I J C T A, 9(13) 2016, pp. 5863-5866

Modeling, Analysis and Design of a 2 DOF Drawing Robot

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ABSTRACT

The advancements of robotics has resulted in improved efficiency and increased speed of operation. But in the field of arts, where a manual reproduction gives a detailed output, the speed of reproduction of an art is much lower. This paper presents the design and fabrication of a 2 DOF drawing robot. Canny edge detection method is used to detect the edges of an already existing image.

1. INTRODUCTION

This paper presents the design and fabrication of a robot arm which can draw any given image by using canny edge detection. The edges of the given image are identified which are then drawn by the robot. This makes the robot behavior more human-like and entertaining.

A robotic arm is a mechanical arm which has similar functionalities like human arm and is programmable. It consists of series of connected links of either revolute joints or prismatic joints which form a kinematic chain. The end of the kinematic chain, termed the end-effector, is where the tool is located and is analogous to human hand. Revolute joints allow rotational motion about an axis, while prismatic joints allow linear translation along an axis.

2. MODELING

The robot has two links and a manipulator which holds the pen. Three servo motors are used for controlling the position of the manipulator. Both the links l_1 and l_2 move in the same plane i.e. x-axis and the manipulator moves in y-axis. A rigid base is made to hold the motor and the links. Only one link has a rigid base while the other link is free end. One servo motor is placed on the rigid base, the second motor is placed between the links i.e. on the free end and the third servo motor is placed at the end of the second link l_2 for holding the pen.

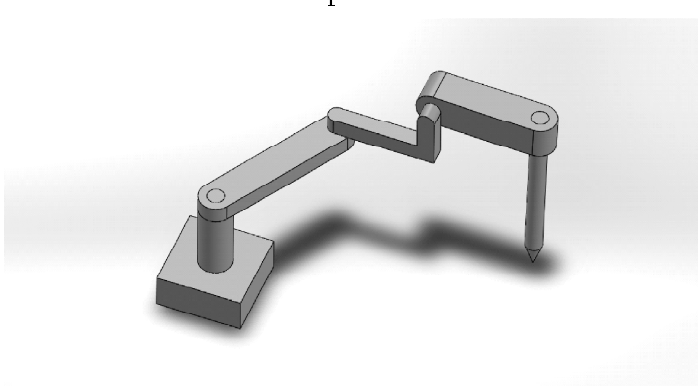

Figure 1: Model of 2DOF robotic arm

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3. ANALYSIS

The robot uses Inverse Kinematics to reach a particular point in the real world. The angles between the links with respect to the axis are calculated using cosine law.

$$a^2=b^2+c^2-2bc*\cos A \tag{1}$$

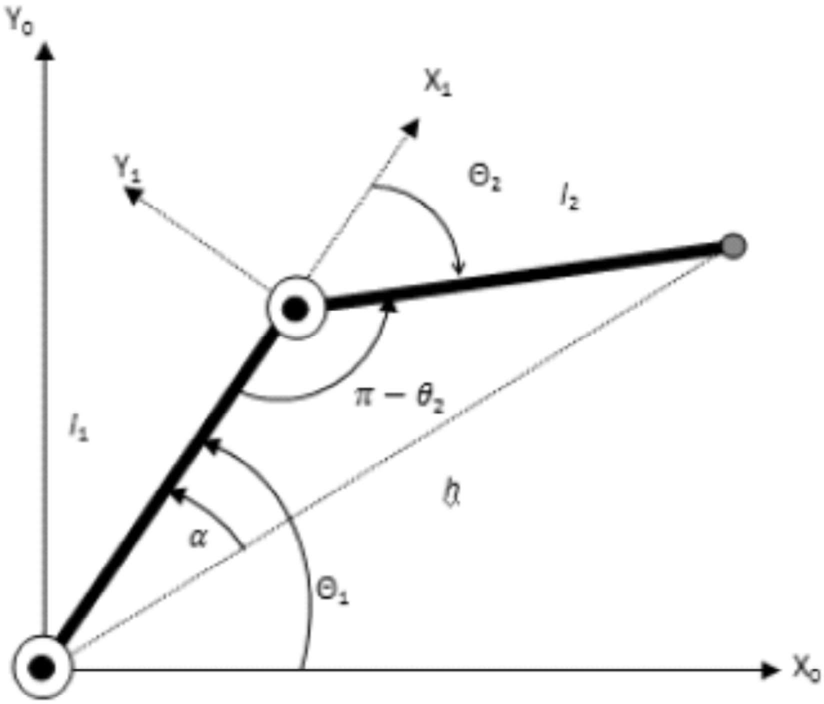

Figure 2: Analysis of 2DOF robotic arm

$$h^2 = L_2^{\,2} + L_1^{\,2} – 2L_2L_1 \cos(\pi – \theta_2) \tag{2}$$

$$\cos(\pi – \theta_2) = (x_p^{\,2} + y_p^{\,2} – L_2^{\,2} – L_1^{\,2})/(-2L_2L_1) \tag{3}$$

$$\cos(\pi – \theta_2) = (L_2^{\,2} + L_1^{\,2} – h^2)/(2L_2L_1) \tag{4}$$

$$(\pi – \theta_2) = \cos^{-1}[(L_2^{\,2} + L_1^{\,2} – h^2)/(2L_2L_1)] \tag{5}$$

$$\theta_2 = \pi – \cos^{-1}[(L_2^{\,2} + L_1^{\,2} – h^2)/(2L_2L_1)] \tag{6}$$

Substituting a for h, b for l_2, c for l_1 and A for $(\pi – \theta_2)$ and solving for θ_2 yields.

to find Θ_p, aTan of the new coordinate was calculated

$$\Theta_p = \mathrm{aTan2}\,(x_p,\ y_p) \tag{7}$$

Substituting all the relevant variables and solving for alpha yields

$$L_2^{\,2} = h_2 + L_1^{\,2} – 2h^2L_1^{\,2} \cos(\alpha) \tag{8}$$

$$\cos(\alpha) = (L_1^{\,2} + h^2 – L_2^{\,2})/(2L_1h) \tag{9}$$

$$\alpha = \cos^{-1} [(L_1^{\,2} + h^2 – L_2^{\,2})/(2L_1h)] \tag{10}$$

$$\Theta_1 = \Theta_p + \alpha \tag{11}$$

4. ALGORITHM

The design algorithm for the 2 DOF drawing robot has two major steps

(a) The image, which ones copy has to be made is processed to find its edges with the help of canny edge detection using Matlab. This involves finding the pixel which is 1 as the given image is now in the form of 0s and 1s and then its local pixels are checked. If any one of them is also 1 then the pen reaches that pixel and deletes the previous 1. The function repeats itself recursively and creates smooth lines.

(b) The inverse kinematics which enables the end-effector to reach that particular pixel. The co-ordinates of the pixel are taken from the corresponding output of the Matlab and the corresponding angles for the pivots are calculated.

The calculations are shown in the above equations.

Figure 3: left: original image, right image after edge detection

The algorithm starts checking the pixels of the converted image and when it finds 1 which is indicated as the white pixel in the image above, the pen tip reaches that point and puts the pen down then it checks neighboring 8 pixels, if it finds a 1 it reaches that point without lifting the pen up and deletes the previous pixel to avoid repetition. Now this continues till it finds no 1s in the neighborhood (this is a recursive function) hence it draws smooth lines. Then it completes other branches of lines that emerge from the drawn line as it checks every neighboring pixel. This algorithm ultimately creates the whole image.

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