Analysis of the robot PROW based on robotics

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Abstract. Through the three stages of the development of robot- teach and playback robot, the robot with sensors, and the intelligent robot-we come to the generation that industrial robots are widely produced and utilized in our industrial manufacture. Its applications expands everywhere. In the meanwhile. The robots for entertainment and service appear and the amount is increasing rapidly. The first part of the paper is a general introduction of the development of robotics, especially industrial robots. The second part aims to introduce the fundamentals of robotics with some examples based on our manipulator PROW. A painting entertainment robot PROW (painting robot on web) is designed preliminarily with some basic theoretical research and experimental verification have been carried out on the serial robot with four degrees of freedom.

Keywords: Industrial robot, fundamentals of robotics, PROW, robotics toolbox, D-H algorithm

1 Introduction

Once the first electronic programmable robot was born in 1954， "robot is no longer a science fiction of Czech novelist, but the life-long goal struggled by many scientists and engineers"(1). Science fiction books and films have strongly influenced what many people expect a robot to be or what it can do. What disappoints us is that our research and practice of robotics is "far behind the popular conception"(2). Going through the Vaucanson's duck and the fantastic science fiction of Czech, who supposed that the robots androids the word, "the first patent for what we would now consider a robot was filed in 1954 by George C. Devil and issued in 1961"(2). Through the three stages of the development of robot- teach and playback robot, the robot with sensors, and the intelligent robot-we come to the generation that industrial robots are widely produced and utilized in our industrial manufacture. "Research and application of robot is far from stopped, but developing day by day with the trend of intelligent, modular and systematic."(Liu, 9) Its applications expand from traditional field of manufacturing to new fields of "architecture, agriculture, disaster prevention, medical care, the universe, the ocean". (Liu, 9) In the meanwhile, varieties of service robots come to appear." Recent developments in the area of service robotics show an increasing interest in personal robots"(3), Kozlowski said. Those personal robots can help to handle daily work and to entertain people. Both tasks require a robot that is able to communicate with people in a natural way. In the recent years, robots that can participate in football games, dance, do housework, help the medical surgical operations and so on. The robots for entertainment and service appear and the amount is increasing rapidly. Our robot PROW (Painting Robot on Web) is an entertainment robot which is designed to draw a portrait like an artist after taking several photographs. A painting entertainment robot PROW (painting robot on web) is designed preliminarily with some basic theoretical research and experimental verification have been carried out on the serial robot with four degrees of freedom. In the paper, the mathematical modeling depending on D-H algorithm and the direct and inverse kinematics outputs will be given.

2 The development of robot

The field of robotics has its origins in science fiction. It took about 40 years before the modern technology of industrial robotics began. At the three stages of the development of robot, "robots are highly automated mechanical manipulators controlled by computers." (Kafrissen, 5)

2.1 The history of robot

"Science fiction has no doubt contributed to the development of robotics, by planting ideas in the minds of young people who might embark on careers in robotics, and by creating awareness among the public about this technology."(Kafrissen, 7) The very early robot is simple, or change a word, it was resting on the ancients' minds in a long time. Some of the early developments in the field are not directly with robotics. In more recent times, "numerical control and telecherics are two important technologies in the development of robotics."(Kafrissen, 7). When it comes to robotics, we have to talk about automation. Automation and robotics are two closely related technologies. There are three broad classes of industrial automation: fixed automation, programmable automation, and flexible automation. (Kafrissen, 3) Through the three stages of the development of robot- teach and playback robot, the robot with sensors, and the intelligent robot-we come to the generation that industrial robots are widely produced and utilized in our industrial manufacture. The history of robot, as what has been introduced in the introduction.

2.2 The future of robot

When it comes to the direction which our technology and society develop and what it is in store for us in the future, Schilling (5) gives us a general description.

"The human race is now poised on the brink of a new industrial revolution which will at least equal, if not far exceed, the first industrial Revolution in its impact on mankind. The first industrial Revolution was based on the substitution of mechanical energy for muscle power. The next industrial revolution will be based on the substitution of electronic computers for the human brain in the control of machines and industrial processes. "(Schilling qtd.in James S. Albus) Schilling's words are not as thrilled as what appears in the science fiction books and films. On the contrary, it represents a fantasy vision for the future. robotics will be an important technology in this century. Productssuch as vacuum cleaning robots are the vanguard of a wave of smart machines that will appear in everyone's homes and workplaces.

3 The analysis of PROW

The second part aims to introduce the fundamentals of robotics with some examples based on our manipulator PROW.

3.1 The fundamental of robotics

The objective is to control both the position and the orientation of the tool in three-dimensional space. The tool, or end-effector, can then be programmed to follow a planned trajectory so as to manipulate objects in the workspace. In order to program the tool motion, we must first formulate the relationship between the joint variables and the position and the orientation of the tool. This is called direct kinematics problem, we will first solve the direct kinematics problem.

As we know that a robot covers three basic components-controller, manipulator and tooling. And "a manipulator can be modeled as a chain of rigid bodies called links"(3). The links are interconnected to one another by joints which can be typically divided into two types: the revolute joints and the prismatic joints.

3.2 D-H algorithm

In robotics, we usually describe a manipulator by the D-H algorithm. And the D-H algorithm can be briefly expressed below:

If we number the joints from 1 to n starting with the base and the ending with the tool. We can assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Assign z^k with the axis of joint k+1. Then we can locate the origin of

L_k at the intersection of z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}. Next, we can select x^k to be orthogonal to both z^k and z^{k-1} and select y^k to form a right-handed orthonormal coordinate frame L_k.
Obeying the rules listed above, we can illustrate a robot with some variables. Locate point b^k at the intersection of x^k and z^{k-1} axes. We computer θ_k as the angle of rotation from x^{k-1} to x^k measured aboutz^{k-1}. Computer d_k as the distance from the origin of frame L_{k-1} to the point b^k measured along z^{k-1}. Computer a_k as the distance from point b^k to the origin of frame L_k measured along x^k. Computer α_k as the angle of rotation from z^{k-1} to z^k measured about x^k. (Kozlowsk, 26)

When constructing the homogenous transformation matrix which maps frame k coordinates into frame k-1 coordinates, we successively rotate and translate coordinate frame k -1 to render it coincident with coordinate frame k. (Kozlowsk, 57) and we can get the transformation matrix shown in Equation 1.

$$\boldsymbol{A_i} = \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & \sin\theta_i\sin\alpha_i & a_i\cos\theta_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & -\cos\theta_i\sin\alpha_i & a_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

3.2 PROW

Our robot is called PROW (Painting Robot on Web), which is designed to draw a portrait like an artist after taking several photographs. The robot is an entertainment robot which is expected to be placed in the front of the markets. The robot is supposed to fulfill several functional demand: PROW should first use its eyes to take a picture of the people (or we can use only one eye, but correspondingly PROW should take more pictures from different direction), among which we may use the light on adverse lighting condition; PROW may handle these photographs in the Open CV and then translate the photos into some simple lines. PROW needs to decide in which order the portrait should be painted according to some fixed rules. After that, it can draw the portrait in a specific way. The time for each portrait is expected to be under 5 minutes. Of course, if possible, we hope it can collect fee itself.

It is the serial robot with four degrees of freedom. The four joints are all revolute joints. The approximate structure and the poses when it works are shown in Figure 1.

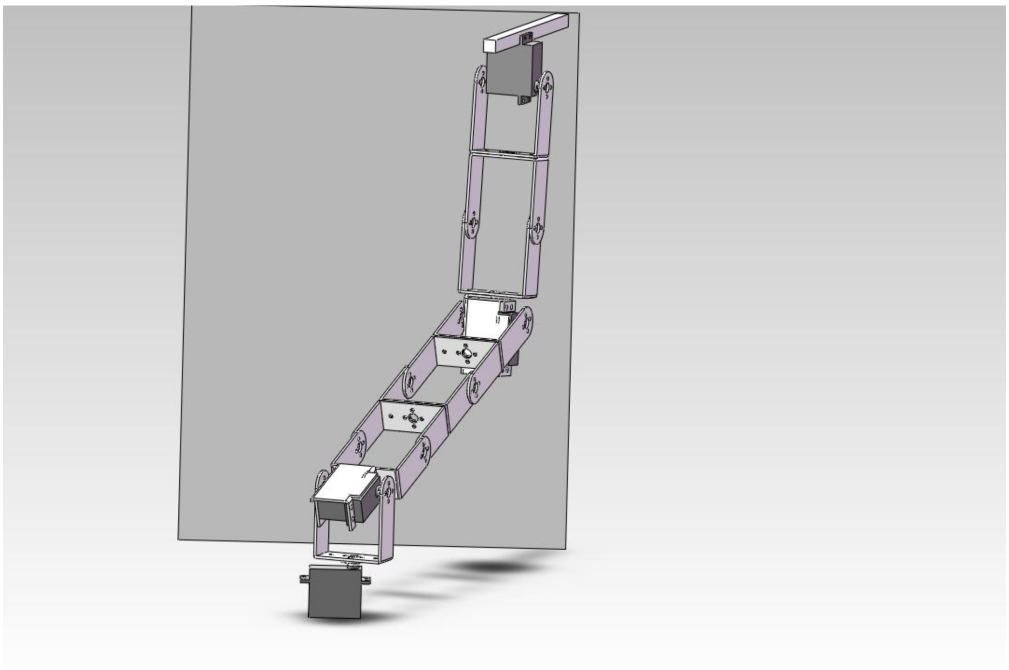

Fig.1. Structure of PROW

The point is that the figure only shows the manipulator of PROW instead of the full view of the robot. The framework of the manipulator is expected with an appropriate appearance which is at present in research. The holder of the robot is neglected by the figure which is under the first electric motor.

Further, we can identify the specific size of each link. The main parameter is shown in Figure 2. And some measures are not marked. The marker pen adhered to the last electric motor is about 12.00 ceilometers which is adjustable. Therefore, in the mathematical modeling and calculating, we suppose it measures 12.00 ceilometers. Otherwise, we suppose the origin of the platform is 5.80 ceilometers below the axis of joint 2, crossed with the axis of joint 1.

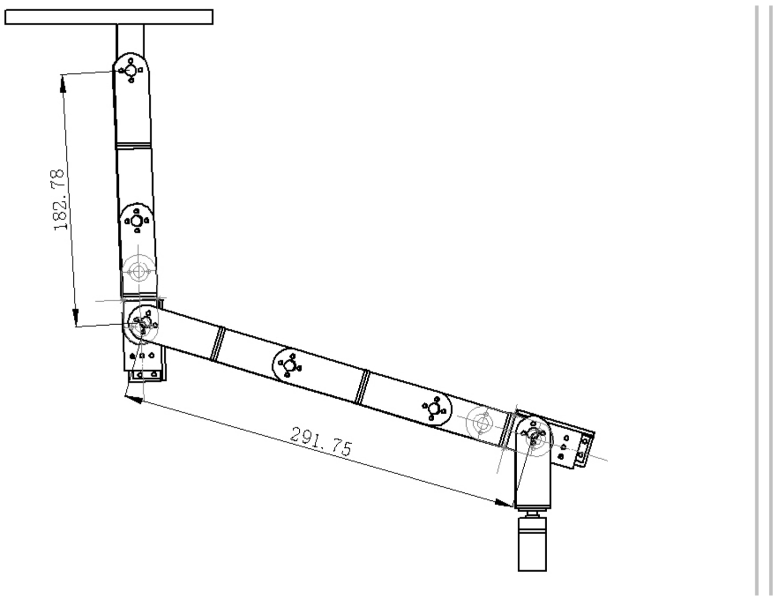

Fig.2. parameters of PROW

We can at first list the D-H parameters according to the choice of coordinates clarified above as Table 1.

Parameter Joint	θ /。	d/mm	a/mm	α /。
1	θ_1	58.00	0	90
2	θ_2	0	291.75	0
3	$\theta_3 + \pi/2$	0	182.78	0
4	θ_4	120.00	0	90

Table 1. The D-H parameters

Therefore, we can calculate the transformation matrix of each joint. We leave out the procedure of the calculation, and present the final transformation matrix of the robot what is the Link-Coordinate Transformation matrix.

$$T6 = A1\ A2\ A3\ A4\ A5\ A6 = \begin{bmatrix} n_x & o_x & a_x & P_x \\ n_y & o_y & a_y & P_y \\ n_z & o_z & a_z & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

nx = - c4(c1c2s3 + c1c3s2) - s4(c1s2s3 + c1c2c3);
ny = - c4(c2s1s3 + c3s1s2) - s4(s1s2s3 + c2c3s1);
nz = c4(c2c3 - s2s3) + s4(c2s3 - c3s2);
ox = s1;
oy =-c1 ;
oz = 0;
ax = c4(c1s2s3 + c1c2c3) - s4(c1c2s3 + c1c3s2);
ay = c4(s1s2s3 + c2c3s1) - s4(c2s1s3 + c3s1s2);
az = 0;
px = 120s1 + (1167c1c2)/4 - (9139c1c2s3)/50 - (9139c1c3s2)/50;
py = (1167c2s1)/4 - 120c1 - (9139c2s1s3)/50 - (9139c3s1s2)/50;
pz = s4(c2c3 - s2s3) - c4(c2s3 - c3s2);

In the meanwhile, we can use the Matlab robotics toolbox to simulate the robot, the output is shown in Fig.3.

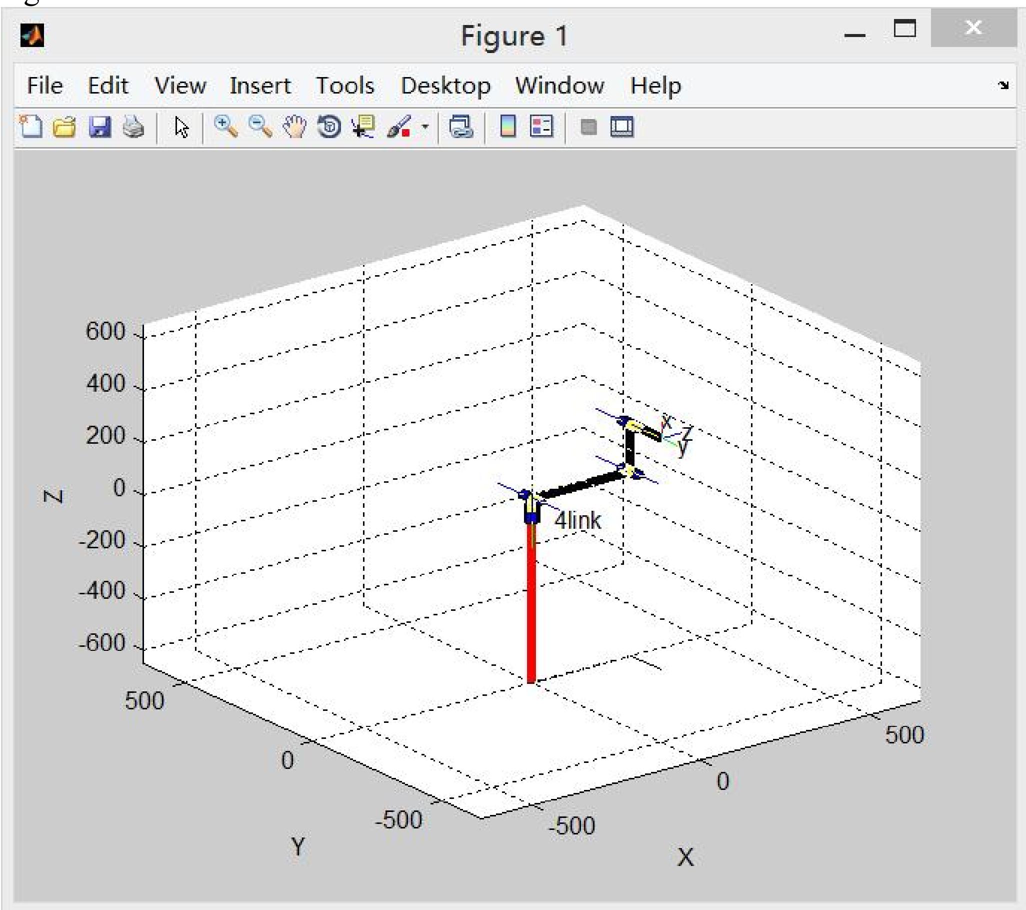

Fig.3. Simulation on Matlab

As for the inverse kinematics of PROW, we use the 4th column of the transformation matrix, the former three variable respectively represent px, py, pz. If we know the value of the three variables in advance, we can solve the angles each joint turns respectively. However, the solution may not be unique. We need to choose every solution according to the fact. For example, if the angles the electric motor can turn is limited owing to the structural obstacles, we have to choose the solution that satisfies the answer. In the meanwhile, we have to guarantee that when the manipulator is moving in a short time, the inverse solution should be "continuous", which means that the inverse solutions are appropriately equal and do not have a sudden change. According to the rule, the inverse kinematics answer can be figured out.

Summary

In the paper, a general history of robot is introduced, and we know the popularization of industrial robots and the increasingly developed service robots. In the second part, the paper briefly introduced the fundamental robotics and the D-H algorithm which is widely used in robotics to mathematically model our robot PROW. In the end, we give the solution of kinematics and carry out some simulations. Some work in other aspects is not induced here. And the program is in research, the robot PROW is expected to implement some functions listed in the paper. More work is going to be done in the future.

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