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CAMERA CALIBRATION TECHNIQUE USING TSAI'S ALGORITHM

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Abstract

This Paper deals with camera calibration system based on Tsai's algorithm and from that calibration data we obtain the depth information of an object in stereovision system. Tsai's method for camera calibration recovers the interior orientation (*intrinsic parameters*), the exterior orientation (*extrinsic parameters*) , the power series coefficients for distortion, and an image scale factor that best fit the measured image coordinates corresponding to known target point coordinates.

For recovering the depth estimation in stereovision systems two cameras are used and should be calibrated both properly. Without information about the relative positions of the two cameras, stereovision becomes less important. The relative positions of the two cameras are necessary for rectification of the images.

Keywords: Camera Calibration, Linear and Non Linear Calibration, Tsai Algorithm, Stereovision

Introduction

Camera calibration, Depth estimation and 3D reconstruction are important terms in stereovision systems. With stereo vision, we can see *where* objects are in relation to our own bodies with much greater precision-especially when those objects are moving toward or away from us in the *depth dimension*.

Camera calibration is a preliminary step towards computational vision. It is necessary to derive metric information from the images. Good calibration is important when we need to reconstruct a world model. Generally, camera calibration means the process of computing the camera's physical parameters, like image center, focal length, position and orientation, etc.

Camera calibration can he broadly classified according to some criteria: linear and non-linear. Here, we derive a linear camera calibration technique using Tsai's algorithm [4] and give a way for non-linear camera calibration technique to acquire the depth estimation of a stereovision system. With this concern we have to calculate the projective camera matrix using some points in 3D space and its 2D perspective projection and the basis for our adjustable camera model is the 3D to 2D projection model described by Tsai method [7].

Tsai's Algorithm

The algorithm given by Tsai is a two-stage process designed to be performed without operator assistance. It calibrates the R, T, f, $k1$ and sx parameters from the camera model. The algorithm executes quickly on PC hardware due to the absence of large non-linear searches.

A calibration pattern is required by this algorithm and Tsai provides different versions for coplanar and non-coplanar calibration patterns. It is a single view algorithm; however it can be adapted to be used with multiple views of the calibration pattern.

The first stage of the process determines the extrinsic parameters *sx*, *R* and the first two components of the translation vector, *Tx* and *Ty.* The focal length *f* and the *z* component of the translation vector *Tz* are also estimated at this stage. This is achieved by solving a system of linear equations whose input is the coordinates of points in the calibration pattern, both in the image and in the real world. The various parameters are then recovered from the solution to this system.

The second stage of the process involves a steepest descent search. This is used to determine the radial distortion factor *k*1 which cannot be determined from the calibration pattern; *f* and *Tz* are also adjusted during the search [3].
R

Calibration Pattern in Tsai's Algorithm

If the uncertainty factor *sx* is unknown, it is necessary to use the version of Tsai's algorithm whose calibration pattern involves non-coplanar points. In this work a simple, two-plane pattern using a pair of wooden boards fixed at right angles to each other is used whose the corners of the black squares are detected and used as calibration points (Figure 1).

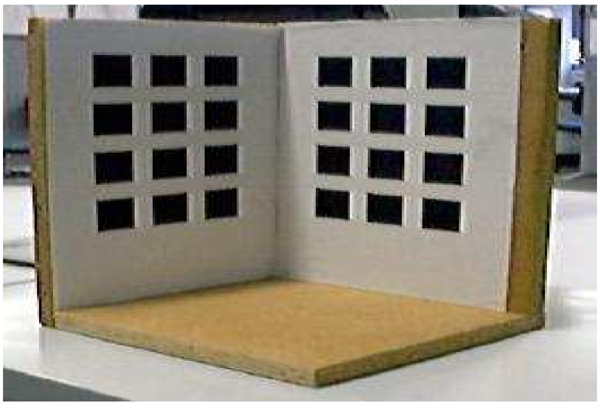

Figure 1: A 3D calibration pattern

Tsai's experiments with non-coplanar calibration patterns used an adjustable platform with accuracy measured in micrometers to take multiple images of the pattern varied over a distance of less than an inch. It is obviously much easier to build accurate calibration patterns when only a single plane is used. These cannot be used to determine the uncertainty factor in Tsai's algorithm, unless multiple images are taken and combined, using a method similar to the one used by Tsai [3].

Experimental Results and Analysis for Linear Calibration

The linear calibration gives us the six parameters of a camera namely the focal length, the coordinates of the origin of the camera co-ordinates, the rotational matrix and the translation matrix. For experimental setup we place the camera at a distance of 10 cms from one of the planes of the 3D object as show in Figure 2 and measure the six parameters.

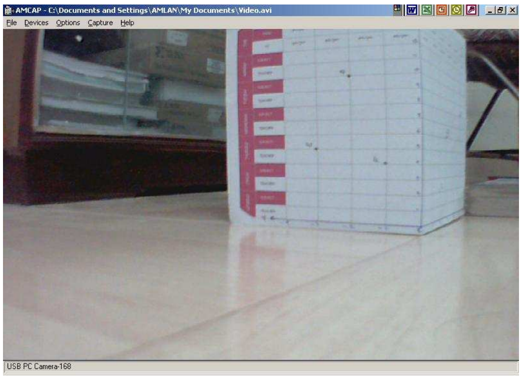

Figure 2: 3D object when the camera is placed at a distance of 10 cms

Table 1

Input Parameters w.r.t. the World	Corresponding Image Co-ordinates (in pixels,

Co-ordinate (3D)	2D)
XYZ =	xy=
5 0 8;	186.6053 683.4493
3 0 6;	220.2895 648.4263
2 0 2;	299.4474 635.5230
0 2 10;	142.8158 486.2143
0 3 5;	243.8684 451.1912
0 1 4;	259.0263 539.6705

Table 1I

fx	**fy**
372.9902	949.9898

Table 1II

O_x	O_y
285.5531	306.5470

Table 1V

R			**T**
0.1118	0.0702	0.9912	-2.5056
-0.5414	0.8408	0.0015	-6.0664
0.8333	0.5368	-0.1320	16.6439

Experimental Results and Analysis for Non-linear Calibration

The non-linear calibration is a process of using two identical cameras to set up a stereovision system that can be used to measure the *depth* of the object [5], [6], [7], [8], [9], [10]. In our approach we use a single camera placed at a distance of 10 cms from the 3D object as shown in Figure 2 and perpendicular to one of the planes that can be seen. We measure the six parameters. We then place the same camera at a distance of 20 cms such that both the initial position and the final position of the cameras are in the same plane. Using Equation we then find out the ratio of the depth measured by the initial position and the final position of the camera. Table I, II, III and IV gives us the six parameters of the camera when the camera is placed at a distance of 10 cms from the 3D object as shown in Figure 2. Figure 3, shows the same 3D object of Figure 2 when the camera is placed at a distance of 20 cms.

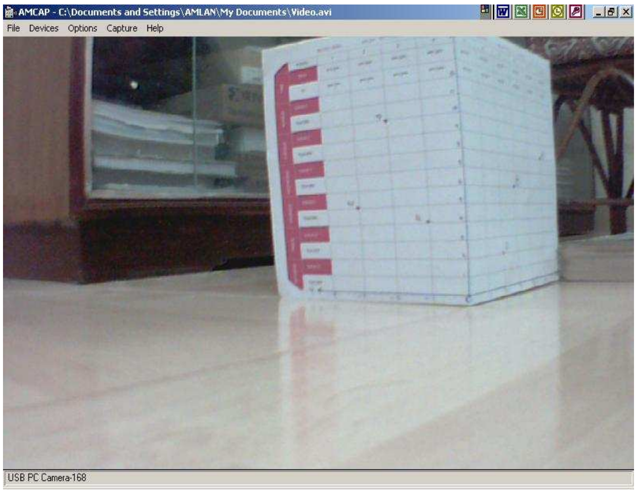

Figure 3: 3D object when the camera is placed at a distance of 20 cms

Table V, VI, VII and VIII gives us the six parameters of the camera when the camera is placed at a distance of 20 cms from the 3D object as shown in Figure 3.

Table V

Input Parameters w.r.t. the World Co-ordinate (3D)	Corresponding Image Co-ordinates (in pixels, 2D)
XYZ =	xy=
5 0 8;	179.8684 683.4493
3 0 6;	216.9211 648.4263
2 0 2;	296.0789 637.3664
0 2 10;	139.4474 486.2143
0 3 5;	243.8684 451.1912
0 1 4;	260.7105 539.6705

Table VI

fx	fy
622.5419	1101.5

Table VII

O_x	O_y
29.5734	1.6582e+003

Table VIII

R	T

-0.2922 -0.1299 0.9475	-15.2909
0.2180 0.9556	29.0456
0.1982	30.0395
0.9312 -0.2645	
0.2509	

Table IX gives the ratio of Z_r / Z_l.

Table IX

Z_r / Z_l
1.3502

Conclusion

In this paper we discuss an approach to calibrate a single camera and estimate the depth of an object in a stereo vision system. Camera calibration is done to get the intrinsic and extrinsic parameters of a camera. These parameters can further be used to acquire the knowledge of depth information of an object in stereovision system. The depth together with the orientation can be used to reconstruct the 3D image of the object in a two dimensional plane which is also called 3D reconstruction.

As our previous works give an idea of depth information of an object in stereovision system and from that depth information we can obtain the mesh concept about the object and we hope that it will help us to reconstruct a 3D object in the near future.

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