DESIGN AND SIMULATION OF POWDER COATING OPERATION USING KAWASAKI KF 121 ROBOT

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ABSTRACT

Industrial robots are mainly employed to perform repetitive and hazardous production jobs, multi-shift operations etc. to reduce the delivery time improve the work environment; lower the production cost and even increase the product range to fulfil the customers' needs. Robots have assumed a very great significance in this industrial world today. The features of modern day robot are responding to simple questions, deaf dumb and blind but do not suffer boredom, complaint and fatigue. The aim of this research work is to simulate powder coating operation by using of KF 121 robot. In this work, we have used the Autodesk Maya 2011 to create a video rendered operation of KF 121 robot. This work can be used as a teaching aid demonstrates the working of KF 121 robot in industrial environment.

Keywords: *Simulation, Powder Coating Operation, Kawasaki KF 121 robot, Maya Software.*

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1. INTRODUCTION

The paper describes the simulation powder coating operation making use of Kawasaki KF 121 robot. The word robot was first defined 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 coated the object. The next objects are jigged and loaded onto continuously moving overhead conveyor and then presented to the robot. The consistency and repeatability of a robot's motion have enabled almost perfect quality to the finished goods while at the same time wasting no powder. In fact, the spray powder coating is seems to be optimizing the proper applications of robotics. In other word, it helps to relief the human operator from a hazardous substance from the spray nozzle, perform a very skilful job continuously, while at the same time increasing work quality, uniformity, and cutting costs. The powder coating demonstration is imperative to visit the site, but this may not be feasible all the time. The cost of a Kawasaki KF 121 robot is approximately 7 million yen, therefore it is difficult to obtain a real Kawasaki KF 121 robot model. Also the hardware model has a lot of mobility constraints and hence, it poses an obstacle for demonstration to students or workers. 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 a solution by using 3D computer graphics software. Thus our work which is an animated simulation of the robot can be used as a teaching aid for professors in the field of Robotics and those operators perform the coating operation.

2. KAWASAKI KF 121 6 AXIS ARTICULATED ROBOT

In general, the use of applying a layer coat of powder which, covers up partial or entire product, are to extend the life of the good or product, to give an extra credit on the product's looks or finishing. As we know, the consumers will be attracted to the product if the products are well fashioned and bright. In order to produce a skilful panting job continuously without compensate more time, a design of a robotic automation system should be placed in the production line. The result of robotic coating automation would not downgraded the finished good, in fact, the use of a robotic spraying automation would give a similar finish to all products and the output of the productivity can be increased enormously.

In this case, the consistency and the repeatability of the robot motion itself are placed in a good benefit, where the use of robotic spraying automation on finish goods can be done faster and with a lower cost without losing the quality of the finish goods. The facts that robot spraying automation keeps a lower cost that, amount of paint that are used in a single product is fixed without any lost of powder. As we know, a robotic automation system would be a high capital expenditure but, the products that are produced with a great quantity and quality would return back the cost of the robotic automation itself. KF 121 is ideal for any repetitive, human equivalent production operation with a payload up to five kilograms and repeatability requirements up to ± 0.2 mm.

3. FORWARD KINEMATIC ANALYSIS

These industrial robots are basically composed by rigid links, connected in series by joints, having one end fixed (base) and another free to move and perform useful work when properly end-effecter. As with the human arm, robot manipulators use the first three joints (arm) to position the structure and the remaining joints (wrist, composed of three joints in the case of the industrial manipulators) are used to orient the end-effecter. Table I shows the DH parameters whole set of Kinematic parameters for the Kawasaki KF 121 Robot. The graphic representation of the Kawasaki KF 121 robot is shown in Fig.1

Table1: Complete DH parameter for the Kawasaki KF 121 Robot

Joint	θ (deg)	d (m)	a (m)	α (deg)	Variable
1	±160°	0.4	0	90	□ 1
2	±90°	0	0	0	□ □
3	±150°	0	0.3	0	□ □
4	±270°	0.24	0	0	□ □
5	±145°	0	0.08	0	□ □
6	±360°	0	0	0	□ □

This notation utilizes six parameters to define an adjacent joint, these are

θ_i - Represents the rotational parameter around the principal Z_{i-1} axis.

d_i - Represents the translation along the principal Z_{i-1} axis.

a_i - Represents the translation along the X_{i-1} axis.

α_i - Represents the rotation around the principal X_{i-1} axis.

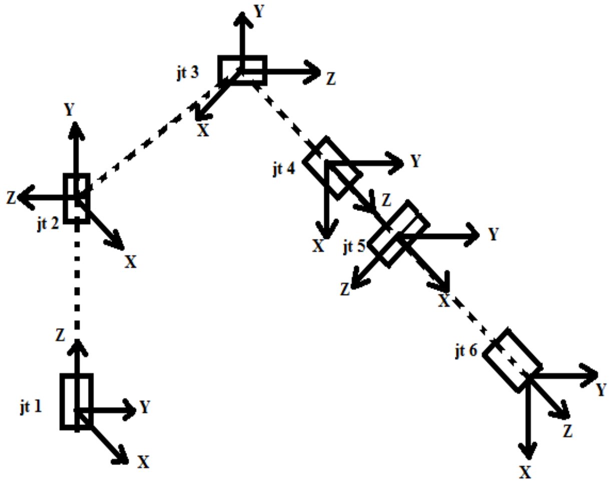

Figure 2. Link frame assignments for the KF 121 manipulator

In KF 121 a gearing arrangement in the wrist of the manipulator couples together the motion of joint 4, 5, and 6. In this we will consider only the kinematics from joint space to Cartesian space.

The resulting homogeneous transformation matrix is:

$$ {}^{i-1}_{\;\;i}T = \text{Rot}(z, \theta i)\ \text{Trans}(Z, d_i)\ \text{Trans}(X, a_i)\ \text{Rot}(X, \alpha_i) $$

$$ = \begin{bmatrix} \cos\theta i & -\sin\theta i.\cos\alpha i & \sin\theta i.\sin\alpha i & ai\cos\theta i \\ \sin\theta i & \cos\theta i.\cos\alpha i & -\cos\theta i.\sin\alpha i & ai\sin\theta i \\ 0 & \sin\alpha i & \cos\alpha i & di \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

We obtain the product of all six link transforms

$$ {}^{0}_{6}T = {}^{0}_{1}T \; {}^{1}_{6}T = \begin{bmatrix} r_{11} & r_{12} & r_{13} & Px \\ r_{21} & r_{22} & r_{23} & Py \\ r_{31} & r_{32} & r_{33} & Pz \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

Where

$r_{11} = c1[$ c23 (c4c56 − s4s56) − s23 (c4s56+s4c56)]

$r_{12} = c1[$ c23(− s4c56 − c4s56 − s23(− s4s56 + c4c56)]

r_{13} = s1

r_{21} = s1 [c23 (c4c56 − s4s56) − s23 (c4s56+s4c56)]

r_{22} = s1 [c23 (− s4c56 − c4s56) − s23(− s4s56 + c4c56)]

r_{23} = − c1

r_{31} = s23 (c4c56 − s4s56) + c23 (c4s56+s4c56)

r_{32} = s23 (− s4c56 − c4s56) + c23 (− s4s56 + c4c56)

r_{33} = 0

Px = C1 [0.08 C23 + 0.3 C2] + 0.24 S1

Py = S1 [0.08 C23 + 0.3 C2] − 0.24 S1

Pz = 0.08 S23 + 0.3 S2 + 0.4

4. INVERSE KINEMATIC ANALYSIS

Inverse kinematics are used in the reverse form of a forward kinematic, where a forward kinematic finds the last position of an end effecter. Instead of finding the last position of the end effecter, inverse kinematic find joint angels that are used to obtain the last point of the end effecter. So, in inverse kinematic, the last positions of the end effecter are given but the rotations of each joints of the robot are missing. The function of inverse kinematic (IK) is to find the joint angels.

Mathematically, we rearrange equation so that we isolate the homogeneous transformations which are a function of the unknown joint values and somehow solve for the joint values by the following equation:

$$ \mathbf{H1\ H2\ H3...Hn.} = G^{-1}\mathbf{T} $$

Where, T is known

If n is 6, then the robot has 6 degrees-of-freedom. When the degree of freedom expends or has a larger number, the method on finding the inverse kinematic on the robot is much more difficult. The Inverse kinematic solution procedure begins by the user examining the complex transcendental equations that arise by comparing each term generated by the resultant product matrix on the left hand side with the known terms on the right hand side (once the n H matrices have been multiplied to arrive at a single matrix).

Also there are many robots that have configurations for which an exact IK solution simply cannot be found. These robots can only be commanded in a forward kinematics mode.

5. WORK VOLUME OF KF 121 ROBOT

Work volume is the term that refers to the space within which the robot can manipulate its wrist end. The convention of using the wrist end to define the robot's work volume is adopted to avoid the complication of different size of end effectors that might be attached to the robot's wrist. The end effector is an addition to the basic robot and should and not be counted as part of the robot's working space. A long end effector mounted on the wrist would add significantly to the extension of the robot compared to a smaller end effector. Also the end effector attached to the wrist might not be capable of reaching certain points within the robot's normal work volume because of the particular combination of joint limits of the arm. The work volume is determined by the following physical characteristics of the robot:

- The robot's physical configuration.
- The size of the body, arm, and wrist components.
- The limits of the robot's joint movements.

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 a gantry system, which further expands their work envelopes. A robot's strength affects its work space. In this work the robot is assumed to be stationary. The spray gun is attached to the end effector. As soon as one object is painted the next is provided on the overhead conveyor.

6. FUNDAMENTALS OF AUTODESK MAYA

Autodesk Maya is rendering\animation\game development 3D computer graphics software maintained by the Autodesk, Inc. The original author is Alias Systems Corporation. Maya is a 3D graphics application released in February 1998; 13 years ago software under the Proprietary License. It can be used for modelling, UV unwrapping, texturing, rigging, water simulations, skinning, animating, rendering, particle and other simulations, non-linear editing, compositing, and creating interactive 3D applications. Maya is available for several operating systems, including GNU, FreeBSD, IRIX, Linux, Mac OSX, and Microsoft Windows. Maya has a robust feature set similar in scope and depth to other high-end 3D software such as Softimage|XSI, Cinema 4D, 3ds Max and Lightwave. These features include advanced simulation tools such as rigid body, fluid, cloth and softbody dynamics, and modifier based modelling tools, powerful character animation tools, a node based material and compositing system. Maya is preferred because of its robust nature. After thoroughly analyzing the animation software i.e. Maya we have divided the entire procedure in sections:

Modelling: In this module we designed the robot using modelling 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 Robot movements and spraying actions using Maya. The Maya functions used were Particle system, Armature, IPO Curves, Timeline.

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 colour and textures. Materials provide realism with added effects. We can control glossiness, 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.

Lighting: Lighting provides the realism to your scene through reflections and shadows. We can control the type of light, intensity and colour. Some lights can give a “fog” or “dusty” look with a halo or volume lighting effect.

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.

7. IMPLEMENTATION OF THE ROBOT

The first step is to design the base for the robot. The base is made up by different meshes, they were merged into a single mesh. The next step in the modelling 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 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 suit. 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.

8. ANIMATION OF THE DESIGN

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

Key frames Complete positions are saved for units of (frames). An animation is created by interpolating an object fluidly through the frames. The advantage of this method is that it allows working 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. Maya uses Armatures for character animation. Rendering is the final process of CG and is the phase in which the image corresponding to 3D scene is finally created. In rendering an AVI video file of the entire coating operation is created.

9. CONCLUSION

The aim of this work is to simulate the powder coating operation making use of Kawasaki KF 121 robot in Autodesk Maya animating software. This software is use for animation because it is closed to the reality and scenes can be saved in a variety of formats. Scene elements are node-based, each node having its own attributes and customization. As a result, the visual representation of a scene is based entirely on a network of interconnecting nodes, depending on each other information. For the convenience of viewing these networks, there is a dependency and a directed acyclic graph.

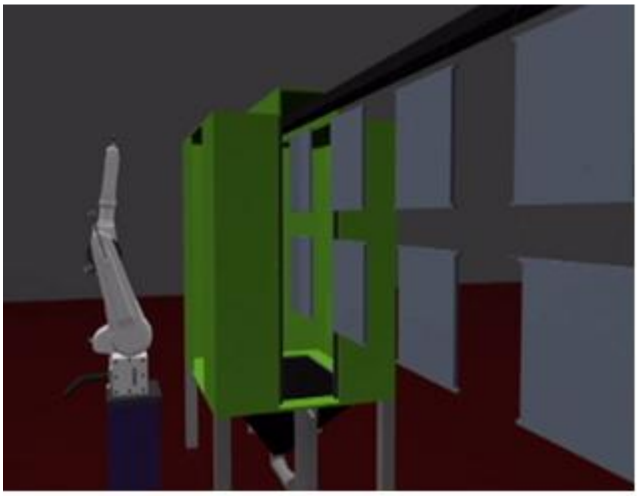

Figure 3. Final output

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