

Simulation of Spray Painting Operation using MICROBOT ALPHA-II

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Abstract

Robots have assumed a very great significance in this industrial world today. Features of modern day robot are responding to simple yes/no questions, deaf dumb and blind but do not suffer boredom, complaint and fatigue. The goal of our work is to simulate spray painting operation making use of Microbot Alpha II robot. In this project we have used the Open Source Animation Software "Blender" to create a video rendered operation of Microbot Alpha-II. This work can be used as a teaching aid to demonstrate the working of Microbot Alpha II in an industrial environment.

Keywords- Microbot AlphaII , Simulation, Spray Painting

I. Introduction

This paper describes the simulation spray painting operation making use of Microbot Alpha II robot. The word robot was first coined by the Czech writer Karel Capek in 1920 to denote a machine in the form of a man. The word robot originated from the Czech word robota or robotnic or a servant or a forced worker or a slave. A Robot is a software controlled mechanical device that uses sensors to guide one or more end effectors through programmed motions in a workspace in order to manipulate physical objects. The object is placed inside the work envelope of the robot. The work envelop is defined as the area in which the robotic influence is experienced or the robot can do useful work. The robot initially moves from its home position and paints the object. The next object is then presented to the robot on the conveyor belt. Inorder to see such demonstration its imperative to visit the site. But this may not be be feasible all the time The cost of a Microbot Alpha-II robot is approximately \$14000.00, therefore it is difficult to obtain a real Microbot Alpha-II robot model, also the hardware model has a lot of mobility constraints and hence, it poses an obstacle for demonstration to students. This makes it difficult to understand the working and various operations of this robot. Therefore our work is an effort to bridge this gap by providing an a solution by using open source software. Thus our project which is an animated simulation of the robot can be used as a teaching aid for professors in the field of Robotics.

This paper is organized as follows. In section II, we introduce Microbot Alpha II. In section III we discuss the direct kinematics of Microbot Alpha II. In section IV we

describe the inverse kinematics of Microbot Alpha II. This is followed by the followed by implementation in section VII. In Section VIII we describe the Animation. Finally, we summarize and conclude in the next Section

II. Microbot Alpha II 5 axis articulated robot

Microbot Alpha II is a proven, low-cost robot system designed specifically to help manufacturing operations management improve productivity by automating low-level tasks that human workers find hazardous or difficult to repeat accurately for long periods of time. Alpha II is ideal for any repetitive, human equivalent production operation with a payload up to three pounds and repeatability requirements up to ± 0.015 ". [5]

III. Direct Kinematics of Microbot Alpha II

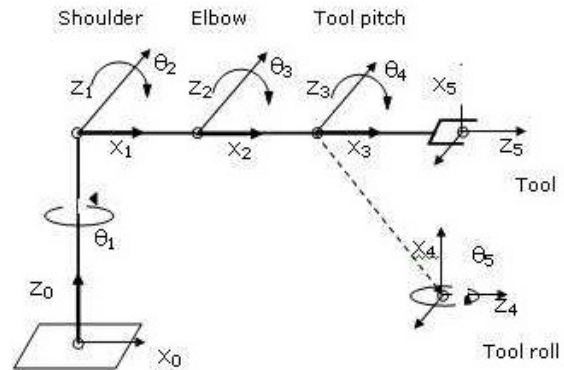


Figure 1 Link coordinate diagram of Microbot Alpha II

Given a vector of kinematic parameters, direct kinematic problem is to find the final position and orientation of the end effector. Direct kinematics gives arm matrix of the Microbot Alpha II [1]

A. Kinematic Parameters

| Link | Var | θ | d | α | a |
|------|------------|--------------------|-------|----------|-------|
| 1 | θ_1 | θ_1 | 215 | $-\pi/2$ | 0 |
| 2 | θ_2 | θ_2 | 0 | 0 | 177.8 |
| 3 | θ_3 | θ_3 | 0 | 0 | 177.8 |
| 4 | θ_4 | $\theta_4 - \pi/2$ | 0 | $-\pi/2$ | 0 |
| 5 | θ_5 | θ_5 | 129.5 | 0 | 0 |

B. Arm Matrix of Microbot Alpha II

$$\begin{bmatrix} c_1c_{234}c_5 + s_1s_5 & -c_1c_{234}s_5 + s_1c_5 & -c_1s_{234} & p_x \\ s_1c_{234}c_5 - c_1s_5 & -s_1c_{234}s_5 - c_1c_5 & -s_1s_{234} & p_y \\ -s_{234}c_5 & s_{234}s_5 & -s_{234} & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix} = \begin{bmatrix} c_1(117.8c_2 + 177.8c_{23} - 96.5s_{234}) \\ s_1(117.8c_2 + 177.8c_{23} - 96.5s_{234}) \\ 215.9 - 177.8s_2 - 177.8s_{23} - 96.5c_{234} \end{bmatrix}$$

IV. Inverse Kinematics of Microbot Alpha II

Tool configuration vector (TCV) for the five axis articulated arm is given by $W(q) = [W_1, W_2, W_3, W_4, W_5, W_6]^T$ [1]

$$W(q) = [C_1(a_2C_2 + a_3C_{23} + a_4C_{234} - d_5S_{234}), S_1(a_2C_2 + a_3C_{23} + a_4C_{234} - d_5S_{234}), d_1 - a_2S_2 - a_3S_{23} - a_4S_{234} - d_5C_{234}, -[\exp(q_5/\Pi)]C_1S_{234}, -[\exp(q_5/\Pi)]S_1S_{234}, -[\exp(q_5/\Pi)]C_{234}]^T$$

- **Base joint – (q1)**

$$q_1 = \text{atan2}(W_2, W_1)$$

- **Elbow joint – (q3)**

Since elbow joint q_3 is strongly coupled with the shoulder and tool pitch angles, the global tool pitch angle q_{234} is isolated. $q_{234} = q_2 + q_3 + q_4$
 $q_{234} = \text{atan2}(-c_1W_4 + c_1W_5) - W_6$

In order to isolate the shoulder and elbow angles the following two intermediate variables are defined.

$$b_1 = C_1W_1 + S_1W_2 - a_4C_{234} + d_5S_{234}$$

$$b_2 = d_1 - a_4S_{234} - d_5C_{234} - W_3$$

This gives :

$$b_1 = a_2C_2 + a_3C_{23}$$

$$b_1^2 = a_2^2 C_2^2 + a_2^2 C_{23}^2 + 2*(a_2a_3C_2C_{23})$$

$$b_2 = a_2S_2 + a_3S_{23}$$

$$b_2^2 = a_2^2 S_2^2 + a_2^2 S_{23}^2 + 2*(a_2a_3S_2S_{23})$$

The elbow angle can be computed by finding

$$\|b\|^2 = b_1^2 + b_2^2$$

$$\|b\|^2 = a_2^2 + 2*a_2a_3C_3 + a_3^2$$

$$Q_3 = \pm \arcsin \frac{\|b\|^2 - a_2^2 - a_3^2}{2*a_2a_3}$$

- **Shoulder Joint – (q2):**

After expanding C_{23} and S_{23}

$$C_{23} = C_2C_3 - S_2S_3$$

$$S_{23} = S_2C_3 + C_2S_3$$

$$b_1 = (a_2 + a_3C_3)C_2 - (a_3S_3)S_2$$

$$b_2 = (a_2 + a_3C_3)S_2 - (a_3S_3)C_2$$

Solving these simultaneous equations for C_2 & S_2 .

$$C_2 = \frac{(a_2 + a_3C_3)b_1 + (a_3S_3)b_2}{\|b\|^2}$$

$$S_2 = \frac{(a_2 + a_3C_3)b_2 - (a_3S_3)b_1}{\|b\|^2}$$

$$q_2 = \text{atan2}[(a_2 + a_3C_3)b_2 - (a_3S_3)b_1, (a_2 + a_3C_3)b_1 + (a_3S_3)b_2]$$

- **Tool Pitch Joint : (q4)**

$$q_4 = q_{234} - q_2 - q_3$$

- **Tool Roll Joint : (q5)**

$$q_5 = \Pi \ln(W_4^2 + W_5^2 + W_6^2)^{1/2}$$

- **Reduced Tool Configuration Vector (\ddot{W})**

In the case of five axis articulated robot with tool pitch and tool roll motion; the following is an example of

reduced tool configuration vector:

$$\ddot{W} = [P_1, P_2, P_3, q_{234}, q_1 - 5]^T$$

Given the position and orientation of the initial and final position of the object inverse kinematic analysis is performed on the Microbot Alpha II robot to determine the vector of joint variables or kinematic parameters for the robot to reach the given position.

V. Work Envelop of Microbot Alpha II

The work space or work volume is defined as the area in which the robotic influence is experienced or the robot can do useful work. It is also defined as the total area that the end of the arm can reach or the locus of all the points in the 3D space that the tip of the end-effector traces. It is also called Gross Work Space. The boundary of the work space is called work envelope. The number of axes a robot has define its flexibility level. The typical industrial robot has six axes of movement. The robot's axes link arm segments which each vary in length. The length of the arms combined with the capabilities of each axis determine a robot's reach. Robots have different mounting options. Their work envelopes vary in scope depending on whether they are shelf, ceiling, wall, or floor mounted. Some robots can be mounted to tracks or gantry systems, which further expands their work envelopes. A robot's strength affects its work space. In this work the robot is assumed to be stationary. Its end effector is placed parallel to the surface being painted. The spray gun is attached to the end effector. As soon as one object is painted the next is provided on the conveyor belt [4]

VI. FUNDAMENTALS OF BLENDER

Blender is a rendering\animation\game development open-sourced program maintained by the Blender Foundation. Blender is a 3D graphics application released as free software under the GNU General Public License. It can be used for modeling, UV unwrapping, texturing, rigging, water simulations, skinning, animating, rendering, particle and other simulations, non-linear editing, compositing, and creating interactive 3D applications. Blender is available for several operating systems, including GNU, FreeBSD, IRIX, Linux, Mac OS X, Microsoft Windows, NetBSD, OpenBSD and Solaris

with unofficial ports for AmigaOS, BeOS, MorphOS, Pocket PC and SkyOS. Blender has a robust feature set similar in scope and depth to other high-end 3D software such as Softimage|XSI, Cinema 4D, 3ds Max, Lightwave and Maya. These features include advanced simulation tools such as rigid body, fluid, cloth and softbody dynamics, modifier based modeling tools, powerful character animation tools, a node based material and compositing system and Python for embedded scripting. Blender is preferred because of its robust nature.

After thoroughly analyzing the animation software i.e. Blender we have divided the entire procedure in six sections:

Modeling: In this module we designed the microbot using modeling functions such as scaling, rotating, extrude, joining, set smooth and manipulation of objects.

Animation: An animation is a series of rendered images that form a movie. The quality of movie is controlled by features such as frames per second(fps), output size, file type and compression. The most common method of animation is called *keyframing*. Key frames are created at various points in the animation while the computer generates all of the transition frames between the two keys. Basic animation options include changing size, rotation and location of objects. It is also required to animate the Microbot movements and spraying actions using blender. The blender functions used were Particle system, Armature, IPO Curves, Timeline.

VIII.

Video Rendering: In this part, the final output i.e the Video was obtained, which involved choosing of proper video codec (.AVI) for the output, video size etc.

A rendering is a pictorial output of a 3D scene or object. Features like materials, lighting, over sampling and shadows control the effects and quality of the rendering. The more of these features are added, the more realistic the scene become, but also lengthens rendering times.

Materials and Textures: We can control they way an object appears by applying color and textures. Materials provide realism with added effects. We can control glossiness (specularity), self-emitting lighting characteristics, transparency and pattern repetition. Textures can be made from any scanned photograph or drawn object in paint. The file needs to be saved as a jpeg or bitmap in most cases, depending on the program. For Blender, the image should be square and based off of 8 x 8 pixels (16x16, 64x64, 256x256), however, off size and rectangular images usually work also. Higher pixel images provide sharper images, but increase file sizes. As Blender has evolved, rectangular images work fine and don't need to be square, but still a good rule to follow.

Lighting: Lighting provides the realism to your scene through reflections and shadows. We can control the type of light, intensity and color. Some lights can give a "fog" or "dusty" look with a halo or volume lighting effect. Illumination distances can also be set.

Cameras: The camera is the point-of-view for the scene. Just like a real camera, we can control lens length to achieve close-ups or wide angles. Clipping distance can also be set to control how far and near the camera sees[2] [3] [4].

Implementation

The first step is to design the base for the robot. We used a variety of meshes comprising of 3 cubed meshes and a cylinder. These different meshes to be separate, they were merged into a single mesh. The next step in the modeling process was to build the robotic arms as well as the end effector with the spray gun. The rotation of arms can be successfully achieved by using armatures (which are basically bones) and the concept of parenting. Parenting basically causes the child object to replicate any changes made to the parent object. Therefore, a rotation, scaling or translation of the parent will cause the child to follow suite. Basic cylindrical meshes have been used to make the arms. The armatures are then added wherever necessary and also extrude them if needed. Now to make the outer cylindrical arm rotate along with the inner armature, we make the armature the parent of the arms .Parenting is also used to make the second arm rotate along with the first arm. The environment s then created for performing the spray painting operation [2] [3].

Animation

Three methods are normally used in animation software to make a 3D object move:

Key frames Complete positions are saved for units of time (frames). An animation is created by interpolating an object fluidly through the frames. The advantage of this method is that it allows to work with clearly visualized units. The animator can work from one position to the next and can change previously created positions, or move them in time.

Motion Curves can be drawn for each XYZ component for location, rotation, and size. These form the graphs for the movement, with time set out horizontally and the value set out vertically. The advantage of this method is that it gives precise control over the results of the movement.

Path A curve is drawn in 3D space, and the Object is constrained to follow it according to a given time function of the position along the path.

In order to animate the robot, the keyframe method is used. Blender uses Armatures for character animation. An armature is just like a skeleton which once parented to character mesh, will l define a number of poses for character along the timeline of animation.

Rendering is the final process of CG (short of post processing) and is the phase in which the image corresponding to your 3D scene is finally created. In rendering an AVI video file of the entire spray painting

operation is created. Since it is not possible to incorporate both horizontal and vertical motion while animating (due to the constraint that parenting imposes) the video is made in parts and finally merged separately [2] [3].

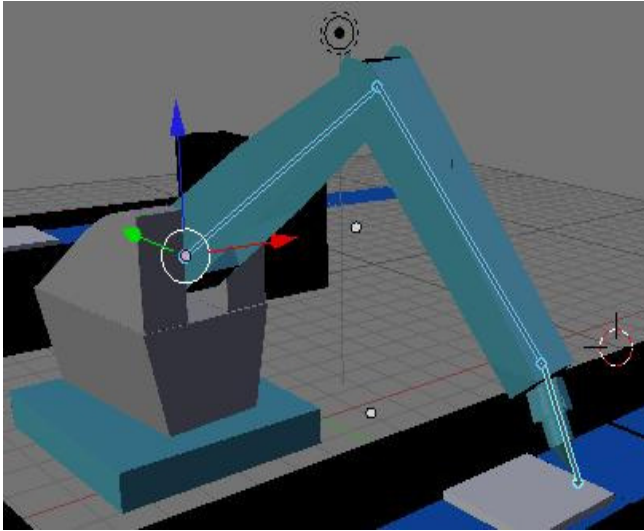


Figure 2 Final output

IX. Conclusion and Future work

The goal of our work is to simulate spray painting operation making use of Microbot Alpha II robot. Blender animating software was preferred because it is an Open source software, it is robust and freely available and it requires lesser resources as compared to other animation softwares such as Maya, 3D Studio. The future enhancement to this work would be to develop an array of simulations to demonstrate more than one industrial applications. Another enhancement could be to give user interactive animation sequence.

References

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