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TSK 퍼지 시스템을 이용한 카메라 켈리브레이션

Camera Calibration using the TSK fuzzy system

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ABSTRACT

Camera calibration in machine vision is the process of determining the intrinsic cameara parameters and the three-dimensional (3D) position and orientation of the camera frame relative to a certain world coordinate system. On the other hand, Takagi-Sugeno-Kang (TSK) fuzzy system is a very popular fuzzy system and approximates any nonlinear function to arbitrary accuracy with only a small number of fuzzy rules.It demonstrates not only nonlinear behavior but also transparent structure. In this paper, we present a novel and simple technique for camera calibration for machine vision using TSK fuzzy model. The proposed method divides the world into some regions according to camera view and uses the clustered 3D geometric knowledge. TSK fuzzy system is employed to estimate the camera parameters by combining partial information into complete 3D information. The experiments are performed to verify the proposed camera calibration.

Key Words : Camera Calibration, TSK fuzzy model, Machine-vision

1. INTRODUCTION

In machine vision, it is important for the sensory system to passively sense the three-dimensional (3-D) structure of its surrounding environment. A common method is through disparity analysis using two images and stereo vision. However, the difficult problem in using disparity is to determine the correspondence of features between two images. Once sufficient correspondence is known, depth information of objects in the scene can be computed by measuring the spatial disparity of image features acquired by two calibrated cameras [1]. Therefore, Camera calibration is a preliminary step toward machine vision in order to extract metric information from 2D image.

To our knowledge, there does not exist any calibration technique reported in the literatures which use Takagi-Sugeno-Kang (TSK) fuzzy system and this is the topic we will investigate in this paper. TSK fuzzy system is a very popular fuzzy system and approximates any nonlinear function to arbitrary accuracy with only a small number of fuzzy rules [2]. It demonstrates not only nonlinear behavior but also transparent structure. In this paper, we present a novel and simple technique for camera calibration for machine vision using TSK fuzzy model. The proposed method divides the world into some regions according to camera view and uses the clustered 3D geometric knowledge. TSK fuzzy system is employed to estimate the camera parameters by combining partial information into complete 3D information. The rest of this paper is organized as follows. In Section 2, New camera calibration method using TSK approach is proposed, In Section 3, experimental results are given to show the performance of the proposed method. Finally, the conclusion is drawn in Section 4.

2. TSK APPROACH TO CAMERA CALIBRATION

The camera model that we consider is the perspective projection model based on the pinhole model. If M has world coordinates (X, Y, Z) and projects onto a point m that has pixel coordinates (u, v), the operation can be described, in homogeneous coordinates, by the following equation:

$$\begin{pmatrix} hm \\ h \end{pmatrix} = \begin{pmatrix} hu \\ hv \\ h \end{pmatrix} = P\begin{pmatrix} M \\ 1 \end{pmatrix} = P\begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix} = \begin{pmatrix} P_1^T & P_{14} \\ P_2^T & P_{24} \\ P_3^T & P_{34} \end{pmatrix}\begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix} \quad (1)$$

where matrix P is commonly referred to as perspective projection matrix and decomposed into two matrices: $P = AD$ where

$$D = \begin{pmatrix} R & t \\ 0_3^T & 1 \end{pmatrix} = \begin{pmatrix} \alpha_u & -\alpha_u/\tan\theta & u_0 & 0 \\ 0 & \alpha_v/\sin\theta & v_0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (2)$$

The 4x4 matrix D represents the mapping from world coordinates to camera coordinates and accounts for six extrinsic parameters of the camera: three for the rotation R which is normally specified by three rotation angles and three for the translation t, the 3x4 matrix A represents the intrinsic parameters of the camera: the scale factors α_u and α_v, the coordinates u_0 and v_0 of the principal point and the angle θ between the image axes. The benefit from this would be that the calibration accuracy will not only be increased, but this will also allow us to maintain the simple relation in (1) thus making following vision tasks easier [3].

In this paper, the proposed method divides the world into some regions according to camera view as shown in Fig. 1 and TSK fuzzy system is employed to combine the partial perspective projection matrices in clustered regions.

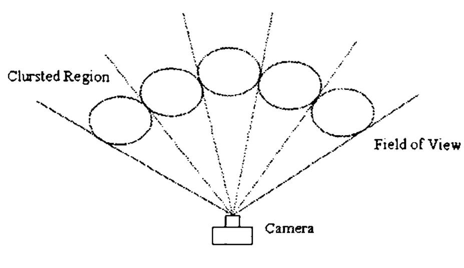

Fig. 1. The clustered regions

In our TSK fuzzy model, the complete image point, $\bar{y}$ which combines partial 3D information is computed by the weighted average of the y^l defined as follow:

$$\bar{y} = \frac{\sum_{l=1}^{M} y^l w^l}{\sum_{l=1}^{M} w^l} = \frac{\sum_{l=1}^{M} P^l x_i^l w^l}{\sum_{l=1}^{M} w^l} \quad (3)$$

where l is the numerical order of cluster regions, x_i^l is the input linguistic variables to represent the world coordinates 3D point, P^l is the lth clustered perspective projection matrix which is computed in the lth clustered region and y^l is the partial image point using P^l. The firing strength, w^l, is defined as (6) instead of training because it is explicable intuitively that firing strength is inversely proportional distance between given 3D point and the clustered regions.

$$w^l = \frac{1/\sqrt{(cc^l - x_i^l)^2}}{\sum_{i=1}^{M} 1/\sqrt{(cc^l - x_i^l)^2}} \quad (4)$$

where M is the number of the cluster regions and cc^l is the center of the lth clustered region.

3. EXPERIMENTAL RESULT

Experiments are conducted using the calibration pattern as shown in Fig. 2. The images (640 x 480) are obtained in five clustered region and consist of a box patch, with size 500mm x 500mm.

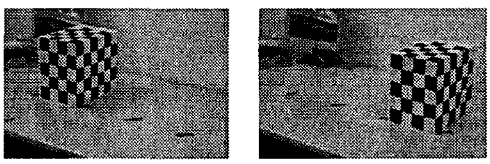

Fig. 2. The calibration pattern

Table 1 shows the perspective projection error of the proposed method. The error, root mean squared calibration error (RMSE), measures have been computed using the proposed method and by conventional direct linear transform (DLT) calibration algorithm and test point pairs are not included in calibration procedure. It can be seen from this table that proposed method is better than the conventional calibration technique.

Table 1. Perspective projection error (pixel)

Measure	*Proposed*	*Conventional*
RMSE	*3.0759*	*4.8201*

Generally, with real images, the accuracy of the calibration is measured in terms of the accuracy in reconstruction 3D points through triangulation [4]. Clearly, the measure shown in Table 2 is in favor of the proposed method.

Table 2. Calibration error in reconstruction 3D points (cm)

Measure	*Proposed*	*Conventional*
RMSE	*1.9591*	*5.3177*

4. CONCLUSION

We propose novel and simple technique for camera calibration using TSK fuzzy model and describe its efficiency. There does not exist any calibration technique reported in the literatures which use TSK fuzzy system and this is the topic we will investigate in this paper. The proposed method divides the world into some regions according to camera viewand TSK fuzzy system is employed to combine the partial perspective projection matrices in clustered regions. The experimental result shows that the efficiency of the proposed method.

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