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A shape constraint based visual positioning method for a humanoid robot

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SUMMARY

This paper proposes a new visual positioning method for a humanoid robot to approach and grasp a valve based on colour and shape constraints. The robot has two cameras in its head and uses constraints of colour rectangle marks to determine the valve's position and pose. When the hands are near the valve, an image-based visual servoing method is employed to catch the handle of the valve via cameras in end-effectors. Experimental results are presented to verify the effectiveness of the proposed method.

KEYWORDS: Visual positioning; Visual control; Hand-eye system; Autonomous manipulation; Mobile manipulator.

I. INTRODUCTION

Visual control is widely used in applications such as hand-eye systems of robots. Hand-eye systems include two types: one is an eye-in-hand system (EIHS) which has cameras installed on and moved with hands, and the other is an eye-to-hand system (ETHS).[1] For EIHS, the absolute measurement error in position-based visual control is reduced while a manipulator is close to a target.[2–6] In contrast, ETHS can make the end-effector reach the target accurately.[7,8] The advantages of both eye-to-hand and eye-in-hand systems are fully exploited in the development of a new positioning method.

II. THE VISUAL POSITIONING METHODS FOR A HUMANOID ROBOT

A humanoid robot consists of a head, a body (with two manipulators as arms) and a wheeled mobile base. Each manipulator has a gripper/end-effector as its hand, and its wrist is equipped with a mini camera and force sensors. The robot head is installed on top of the body, and has two cameras as eyes. Once the robot finds the valve, it moves towards it and operates it using its hands, as shown in Fig. 1.

In the process of finding and operating the valve, the robot firstly uses stereo vision to estimate the rough position of the valve relative to its own position in order to approach the valve. At this stage, the centre of the image area of the red colour marker is selected as the feature point. When the distance between the valve and the robot is less than two meters, the first stage of the positioning method is ended and the second stage begins. The position and pose of the valve are measured, in the robot frame, based on the parallel constraint of the rectangle mark. During the second stage, the mobile base is static and the valve is at a range reachable by the manipulators. The position and pose of the valve, calculated at the end of the second stage, is used for the movement control of manipulators in the third stage of the positioning method. The given pose of the end-effector of the manipulator is calculated, and is kept for later stages. Based on kinematics and inverse kinematics, the end-effector is controlled to move to the handle. At the same time, the camera in the hand operates to measure the image area size of the handle marker in green colour. If the marker size is large enough or a given position is reached, the process changes to the fourth stage. In the fourth stage, an image-based visual servoing method is applied to guide the end-effector to reach and catch the handle.

An experiment was designed to verify the proposed method based on the parallel constraint. The robot head was installed on the end of an industrial robot as shown in Fig. 2(a). The target was laid on the ground under the head. Images captured are as shown in Fig. 2(b). The results are given in Table I.

In a series of experiments, the humanoid robot was able to autonomously find, reach and operate the valve successfully. Fig. 3 provides a pair of images, showing one end-effector, captured at the end of the third stage. It can be seen that the end-effector is at the place near to the handle with an adequate pose.

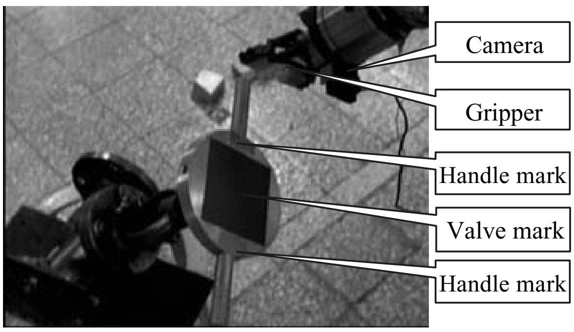

Fig. 1. Valve with a rectangle mark.

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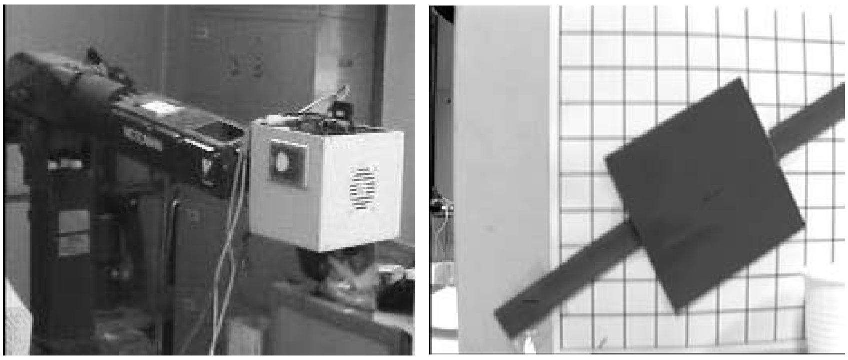
Table I. Experimental results of shape constraint based visual positioning method.

Times	T_{ei} (robot end-effector)	T_{ci} (visual measurement)	T_{wi} (target in the world frame)
1	$\begin{bmatrix} 0.0162 & -0.1186 & 0.9928 & 1100.3 \\ 0.9269 & -0.3706 & -0.0594 & -275.3 \\ 0.3749 & 0.9212 & 0.1040 & 357.7 \end{bmatrix}$	$\begin{bmatrix} 0.9989 & 0.0195 & -0.0418 & 2.0 \\ -0.0362 & 0.8924 & -0.4497 & -9.0 \\ 0.0286 & 0.4508 & 0.8922 & 320.4 \end{bmatrix}$	$\begin{bmatrix} 0.9951 & -0.0827 & 0.0542 & 1142.1 \\ -0.0838 & -0.9963 & 0.0183 & -326.2 \\ 0.0524 & -0.0228 & -0.9984 & -6.9 \end{bmatrix}$
2	$\begin{bmatrix} -0.0530 & 0.1812 & 0.9820 & 1185.6 \\ 0.9200 & -0.3735 & 0.1186 & -282.7 \\ 0.3883 & 0.9097 & -0.1469 & 352.4 \end{bmatrix}$	$\begin{bmatrix} 0.9675 & -0.1499 & 0.2037 & -1.0 \\ 0.2261 & 0.8738 & -0.4306 & -10.1 \\ -0.1134 & 0.4627 & 0.8792 & 313.2 \end{bmatrix}$	$\begin{bmatrix} 0.9957 & -0.0811 & 0.0455 & 1141.2 \\ -0.0822 & -0.9964 & 0.0212 & -326.2 \\ 0.0436 & -0.0248 & -0.9987 & -6.2 \end{bmatrix}$
3	$\begin{bmatrix} 0.1149 & 0.2805 & 0.9530 & 1250.1 \\ 0.7659 & -0.6359 & 0.0948 & -394\ 9 \\ 0.6326 & 0.7190 & -0.2879 & 348.0 \end{bmatrix}$	$\begin{bmatrix} 0.9304 & -0.1362 & 0.3404 & 0.3 \\ 0.1848 & 0.9761 & -0.1144 & -12.6 \\ -0.3167 & 0.1694 & 0.9333 & 324.3 \end{bmatrix}$	$\begin{bmatrix} 0.9958 & -0.0860 & 0.0313 & 1141.9 \\ -0.0860 & -0.9963 & -0.0007 & -326.9 \\ 0.0313 & -0.0021 & -0.9995 & -4.8 \end{bmatrix}$
4	$\begin{bmatrix} -0.1446 & -0.0269 & 0.9891 & 1098.3 \\ 0.4550 & -0.8895 & 0.0423 & -531.1 \\ 0.8787 & 0.4562 & 0.1409 & 294.5 \end{bmatrix}$	$\begin{bmatrix} 0.9903 & -0.1097 & -0.0852 & 3.8 \\ 0.1290 & 0.9538 & 0.2712 & -11.0 \\ 0.0516 & -0.2796 & 0.9587 & 311.9 \end{bmatrix}$	$\begin{bmatrix} 0.9952 & -0.0964 & 0.0195 & 1140.8 \\ -0.0961 & -0.9952 & -0.0140 & -328.1 \\ 0.0207 & 0.0121 & -0.9997 & -3.6 \end{bmatrix}$
5	$\begin{bmatrix} 0.1183 & 0.1075 & 0.9871 & 1198.4 \\ 0.3576 & -0.9320 & 0.0587 & -583.9 \\ 0.9263 & 0.3461 & -0.1488 & 294.5 \end{bmatrix}$	$\begin{bmatrix} 0.9717 & -0.1208 & 0.2030 & -0.3 \\ 0.0462 & 0.9400 & 0.3380 & -22.5 \\ -0.2317 & -0.3191 & 0.9190 & 343.2 \end{bmatrix}$	$\begin{bmatrix} 0.9957 & -0.0916 & 0.0146 & 1142.6 \\ -0.0919 & -0.9955 & 0.0230 & -328.3 \\ 0.0125 & -0.0242 & -0.9996 & -3.1 \end{bmatrix}$
6	$\begin{bmatrix} 0.1555 & -0.0686 & 0.9855 & 1142.4 \\ 0.9485 & -0.2683 & -0.1683 & -241.5 \\ 0.2760 & 0.9609 & 0.0233 & 352.5 \end{bmatrix}$	$\begin{bmatrix} 0.9910 & 0.1292 & 0.0363 & 1.7 \\ -0.0891 & 0.8357 & -0.5420 & -11.2 \\ -0.1004 & 0.5338 & 0.8396 & 318.3 \end{bmatrix}$	$\begin{bmatrix} 0.9948 & -0.0847 & 0.0571 & 1142.9 \\ -0.0853 & -0.9963 & 0.0079 & -327.0 \\ 0.0563 & -0.0127 & -0.9983 & -6.7 \end{bmatrix}$



(a) (b)

Fig. 2. The experimental scene and target image (a) The experiment scene, (b) Target image.

(a) (b)

Fig. 3. Images captured by the cameras on the robot head at the end of the third stage (a) The left image, (b) The right image.

III. CONCLUSION

The position and pose of the valve, calculated using the proposed shape constraint method, are accurate enough to guide manipulators in order to operate the valve. The advantages of using both eye-to-hand and eye-in-hand systems are obvious. The reliability and robustness of the system were significantly improved. The methods can be widely applied in humanoid robots and mobile manipulators etc.

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