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Position Control for a Cable-Driven Planar Robot by using an Aruco Marker Vision

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Abstract: The paper presents the preliminary of a mechatronic system composed by a cable-driven robot and Aruco marker based vision system to be used for upper limb rehabilitation. The proposed system aims to provide repetitive movements for a patient suffered by after-effects of stroke in normal activity and rehabilitation in lifetime. The system is based on the Cable-Driven Planar Robot (CDPR) with vision system where a caregiver controller is set as a master and the Cable-Driven Planar Robot's end-effector works as a slave to help patient's upper arm movement. The end-effector of cable robot can be fixed to the paralyzed hand of the individual. In addition, a vision image processing by OpenCV and Aruco marker is utilized to acquire the target image and the arm pose estimation. The proposed cable-driven planar robot can be control easily and has a feedback control to improve the patient rehabilitation motion via the image processing. The experimental results show the feasibility of the system and the further applicability in real rehabilitation.
Keywords: Cable-driven planar robot, Open CV, Aruco marker, Feedback position control

1. INTRODUCTION

Stroke is the world's leading cause of disability. And it is an especially serious problem in Asia which hold 60% of the world's population [1, 2]. The survivor of Stroke may leave sequelae such as cognitive, behavior, emotion uncontrollable and language deficits. Brain injury most likely cause hemiplegia especially paralysis of the upper limb.

Several robots have been applied to rehabilitation and assistive tasks. The end-effector of Cable-Driven Planar Robot (CDPR) became a possibility of rehabilitation device. The paper inspires by the Mirror Therapy (MT) that induces a visual illusion that appears to mimic of movement of the paretic part in which the perception, more than being a simple feedback mechanism, enhance motor recovery of the impaired part [3]. The proposed robot system aims to easy supporting for rehabilitation by a caregiver. The caregiver controls a master CDPR's end-effector with an Aruco marker which can be detected by Open CV vision system [4, 5]. And then it gives commands to the slave CDPR for rehabilitation motion to the upper limb.

2. THE DESIGN OF CABLE-DRIVEN PLANAR ROBOT

The system is designed to detect Aruco marker for the end-effector pose estimation of the master CDPR and utilize planar position values. The estimated values, as desired position values, are used to input to the slave CDPR. The schematics of the planar robot and data communication are depicted in Fig.1 and Fig. 2. Where a low-pass filter is utilized to reduce the noise caused by image processing. The program output data and command the CDPR to move to target position by ADS.

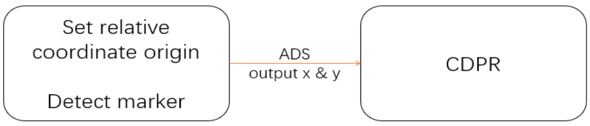

Fig.1Marker detected and send data by ADS to CDPR

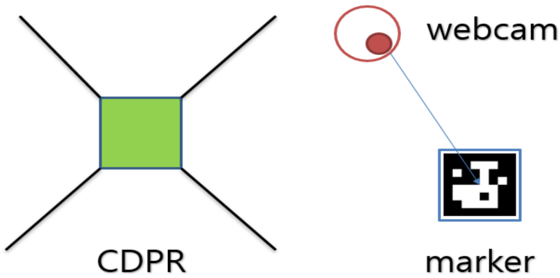

Fig.2CDPR and Master control model with Aruco marker.

In actual After CDPR receive the output x, y coordinate, calculate the cable length by using inverse kinematics as follows:

$$l_i = a_i - r - Rb_i \tag{1}$$

where

$$r = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } R = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix} \tag{2}$$

by above system and solution of cable length, when marker block moving, the CDPR will move follow marker moving.

3. EXPERIMENTAL RESULTS

3.1 Experimental setup

The actual CDPR and marker block (Fig.3) set in the same flat. The block under marker can move by controller. NDI sensor set on marker block and CDPR's end-effector to check the accuracy between marker moving and CDPR moving. Set NDI capture frame speed. Test result is coordinate relative to the initial point, so set NDI sensor axis. by NDI 6D architect Before experiment, ensure uniform illumination in the experimental environment for detecting marker correct and output smooth.

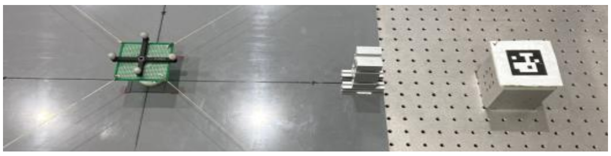

Fig.3 CDPR and Marker block

Among them, when marker detected, set 4 marker corners location as the image 2D point using Perspective-n-Point(PNP) algorithm built in OpenCV to compute object(marker). Before detection, due to the physical distortion of the camera, the camera has to calibration using calibration chessboard.

3.2 Experimental results

Move the marker block and check NDI data, actual data have about 40 fps(0.66s) delay. Cut the delay and detected data shown as Fig. 4. The error of result is shown as Table.1

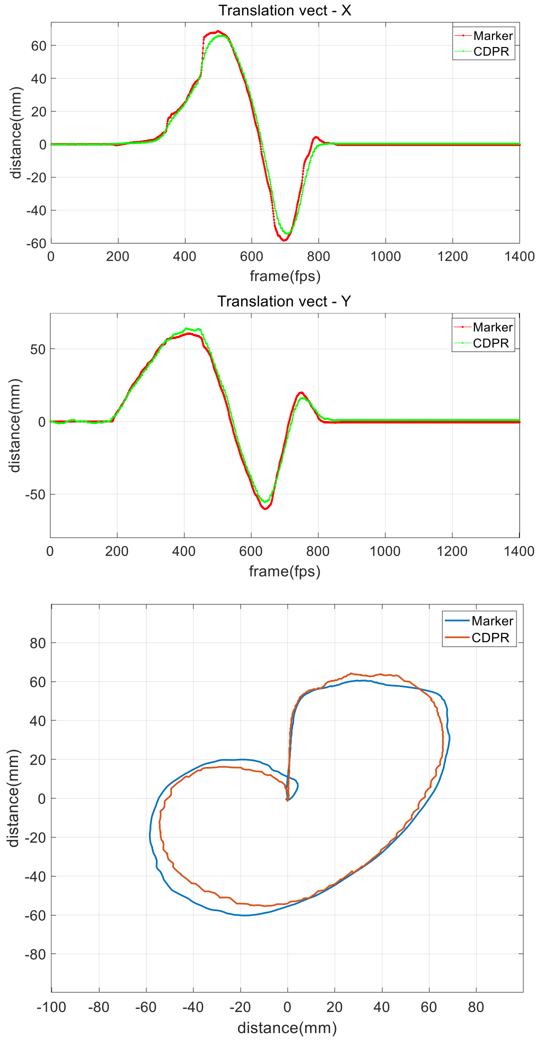

Fig. 4. After cut delay result in X, Y direction and actual moving trajectory in XY plane.

Table 1. The error of CDPR in X and Y direction

unit (mm)	Min error	Max error	Ave error
X direction	5.88^e-04	12.5412	1.5526
Y direction	0.0018	7.6223	1.8847

In actual experiment, the issue that influence the accuracy is when CDPR tracking the marker block, the cables of CDPR became loose. This may end the tracking before end-effector arrive correct position. May set a load sensor can keep cables in tension state and move response faster. Focus on the data that marker detected in x direction, in 400-600fps period, the rate of position changing suddenly increases. There are several reasons could cause this phenomenon. In actual test, unbalanced lighting caused marker detection failure when using almost uniform speed to move. Confirm what causes it happened several times, the lack of one side light lead the marker have reflection and when it moves to specific point , the reflection is too heavy to detect.

5. CONCLUSION

In this paper, we presented the mechatronic design model and rehabilitation system based on CDPR with OpenCV vision system. Test set NDI detect speed 60fps/sec as default. Set detected marker data as reference, detected data of CDPR error is shown on table. Due to experimental condition, basically, the result shows the tracking is accurate, in actual run, the program does not use any about Artificial Intelligence or machine learning library, so if it uses better algorithm, the output may faster and more accurate. Also, the CDPR have possibility of progress if it adds sensor like load sensor, CDPR can move more accurate and smoother by position control, PID controller etc. The test shows caregiver could help patient do rehabilitation.

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