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AUTOMATIC DETECTION OF ROBOTS' MANIPULATOR END-EFFECTOR POSITION USING SIFT ALGORITHM

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Abstract: *Paper treats the problem of automatic recognition of robots' manipulator end-effector position using SIFT algorithm. To achieve complete automation in process of marker recognition it is proposed to set marker on the end-effector. Comparing different marker patterns it was shown that automatic detection reliability of proposed marker is the highest.*

Key words: *robot calibration, computer vision, SIFT, object recognition, stereo matching, feature descriptors*

1. INTRODUCTION

A high level of positioning accuracy is an essential requirement in a wide range of industrial robots applications. This accuracy is affected by geometric factors (geometrical parameters accuracy) and non-geometric factors (gear backlashes, encoder resolution, flexibility of links, thermal effects, etc.). Robot calibration is a process, which can improve robot positioning accuracy. Until the end of twentieth century algorithms for manipulator calibration using open kinematic chain were developed. However, the main constraint in practical implementation of these algorithms was request for accurate measurement of manipulator end-effector. Keeping in mind that the cameras are normally installed outside of the robot workspace, calibration procedure can be done using fixed stereo system. There is request for automatic manipulator calibration without operators' intervention and without additional equipment.

Measurement of robot manipulator end-effector pose (i.e., position and orientation) in the reference coordinate system is unquestionably the most critical step towards a successful open-loop robot calibration. Main step is to use visual system for precise detection of manipulator's end-effector. Thus, it is recommended to set marker on the end-effector of the manipulator. The first step in the automatic calibration of manipulator is 2D marker recognition at any point of robot workspace.

3D position of a marker (end-effector) is determined based on pairs of images from stereo camera system (Sebe & Lew 2003). Any point of the marker can be assumed as referent point of end-effector of the manipulator. For this reason, hereinafter a term „marker" is considered as a whole, rather than a one specified point. In this case, the main problem is automatic detection of corresponding points. The corresponding points are represented by a set of marker points on both images (Maric & Djalic, 2011).

In this paper, SIFT algorithm is proposed for resolving automatic detection problem. In addition, marker pattern is proposed in order to increase reliability of markers' detection.

2. SIFT ALGORITHM

Automatic recognition of marker on image of robot is general problem of object recognition. Object recognition in cluttered real-world scenes requires local image features that are unaffected by nearby clutter or partial occlusion. The features must be at least partially invariant to illumination, 3D projective transforms, and common object variations. However, the features must also be sufficiently distinctive to identify specific objects among many alternatives. The difficulty of the object recognition problem is due in large part to the lack of success in finding such image features. However, recent research on the use of dense local features has shown that efficient recognition can often be achieved by using local image descriptors sampled at a large number of repeatable locations (Matthew & Lowe, 2002).

SIFT (Lowe, 2004) is an algorithm used for detection and description of local image features in the area of computer vision. This algorithm extracts points of interest of desired object for any type of object on the image, which correspond to the centre of characteristic features. Using results of the algorithm, the object can be located on image with plenty of other objects, and is also suitable for matching of correspondent points which can be useful for 3D scene reconstruction. Primary goal of the SIFT algorithm is identification of image feature locations on image scale space, invariant compared to: size of the object, translation, rotation, obstruction, variations of illumination, 3D object projective transformation and deformation. Object models are presented as 2D locations of SIFT features that are invariant to affine transformations.

SIFT algorithm is very robust and it became industrial standard in area of computer vision thanks to its invariance on early mentioned effects. Bearing in mind its good features, SIFT was used for marker detection on manipulator's workspace image.

3. MARKER DETECTION

On the basis of marker pattern SIFT detects several characteristic points on image of robot, which are in the area of marker. As it mentioned, it is recommended to set marker on the end-effector of the robot's manipulator. Markers used for experiments are shown on Fig. 1. Recommended planar marker (black - white) (shown on Fig. 1. - (1)), meets several assumptions: (a) it is very easy to create and set on manipulator's end-effector, (b) it is suitable for automatic recognition and (c) characteristic point in the center of marker is defined very precisely.

Bearing in mind that the SIFT algorithm uses two input images, experiments have been done for each marker independently, so one input image was image of marker and the other was referent image of robots' manipulator which is being searched using SIFT. Tests were conducted on standard Robix robot. Fixed stereo camera system was used for image recording. Cameras are off-the-shelf Logitech C120 (Kosic, et al., 2010). For purpose of this paper only one camera was used. All markers are taken from the same image (image taken on 10cm distance) of robots' manipulator. To increase realability for marker detection the other markers, of same dimensions as test marker, are taken from image of robots' manipulator.

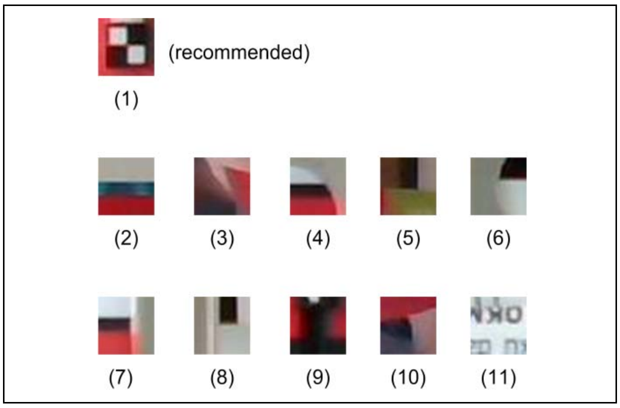

Fig. 1. Training images of marker

Table 1. shows result of marker recognition with different plain texture using SIFT algorithm. It is obviously that recommended marker gave the best result. As mentioned, markers are taken from image on 10cm distance and in corresponding column of Table 1. proposed marker has 6 matches which is the best result. Also, Marker11 has 3 matches, Marker4 and Marker7 have 2 matches and Marker5 has 1 match, but it is not enough number of matching for marker detection using SIFT algorithm. The other markers do not have matches.

Given SIFT's ability to find distinctive keypoints that are invariant to changes in scale, additionally tests were done. To highlight advantages of this type of marker tests were done for different distances between robot's end-effector and stereo system for all markers. As mentioned earlier, stereo system is fixed and robot's end-effector was set on distances of 1cm, 5cm, 10cm and 15cm from the stereo system. Simulations results are shown in Table 1. One can see that recommended marker gave the best results.

The outcome of marker detection using SIFT algorithm is illustrated on Fig. 2. On the same figure detected characteristic points and result of their matching are also shown. For correct matching it is necessary that at least 3 or more characteristic features agree on an object (Lowe, 2004). Conclusions derived from the properties of SIFT algorithm are confirmed by experiments (also illustrated on Fig. 2). On the basis of marker pattern SIFT detects several characteristic points on image of robot, which are in the area of marker. Invariance of SIFT algorithm on mentioned inconsistencies with the marker is confirmed.

From this standpoint it can be argued that SIFT algorithm gives a satisfactory detection reliability of requested object area. On the other hand, plain texture of marker (i.e. insufficiently density of local features) makes correspondence of points from a training image and image that is being searched not sufficiently accurate (Mikolajczyk & Schmid, 2004).

Fig. 2. Characteristic points on the images and their matching as a result of the SIFT algorithm

	Number of matches on specified distance			
	1cm	5cm	10cm	15cm
Marker1	6	4	6	6
Marker2	1	0	0	0
Marker3	0	0	0	0
Marker4	1	2	2	1
Marker5	0	0	1	0
Marker6	0	0	0	0
Marker7	0	1	2	1
Marker8	0	0	0	0
Marker9	0	0	0	0
Marker10	0	0	0	0
Marker11	0	1	3	1

Tab. 1. Marker detection using SIFT algorithm

Area which contains the marker is reliably detected on image which is being searched using SIFT. Some corresponding points on the image that is being searched fall outside of marker area. SIFT algorithm cannot be used for accurately determination of reference point which is in the center of window. It is necessary to use another method to determine marker borders and reference point in the center of window. Marker design is very important step in marker detection problem using SIFT algorithm. Comparing different marker patterns it was shown that proposed marker is very simple to implement and reliability of his automatic detection is the highest.

4. CONCLUSION

In order to increase the reliability of the characteristic points determination it is proposed to set the marker on end-effector of manipulator and to use SIFT algorithm for their determination. In this paper is proposed a simple marker pattern, which is very easy to create and set on manipulator's end-effector. Experimental results show that recommended marker gave the best results and it is very suitable for automatic recognition. Illustrations given in text confirm compliance of conducted analysis, expected features of the algorithm and results of experiments. Algorithm is analyzed in the laboratory, so it is necessary to do additional verification in industrial environment. Hence, it is necessary to continue with analysis of level of algorithm invariance in adverse exploitation conditions. This primarily refers to larger object density in workspace (occlusion and collision), poor lighting and extreme marker rotation.

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