ROBOTIC CURVE TRACKING AND REPRODUCTION USING MACHINE VISION

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ABSTRACT

At the present, the role of the industrial technology is growing rapidly and is continuously developed. The manufacturing process consists of several sub-processes such as design, assembly and inspection. The design process is one of the important processes. This is currently designed to apply to robot and automation systems in the industrial manufacturing. Curve tracking and reproduction using machine vision and the 2-R planar robot have been broadly used for many applications in industry. For example, in the design industry, design engineers usually use free hand drawing that may contains with unusual curves or irregular shapes, the curves are drawn from imagination. This article focuses on the machine vision that is combined with a 2-R planar robot. First, the image is captured by webcam camera. Then the coordinates (x,y) are located using MATLAB software. The curve tracking can be conducted by connecting those coordinate with 1-D spline interpolation method. Because this method is simple and easy to perform curve fitting which provides the same as the original curve. After that, the 2-R planar robot is driven to move by stepping motor that are controlled via Arduino microcontroller (Arduino Mega 2560). Reverse kinematics is performed to enhance robotic reproduction, the robot can reproduce pictures as same as the original picture. The result is impressive. Now we can find the coordinates (x,y) by transforming the analog signal into pixel. The curve then can be draw using Spline function in MATLAB software. The result found that this program is able to reproduce irregular curve very well. In the future work, the robot will be driven to draw the curve pattern.

KEYWORDS

Curve tracking and reproduction, 2-R planar robot and 1-D spline interpolation method

1. INTRODUCTION

Currently, Curve tracking and reproduction are another typical application of robots with vision systems, having a broad range of industrial applications in different fields such as metal cutting, welding, cloth cutting, band automatic inputting of prints. In those kinds of applications, the robot with a vision system tracks the curves in the prints and records their coordinates. The usage of an automatic input of prints is realized. The design process is one of important processes. The designing is designed to apply for robot, automation system in industry. It is considered as one of the most challenges task for design engineers. However, the main problem is most of design engineers often design patterns by free hand drawing which is difficult to use such patterns with robots. Sometimes the patterns are too complicated for robot to understand and work effectively. The drawing is not geometry, it often consists of irregular curve as ideal designs. Consequently, the design engineer cannot apply the CAD program to all sketching. The curve is tracked using cameras that are combined with MATLAB software to increase the efficiency of the design. This system is convenient and popular in the industry. To increase stability of robotic operation in an uncertain environment, a recent trend is to use vision information in the dynamic feedback loop. There are two working styles. The first style uses cameras mounting at the end of the robot forearm, which is referred to as an ‘‘eye-in-hand’’ structure and the second one uses static cameras. Due to different situations, the first working styles is good for tracking with a high accuracy and the second one is fast tracking, simply, easy to control and low cost. (Jing Lin,et al.,1999 and Cao, et al.,1990). Therefore, this research aims to use machine vision to generate a part of end effector of 2-R planar robot for tracking and reproducing the complex curves. This work is divided into two parts: the first part is programming. And the second part is prototyping the robot for reproduction the curve. However this paper present only the programming part.

2. EXPERIMENT

2.1 Experimental Apparatus

2.1.1 MATLAB Software

MATLAB is called Matrix Laboratory is a multi-paradigm numerical computing environment and four-generation programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with program written in other languages, including C, C++, Java, Fortran and Python

In this research, MATLAB is used to process images captured by the webcam camera. MATLAB processes the image by transformating from analog signal to pixel. Then the coordinates (x,y) are located using image processing function in MATLAB software. The coordinates are used by the robot to reproduce picture that is similar to the original picture.

2.1.2 Webcam Camera

A webcam camera is a video camera that feeds or streams its image in real time to or through a computer to computer network. When the video is captured by the computer, the video stream may be saved, viewed or sent to other networks via systems such as the internet, and email as an attachment. When it is sent to a remote location, the video stream may be saved, viewed or sent there. Unlike an IP camera (which connects using Ethernet or Wi-Fi), a webcam is generally connected by a USB cable, or similar cable, or built into computer hardware, such as laptops.

Webcam camera will capture the image that drawn by design engineer. The image is sent to process by image processing function in MATLAB software. And this research installs static cameras method to increase efficiency of image processing, and reduce tracking time.

2.1.3 Stepper motor

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied.

The advantages of stepper motor is simple and convenient for control circuit or microprocessor. In addition, the stepper motor can run with higher accuracy and higher torque compared with other motors.

2.1.4 Microcontroller

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

In this research, Arduino Mega 2560 is used as a mechanism to control the stepper motor. The advantage of this board is low cost, easy to use and there are plenty of input/output channel.

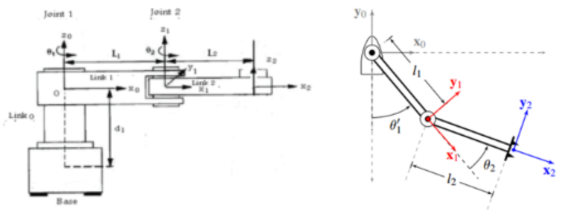
2.1.5 2-R Planar Robot

2-R Planar robot is a 2 degree-of-freedom (DOF). It has advantages in term of easy to calculate and low cost. The kinematic of 2-R Planar Robot will be described in the next section.

2.2 Technique

2.2.1 Kinematics of 2-R Planar Robot

Forward kinematics of the robot : The two degree of freedom planar redundant manipulator is implemented as shown in Figure 1. The joints axes are assigned based on the Denavit-Hartenberg representation (Table 1). The Manipulator moves on a vertical plane, the gravity force is also considered in the numerical simulation.



(a) (b)

Figure 1. The two-joint 2-R robot

Table 1. D-H Parameter of the 2-R robot

Link	a_i	α_i	d_i	θ_i
1	l_1	0	0	θ_1
2	l_2	0	0	θ_2

The (4x4) rigid transformation matrix of the first link is expressed as follows

$$T_1^0 = \begin{bmatrix} c_1 & -s_1 & 0 & l_1c_1 \\ s_1 & c_1 & 0 & l_1s_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

While the matrix of the second link is given by

$$T_2^1 = \begin{bmatrix} c_2 & -s_2 & 0 & l_2c_2 \\ s_2 & c_2 & 0 & l_2s_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

Then we can get the over all manipulator transformation matrix as

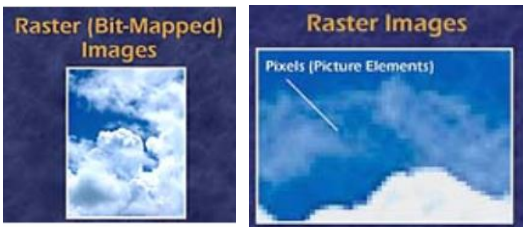
$$T_2^0 = \begin{bmatrix} c_{12} & -s_{12} & 0 & l_1c_1 + l_2c_{12} \\ s_{12} & c_{12} & 0 & l_1s_1 + l_2s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

(Mahmoud Gouasmi, et al., 2012).

2.2.2 The Digital Image

Raster graphic is one type of digital image. Raster graphic consists of with irregular shape also called Bit-mapped which convert from analog devices, such as a scanner or a digital camera.

Figure 3. shows the magnification image of the cloud. The Figure 4 is magnified until the small square is found as shown in Figure 4. Each square called "pixels" (picture element).



(a) (b)

Figure 3. The digital image or Raster graphic

Each pixel has its own numbered address with different colours as shown in Figure 4.

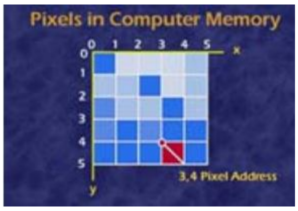


Figure 4. Pixels in Computer Memory

2.2.3 1-D Cubic Spline Interpolation

The cubic spline is used for a piecewise cubic interpolating function. The term "spline" refers to an instrument used in drafting. It is a thin, flexible wooden or plastic tool that is passed through given data points and defines a smooth curve in between. The physical spline minimizes potential energy subjected to the interpolation constraints. The corresponding mathematical spline must have a continuous second derivative and satisfy the same interpolation constraints. The breakpoints of a spline are also referred to as its knots. (x. C. De Boor., 1978).

The world of splines extends far beyond the basic one-dimensional, cubic, interpolatory spline we are describing here. There are multidimensional, high-order, variable knots for spline approximation. The spline interpolation can be performed using the Spline Toolbox for MATLAB

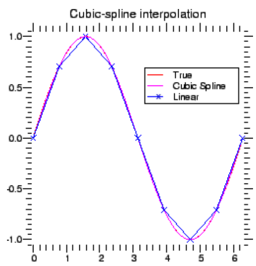
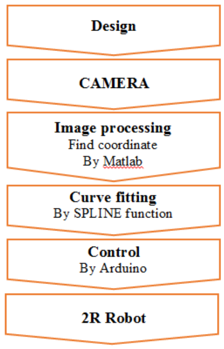


Figure 5. Compare linear and cubic Spline

3. STEP OF ANALYSIS

Procedure of this research has 6 steps

Table 2. Procedure of this research



3.2.1 Step 1 : Design engineer draw the picture, the curve or irregular curve to the paper by pen.

3.2.2 Step 2 : The picture is captured by webcam camera.

Figure 6. Prototyping picture

3.2.3 Step 3 : The coordinates (x,y) are found using MATLAB software.

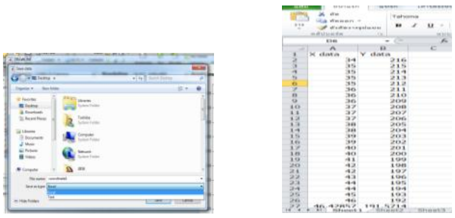


Figure 7. Coordinate (x,y) of picture

3.2.4 Step 4 : The curve tracking can be conducted by connecting those coordinate with 1-D spline interpolation method.

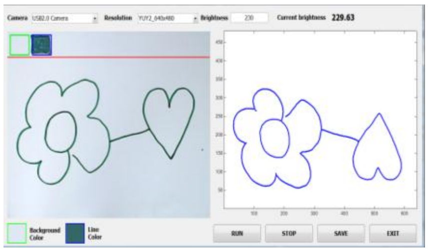


Figure 8. Plot Spline by MATLAB Software

3.2.5 Step 5 : From equation (3), over all manipulator transformation matrix is.

$$T_2^0 = \begin{bmatrix} c_{12} & -s_{12} & 0 & l_1c_1 + l_2c_{12} \\ s_{12} & c_{12} & 0 & l_1s_1 + l_2s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

this research can determine the workspace of robot that shown in Figure 9. The red line is link1 (l_1) with the length of 15 cm., it can move $0° - 180°$. And the blue line is link2 (l_2) with the length of 10 cm., it can move $0° - 360°$.

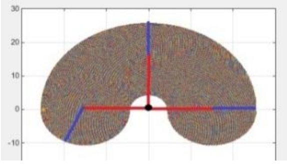


Figure 9. Workspace of robot

The 2-R planar robot is driven to move by stepping motor that are controlled via Arduino microcontroller (Arduino Mega 2560).

3.2.6 Step 6 : Reverse kinematics is performed to enhance robotic reproduction, the robot can reproduce pictures as same as the original picture.

4. CONCLUSION

This article describes irregular curve tracking using Spline function in MATLAB software. The result found that this program is able to reproduce irregular curve very well. The result indicates that integrated system is static camera, find coordinate by image processing and curve fitting by spline interpolation can be possibly used for reproduce irregular curve efficiently.

In second part (step 5 and 6) is the prototyping of the 2R Planar robot for reproducing the curve, The author and team will conduct it as the future work. Which we expected reverse kinematics is performed to enhance robotic reproduction, the robot can reproduce pictures as same as the original picture.

5. REFERENCES

1. Jing Lin, Hui-Tang Chen, Ping Jiang, Yue-Juan Wang, Curve Tracking and Reproduction by a Robot with a Vision System, Journal of Robotic Ststems, 1999. 16(10): p. 547-556
2. B.L. Cao, X. Wang, and H.T. Chen, A real-time visual servoing control scheme for robot manipulator. Proc Int Conf Automat Robotics Computer Vision, 1990. pp. 936-939.
3. Mahmoud Gouasmi, Mohamme Ouali, Brahim Fernini, M'hamed Meghatria, Kinematic Modelling and Simulation of a 2-R Robot Using Solidworks and Verification by MATLAB/Simulink, International Journal of Advanced Robotic Systems, 2012. Vol. 9: p. 245
4. x. C. De Boor, A practical Guide to Splines, Springer-Verlag, New York, 1978

6. NOMENCLATURE

C_i	:	$\text{Cos}(\theta_i)$
S_i	:	$\text{Sin}(\theta_i)$
C_{ij}	:	$\text{Cos}(\theta_i + \theta_j)$
l	:	Length of each link [cm]

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