \lambda_3]^T$, where $\lambda_i, i = \overline{1,3}$, are three unknown parameters (Lagrange's parameters), we must find the values of the coordinates $q_i, i = \overline{1,4}$, for which the function *L* is minimum and the coordinates of the point *P* given by the relation (9) take the imposed values: x_P, y_P and z_P.

After calculations, it results the following system of equations:

$$\begin{cases} f_1 - x_P = 0;\ f_2 - y_P = 0;\ f_3 - z_P = 0 \\ q_i + \dfrac{\partial f_1}{\partial q_i}\cdot\lambda_1 + \dfrac{\partial f_2}{\partial q_i}\cdot\lambda_2 + \dfrac{\partial f_3}{\partial q_i}\cdot\lambda_3 = 0;\ \mathrm{i} = \overline{1,4} \end{cases} \tag{12}$$

where:

$$\begin{cases} f_1 = s1\cdot(s2\cdot b + c23\cdot c + c234\cdot d) \\ f_2 = -c1\cdot(s2\cdot b + c23\cdot c + c234\cdot d) \\ f_3 = a + c2\cdot b - s23\cdot c - s234\cdot d \end{cases} \tag{13}$$

The method has been transposed into a computer program. As a numerical example, by considering: $x_P = -34$ mm; $y_P = -223.5$ mm; $z_P = 100$ mm, the following values for the coordinates $q_i, i = \overline{1,4}$, have been obtained: $q_1 = -8.65^\circ$; $q_2 = 11.43^\circ$; $q_3 = 6^\circ$; $q_4 = 3.2^\circ$.

Conclusions

The paper presents a method that allows the calculus of the inverse geometric model of the Lynx 5 robot system by considering an optimization criterion. The optimization criterion imposes that the displacements of the motor axes of the robot system for achieving an imposed position of the gripper characteristic point is minimum compared to the zero configuration of the robot. The method is very useful to be applied for operations of manipulation, when the robot mechanism has more degrees of freedom than necessary to fulfill a task.

References

1. Craig, J.J. - *Introduction to robotics: mechanics and control,* Addison-Wesley, 1986;
2. Dombre, E., Khalil, W. - *Modélisation et commande des robots,* Ed. Hermès, Paris, 1988;
3. Lallemand, J.P., Zeghloul, S. – *Robotique – Aspects fondamentaux,* Ed. Masson, Paris, 1994.

Cercetări privind sinteza poziţională optimizată a sistemului robot Lynx 5

Rezumat

Articolul prezintă o metodă care permite calculul modelului geometric invers al sistemului robot Lynx 5 atunci când se adoptă un criteriu de optimizare. Criteriul de optimizare impune ca deplasările axelor motoare ale sistemului robot pentru atingerea unei poziţii impuse a punctului caracteristic al griperului să fie minime în raport cu configuraţia zero a robotului (configuraţia în care toate coordonatele robotului sunt egale cu zero). In final, sunt prezentate o serie de rezultate ale simulărilor.