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3D SIMULATION OF ROBOT STANFORD USING LABVIEW

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Abstract:
The paper presents 3D simulation of robot Stanford using Labview. The simulation program involves two working modes: automation mode and manual mode. In the automation mode, robot Stanford works with known trajectory resulted by resolving optimization problems. In the manual mode, the moving of the robot is controlled by external joystick.
Keywords: *PID control; Nanomaterial; Nanomaterial delivery; Nonlinear model; PID Controller.*

1. Introduction

Today, robot technology is widely applied in many fields such as industry, rescue, and health.

These are indispensable devices to production systems, especially the flexible ones. Robots are designed to be more intelligent and capable of performing various operations with complex motion trajectories. Robot control problems are often based on design objectives to choose the appropriate method. For robots with complex designs, to achieve the goal of the problem, we may have to use a combination of many different methods for many stages such as balance control, control of movement orbit. This is an area that many scientists are interested in studying.

Robot Stanford is one of the classic robot models with five rotary motion stages and one translational motion stage. Computer simulations to investigate instantaneous joint variables are useful for research and development of this type of robots.

LabVIEW [5] is a development environment based on the graphical programming language, commonly used for the purpose of measuring, inspecting, evaluating, processing and controlling parameters of devices. This is a versatile programming language, like other modern programming languages.

LabVIEW includes data acquisition libraries, a variety of control devices, data analysis, representation and storage. It also has development tools specifically designed for device coupling and control.

Based on the dynamic problem solving for robot Stanford, the paper focuses on building simulation programs on the Labview environment with two modes: automation mode and manual mode.

2. Main Content

2.1. The Dynamic Problem

For the dynamic problem of robots in general and robot Stanford in particular, there are three parameters that needs to be set [1, 2]: The Denavit-Hartenberg parameter (DH), the positioning matrix and the end-to-end state matrix.

The native position of the two linkages is determined by d_n and θ_n. In that, d_n is the distance between the normal lines along the n-axis. θ_n is the angle between the normal lines in the plane perpendicular to the axis. a_n, θ_n, α_n and d_n are called DH parameters.

According to Denavit-Hartenberg, matrix A is defined by the rotation and the relative translation between coordinate systems of two successive stages. This matrix will describe the relative position and direction between coordinate systems of the stages.

According to Denavit-Hartenberg also, the product of matrices A is called the matrix T. For example, a robot has six stages:

$$T_6 = A_1 * A_2 * A_3 * A_4 * A_5 * A_6 \quad (1)$$

T_6 describes relationship of the direction and position of the last stage to the basic coordinate system.

2.2. Theoretical basic of dynamic equation system and inverse dynamical methods of robot Stanford

2.2.1. The Dynamical equation of Stanford Robot

The DH parameter table of robot Stanford is defined as follows: (* is joint variable).

step	θ_i	α_i	a_i	d_i
1	θ^*_1	-90^0	0	0
2	θ^*_2	90^0	0	d_2

3	0	0	0	d^*_3
4	θ^*_4	-90^0	0	0
5	θ^*_5	90^0	0	0
6	θ^*_6	0	0	d_6

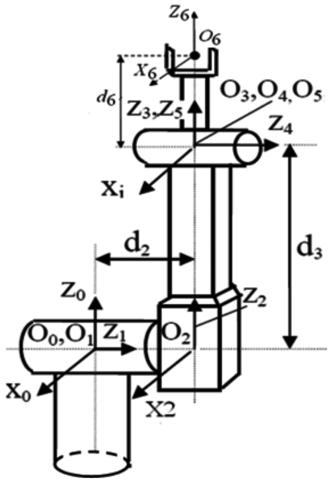

Figure 1. *Model of robot Stanford*

For simplicity in the process of writing matrices A and dynamic equations [1,3], we abbreviate the trigonometric functions as follows: **ci = cos**(θ_i) ; **si = sin**(θ_i), we have:

$$A_n = \begin{bmatrix} cos\theta & -sin\theta cos\alpha & sin\theta sin\alpha & acos\theta \\ sin\theta & cos\theta cos\alpha & -cos\theta sin\alpha & asin\theta \\ 0 & sin\alpha & cos\alpha & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_1 = \begin{bmatrix} c1 & 0 & -s1 & 0 \\ s1 & 0 & c1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} c2 & 0 & s1 & 0 \\ s2 & 0 & -c1 & 0 \\ 0 & 1 & 0 & d2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_4 = \begin{bmatrix} c4 & 0 & -s4 & 0 \\ s4 & 0 & c4 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_5 = \begin{bmatrix} c5 & 0 & s5 & 0 \\ s5 & 0 & -c5 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_6 = \begin{bmatrix} c6 & -s6 & 0 & 0 \\ s6 & c6 & 0 & 0 \\ 0 & 0 & 1 & d6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

We have the dynamic equation of robot Stanford as follows:

$$T_6 = A_1*A_2*A_3*A_4*A_5*A_6$$

$$\begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} = A_1*A_2*A_3*A_4*A_5*A_6 \qquad (2)$$

Multiply the matrices and balance the corresponding elements of the two matrices, we get the dynamic equation system of robot Stanford as follows:

n_x = - s6*(c4*s1 + c1*c2*s4) - c6*(c5*(s1*s4 - c1*c2*c4) + c1*s2*s5); (3)

n_y = s6*(c1*c4 - c2*s1*s4) + c6*(c5*(c1*s4 + c2*c4*s1) - s1*s2*s5); (4)

n_z = s2*s4*s6 - c6*(c2*s5 + c4*c5*s2); (5)

o_x = s6*(c5*(s1*s4 - c1*c2*c4) + c1*s2*s5) - c6*(c4*s1 + c1*c2*s4); (6)

o_y = c6*(c1*c4 - c2*s1*s4) - s6*(c5*(c1*s4 + c2*c4*s1) - s1*s2*s5); (7)

o_z = s6*(c2*s5 + c4*c5*s2) + c6*s2*s4; (8)

a_x = c1*c5*s2 - s5*(s1*s4 - c1*c2*c4); (9)

a_y = s5*(c1*s4 + c2*c4*s1) + c5*s1*s2; (10)

a_z = c2*c5 - c4*s2*s5; (11)

p_x = c1*d3*s2 - d6*(s5*(s1*s4 - c1*c2*c4) - c1*c5*s2) - d2*s1; (12)

p_y = c1*d2 + d6*(s5*(c1*s4 + c2*c4*s1) + c5*s1*s2) + d3*s1*s2; (13)

p_z = c2*d3 + d6*(c2*c5 - c4*s2*s5); (14)

If the values of the joint variables are known then the matrix T_6 is defined.

SOLVE THE DYNAMIC EQUATION OF ROBOT STANFORD

The dynamic equation system of robot Stanford:

$$T_6 = A_1 * A_2 * A_3 * A_4 * A_5 * A_6 \qquad (15)$$

Multiply (15) with inverse matrices of A, we obtain:

$$A_1^{-1} * T_6 = A_2 * A_3 * A_4 * A_5 * A_6 \quad (16)$$

$$A_2^{-1} * A_1^{-1} * T_6 = A_3 * A_4 * A_5 * A_6 \quad (17)$$

$$A_3^{-1} * A_2^{-1} * A_1^{-1} * T_6 = A_4 * A_5 * A_6 \quad (18)$$

$$A_4^{-1} * A_3^{-1} * A_2^{-1} * A_1^{-1} * T_6 = A_5 * A_6 \quad (19)$$

$$A_4^{-1} * A_4^{-1} * A_3^{-1} * A_2^{-1} * A_1^{-1} * T_6 = A_6 \quad (20)$$

Solve the dynamic system equations {(16), (17), (18), (19), (20)} we obtain:

$$\theta_1 = arctg2\left(m, n\right) - arctg2\left(d2/\left(r * d6\right), \pm\sqrt{1 - \left(\frac{d2}{r * d6}\right)^2}\right) \quad (21)$$

with: $$\begin{cases} m = \left(\frac{py}{d6} - ay\right) \\ n = \left(\frac{px}{d6} - ax\right) \\ r = \sqrt{m^2 + n^2} \end{cases}$$

$$\theta_2 = arctg2\left(\begin{array}{l} c1 * px + py * s1 - \\ d6 * \left(ax * c1 + ay * s1\right), pz - d6 * az \end{array}\right) \quad (22)$$

$$d_3 = c2 * \left(pz - d6 * az\right) + c1 * s2\left(px - d6 * ax\right) + + s1 * s2\left(py - d6 * ay\right) \quad (23)$$

$$\begin{cases} \theta_4 = arctg2\left(\begin{array}{l} ay * c1 - ax * s1, \\ ay * c2 * s1 + ax * c1 * c2 - az - s2 \end{array}\right) \\ \theta_4 = \theta_4 + 180 \end{cases} \quad (24)$$

$$\theta_5 = arctg2(s5, c5) \quad (25)$$

$$\theta_6 = arctg2(s6, c6) \quad (26)$$

Equations (21), (22), (23), (24), (25), (26) determine the roots when solving the inverse problem of robot Stanford.

2.3. Simulation Program

LabVIEW is a powerful graphical programming language [4, 5] that supports computation in measurement, control, culling and simulation. The basic functions used in the article are: 3D Picture Controls and Input Device Control.

Based on the dynamics problem of robots, this article simulates motion of robot Stanford on the LabVIEW platform with two modes: automation mode and manual mode, according to the following algorithmic flowchart (Figure 2):

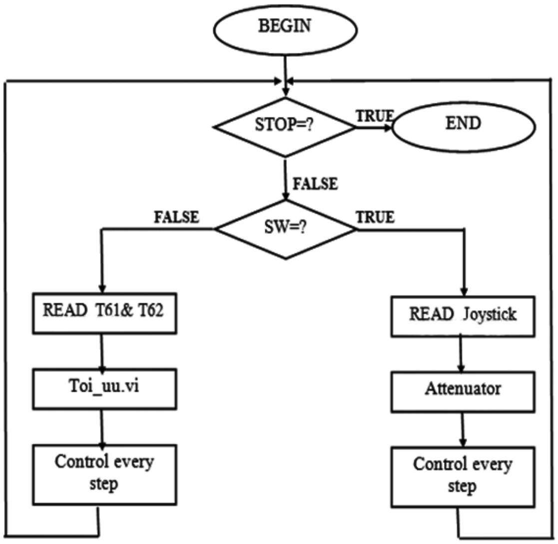

Figure 2. *Flowchart of the simulation program*

The parameters to be calculated are the joint variables: θ_1, θ_2, θ_3, θ_4, θ_5, θ_6. These parameters are displayed immediately during the movement of joints (Figure 3).

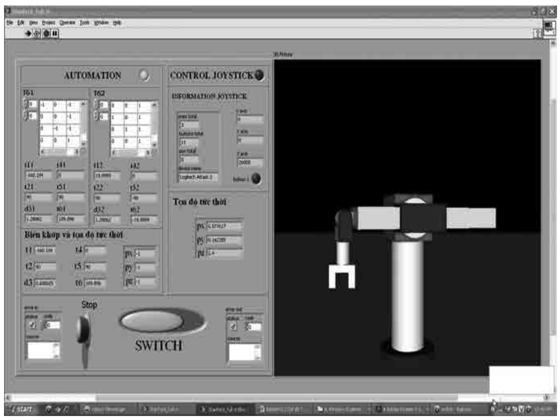

Figure 3. *The main interface of 3D simulation program of robot Stanford on LabVIEW environment*

In automation mode: enter the substitution parameters (position and direction) of the end points, the joint variables will be calculated through the reverse dynamic problem. Instantaneous parameters are calculated and displayed in digital form.

Figure 4 and Figure 5 show the results of the movement of robot Stanford in automatic run mode. The joint variables are displayed immediately during the movement.

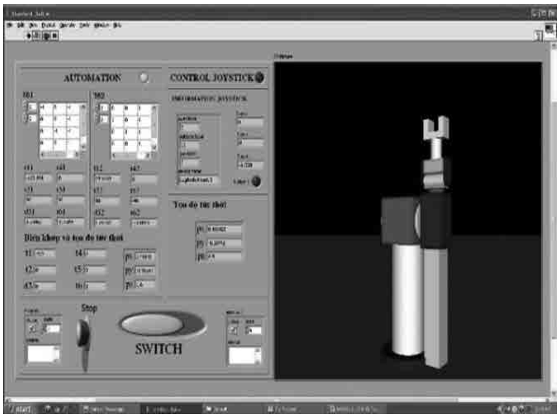

Figure 4. *Robot Stanford is in the first place*

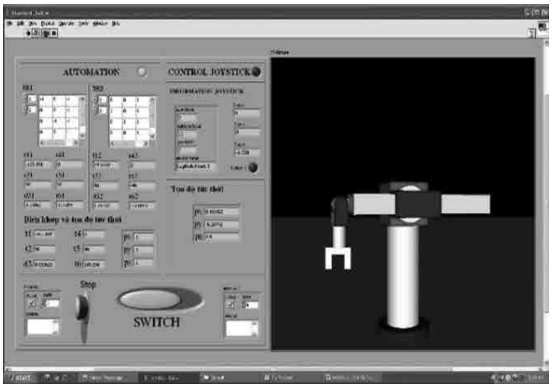

Figure 5. *Robot Stanford is in the second place*

In manual mode: the Joystick issues commands via USB. Software written in LabVIEW reads values from this port and gives output in respond to input command. Instantaneous coordinates will be calculated by solving the direct dynamic problem and displayed in digital form.

Figure 6. *Joystick Attack 3 issues commands via USB*

Figure 7 and Figure 8 show the result of robot Stanford controlled by a Joystick.

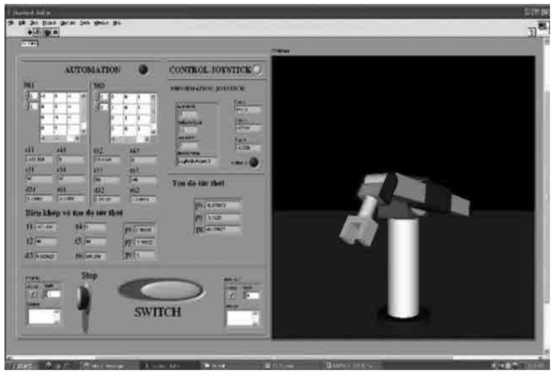

Figure 7. *The program runs in joystick mode*

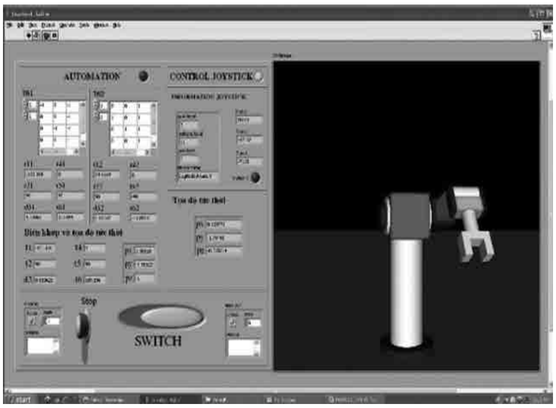

Figure 8. *The program runs in joystick mode*

3. Conclusions

In addition to studying the theory of solving dynamic problems for robots in general and for robot Stanford in particular, the paper combined LabVIEW graphical programming language with solving problem on Matlab to put into the main program core to construct visual objects with instantaneous joint variables.

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MÔ PHỎNG 3D ROBOT STANFORD TRÊN MÔI TRƯỜNG LABVIEW

Tóm tắt:

Bài báo trình bày kết quả mô phỏng 3D robot Sanford trên môi trường Labview. Chương trình mô phỏng 3D trực quan, dễ dàng quan sát quá trình hoạt động của robot Standford. Mô phỏng hoạt động theo hai chế độ: chế độ chạy tự động và chế độ điều khiển từ thiết bị ngoại vi. Chế độ chạy tự động sẽ chạy theo quỹ đạo và nghiệm số tối ưu đã được giải. Trong chế độ điều khiển từ ngoại vi, robot mô phỏng sẽ chuyển động theo tín hiệu điều khiển từ tay cầm bên ngoài.

Từ khóa: *Điều khiển PID; Vật liệu na nô; Phân phối vật liệu na nô; Mô hình phi tuyến.*