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Research Concerning the Positional Model of the Lynx 6 Robot System

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Abstract

The paper presents a method that permits the design of the positional model of the Lynx 6 robot system, that is, the calculus of the relative position and orientation between the component modules. With this end in view, Khalil-Kleinfinger parameters have been used. The verification of the results obtained with the positional model has been done using the robot arm interactive operating system Lynxmotion Rios SSC-32 V1-04 which controls the robot system. Finally, some simulation results are presented.

Key words: *robot, joints, position, orientation, trajectory*

Introduction

Generally, the robots are characterized by an automatic and programmable running, one of their more used task being to substitute the human operator in different operations of manipulation that are part of industrial process. In many cases, the analysis of this kind of tasks that the robots have to do, requires the design of the positional model that permits the calculus of the relative position and orientation between the component modules and between the grasping module and the base of the robot. These models have to be very precise and, generally, they are verified using the control system of the robot.

In this paper it is presented a method that allows the positional model design of the Lynx 6 robot system (fig. 1). In this scope, Khalil-Kleinfinger parameters have been used. The verification of the model has been done using the robot arm interactive operating system Lynxmotion Rios SSC-32 V1-04 which controls the robot system.

Theoretical Considerations and Verification Results

In figure 1, the cinematic scheme of the mechanism of the Lynx 6 robot is presented. The systems of coordinates $(T_i), i=\overline{0,5}$, has been attached to each component module *i*, $i=\overline{0,5}$, using the Khalil-Kleinfinger method [4] (the module zero is the fixed part of the mechanism).

In this case, the systems of coordinates (T_i) attached to each component module of the robot, are chosen in the following way: the axis $(O_i z_i)$ has the direction of the joint (C_i) between the modules i-1 and i, the axis $(O_i x_i)$ has the direction of the common perpendicular between the axes $(O_i z_i)$ and $(O_{i+1} z_{i+1})$, the axis $(O_i y_i)$ is chosen in such a way that the system of coordinate (T_i) be an right-orthogonal one. In order to simplify the presentation of the cinematic scheme, the $(O_i y_i)$ axes have not been represented.

The fixed system of coordinate (T_0) is chosen so that it coincides with (T_1) when $q_1 = 0$, q_1 being the generalized coordinate corresponding to the joint (C_1).

The system of coordinates (T_5), attached to the last component module of the robot, is chosen in the following way: the axis $(O_5 x_5)$ will be collinear with the axis $(O_4 x_4)$ when $q_5 = 0$ (q_5 is the generalized coordinate corresponding to the active joint (C_5)) and the origin O_5 is chosen at the intersection of the axes $(O_4 x_4)$ and $(O_5 z_5)$.

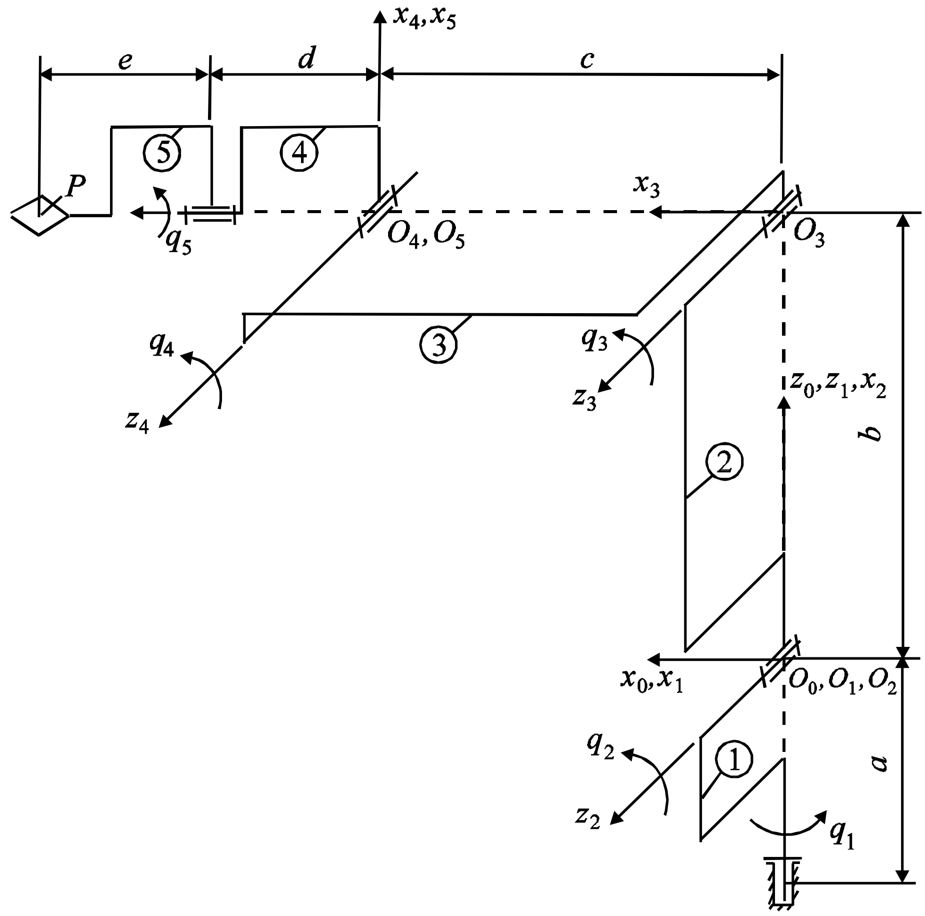

Fig. 1. Lynx 6 robot mechanism

The systems of coordinates (T_{i+1}) and (T_i), $i = \overline{0,4}$, are relatively positioned using four parameters (fig. 2): the angle α_{i+1} between the axes $(O_i z_i)$ and $(O_{i+1} z_{i+1})$, the distance d_{i+1} between the same axes, the angle θ_{i+1} between the axes $(O_i x_i)$ and $(O_{i+1} x_{i+1})$ and the distance r_{i+1} between $(O_i x_i)$ and $(O_{i+1} x_{i+1})$, measured on the positive direction of the axis $(O_{i+1} z_{i+1})$.

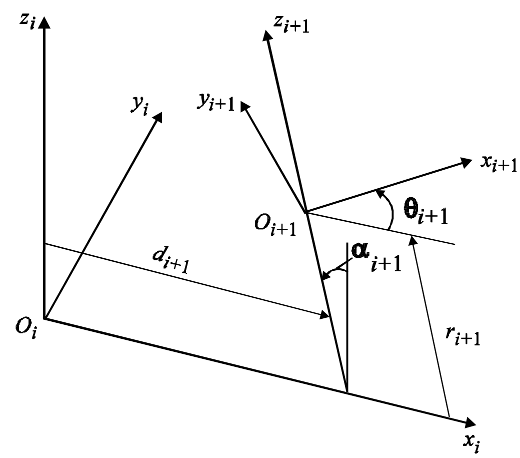

Fig. 2. Khalil-Kleinfinger parameters

The homogeneous matrix corresponding to the relative position and orientation of the systems of coordinates (T_{i+1}) and (T_i), $i=\overline{0,4}$, has the following general form [4]:

$$^{i}T_{i+1} = \begin{bmatrix} ^{i}R_{i+1} & ^{(i)}O_iO_{i+1} \\ 0 & 1 \end{bmatrix} = Rot(x,\alpha_{i+1}) \cdot Trans(x,d_{i+1}) \cdot Rot(z,\theta_{i+1}) \cdot Trans(z,r_{i+1}) =$$

$$= \begin{bmatrix} \cos\theta_{i+1} & -\sin\theta_{i+1} & 0 & d_{i+1} \\ \cos\alpha_{i+1}\cdot\sin\theta_{i+1} & \cos\alpha_{i+1}\cdot\cos\theta_{i+1} & -\sin\alpha_{i+1} & -r_{i+1}\cdot\sin\alpha_{i+1} \\ \sin\alpha_{i+1}\cdot\sin\theta_{i+1} & \sin\alpha_{i+1}\cdot\cos\theta_{i+1} & \cos\alpha_{i+1} & r_{i+1}\cdot\cos\alpha_{i+1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

where: $^{i}R_{i+1}$ is the rotation matrix corresponding to the relative orientation of the systems of coordinates (T_{i+1}) and (T_i), the homogeneous transformation matrices of type *Rot* correspond to rotations along the axes of the system of coordinates (T_i) and the matrices of type *Trans* correspond to translations along the axes of (T_i).

The generalized coordinates q_i, $i=\overline{1,5}$, corresponding to the movement at the active joints (C_i), $i=\overline{1,5}$, level will be the angles θ_i because all (C_i) are of rotation.

In table 1 the values corresponding to the Khalil-Kleinfinger parameters are presented.

Table 1. The values of the Khalil-Kleinfinger parameters

i	α_i	d_i	θ_i	r_i
1	0	0	q_1	0
2	-90°	0	q_2	0
3	0	b	q_3	0
4	0	c	q_4	0
5	-90°	0	q_5	0

By applying the relation (1) and taking into account the values of the Khalil-Kleinfinger parameters in table 1, the following expressions for the homogeneous matrices ${}^{i}T_{i+1}, i=\overline{0,4}$, are obtained:

$$ {}^{0}T_1 = \begin{bmatrix} c1 & -s1 & 0 & 0 \\ s1 & c1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad {}^{1}T_2 = \begin{bmatrix} c2 & -s2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -s2 & -c2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad {}^{2}T_3 = \begin{bmatrix} c3 & -s3 & 0 & b \\ s3 & c3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; $$
$$ {}^{3}T_4 = \begin{bmatrix} c4 & -s4 & 0 & c \\ s4 & c4 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad {}^{4}T_5 = \begin{bmatrix} c5 & -s5 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -s5 & -c5 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \qquad (2) $$

where:

$$ \begin{cases} si = \sin q_i \\ ci = \cos q_i \end{cases} \quad i = \overline{1,5} \qquad (3) $$

The position of the reference point P belonging to the grasping device (fig. 2) can be determined with the following relation:

$$ {}^{(0)}O_0P = {}^{0}T_5 \cdot {}^{(5)}O_5P \qquad (4) $$

where: the homogeneous matrix ${}^{0}T_5$ is given by:

$$ {}^{0}T_5 = {}^{0}T_1 \cdot {}^{1}T_2 \cdot {}^{2}T_3 \cdot {}^{3}T_4 \cdot {}^{4}T_5 \qquad (5) $$

and the position vector ${}^{(5)}O_5P$, expressed in a homogeneous form [1], has the following expression:

$$ {}^{(5)}O_5P = \begin{bmatrix} 0 & 0 & e+d & 1 \end{bmatrix}^{\mathrm{T}} \qquad (6) $$

The values of the geometric parameters are: $a = 79\,\text{mm}$; $b = 120.66\,\text{mm}$; $c = 120.65\,\text{mm}$; $d + e = 144.9\,\text{mm}$.

The relations above have been transposed in a computer program which allow to calculate very easy and precisely the positional parameters of the Lynx 6 robot.

The results obtained with the computer program have been verified using the robot arm interactive operating system Lynxmotion Rios SSC-32 V1-04 which controls the robot system. The relations between the generalized coordinates $q_i, i = \overline{1,5}$, used in the positional model and those used by the controller and noted with $q_i^r, i = \overline{1,5}$, are the following:

$$ \begin{cases} q_1 = -q_1^r \\ q_2 = -90° - q_2^r \\ q_3 = 90° - q_3^r \\ q_4 = -90 - q_4^r \\ q_5 = q_5^r \end{cases} \qquad (7) $$

Also, the relations between the coordinates of the reference point *P* calculated with the relation (4) and those given by the controller and noted with *xPos, yPos* and *zPos* are:

$$\begin{cases} {}^{(0)}x_P = xPos \\ {}^{(0)}y_P = -zPos \\ {}^{(0)}z_P = yPos - a \end{cases} \tag{7}$$

In table 2 some results obtained with the controller are presented.

Table 2. Results obtained with the controller

q_1^r [°]	0.09	30	44.95	-44.95	60.09
q_2^r [°]	0.09	0.09	-30	30	30
q_3^r [°]	0.01	59.9	45.01	24.83	-44.98
q_4^r [°]	0.09	-30	10	-30	40.9
q_5^r [°]	0.07	0.07	19.97	-15.03	5.01
xPos [mm]	265.29	160.73	210.05	99.5	93.43
yPos [mm]	200.34	376.52	275.94	342.95	213.74
zPos [mm]	0.42	92	217.7	-99.34	162.42

In table 3 the results obtained with the computer program are presented.

Table 3. Results obtained with the computer program

${}^{(0)}x_P$ [mm]	265.359	160.780	210.104	99.555	93.018
${}^{(0)}y_P$ [mm]	-0.4168	-92.826	-217.723	99.382	-161.697
${}^{(0)}z_P + a$ [mm]	200.351	376.563	276.002	342.967	213.647

Conclusions

The paper presents a method that allows the positional model achievement of the Lynx 6 robot system. Khalil-Kleinfinger parameters have been used for positional analysis. The verification of the model has been done using the robot arm interactive operating system Lynxmotion Rios SSC-32 V1-04 which controls the robot system. The methodology presented, which has been transposed into a computer program, can then be used for an optimum design for generating different trajectories in the corresponding work space.

References

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Cercetări privind modelul poziţional al sistemului robot Lynx 6

Rezumat

Articolul prezintă o metodă care permite obţinerea modelului poziţional al sistemului robot Lynx 6. Parametrii Khalil-Kleinfinger au fost folosiţi pentru analiza poziţională. Verificarea modelului s-a realizat folosind sistemul de operare interactiv Lynxmotion Rios SSC-32 V1-04 care controlează sistemul robot. Metodologia prezentată, care a fost transpusă într-un program de calculator, poate fi apoi folosită pentru proiectarea optimă a diferitelor traiectorii în spaţiul de lucru corespunzător.