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Automatic Calibration of Computer Vision Based on RAC Calibration Algorithm

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Abstract
In order to improve the precision of automatic calibration of computer vision, RAC calibration algorithm is used to realize automatic calibration. First, some briefly introduction of calibration method should be known, then the details of Mathematical model of the RAC calibration algorithm and the calibration process will be introduced. Finally, we use the simulation example to validate the performance of this method. The results of the experiments show that this method has realized the automatic calibration of computer vision. The fit of the measured value and the actual value is high, so this method has high application value.
Key words: COMPUTER VISION AUTOMATIC CALIBRATION RAC CALIBRATION

Introduction

In applications of machine vision, the calibration of visual image is necessary. In order to get precision measurement, the distortion of lens is inevitable. and the precision must satisfied customer`s demand at the same time, so the image of what being measured must be very accurate, otherwise the result will have much error no matter how professional the software we used. Because the result is based on the image which has error [1]. High-precision of system calibration is the basis and premise for precision measuring when using machine vision system, there are two steps to improve the accuracy of measurement. The first thing is. We can use the precision positioning system which uses ultra-precision professional image calibration board to grab images in the machine vision system environment, and professional labeling algorithm to measurement and evaluation of the error. The system can show error s of any position accurately in view. and the precision of the machine vision system level can be evaluated on the basis of error data[2]. The second step is to correct the error of the image, it is the key step to tell whether the calibration algorithm has good performance. The first step can be completed for most of the calibration algorithm, but a great difference between the performances of each calibration algorithm for the second step. In some way, the best calibration algorithm has high efficiency and high accuracy.

Any machine vision system involving precision of location and size should be calibrate, but to choose appropriate calibration method according to different application areas[3]. In general, the precision of the calibration system and measuring system should be in the same order of magnitude, and the error of calibration should be less than a measurement unit. For example the demand of the precision of the measurement system is ±50 microns, so the precision of calibration system must achieve 10 microns, and the calibration system error should less than 10 microns.

In general, automatic calibration method is complexity and unstable. This paper shows how to precede the automatic calibration method of computer vision based on RAC. The experiments show that the calibration algorithm has high precision and small error.

RAC calibration

RAC calibration was put forward by Tsai. It occupies a very important position among the current calibration of computer vision for this method has low complexity, high efficiency, and high precision [4].

RAC automatic calibration model in detail will be introduced in next part of the page.

The relationship between world coordinate system and camera coordinate system:

$$\begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \approx K(R \quad t)\begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix} \tag{1}$$

K will be taken as

$$K = \begin{pmatrix} fs, & 0, & u_0 \\ 0, & f, & v_0 \\ 0, & 0, & 1 \end{pmatrix} \tag{2}$$

And then transform the world coordinate system transformation to camera coordinate system

$$(y - v_c)(1 + k_1(u^2 + v^2)) = v - v_c \tag{3}$$

$$(x - u_c)(1 + k_1(u^2 + v^2)) = u - u_c \tag{4}$$

(u, v) and (x, y) indicate coordinate values of the camera coordinate system and world coordinate system respectively. (u_c, v_c) indicates mapping fault.

$$\frac{x - u_c}{y - v_c} = \frac{u - u_c}{v - v_c} \tag{5}$$

In general, in order to simplify the calculating, the center of the images demarcated is always taken as center of error.

$$\frac{x - u_0}{y - v_0} = \frac{u - u_0}{v - v_0} \tag{6}$$

The steps to ensure coordinate

(1)Get R, t_1, t_2 and s

(2)get the effective focal length f, the displacement t_3 of coordinate axis of z and distortion k_1.

$$K = \begin{pmatrix} fs, & 0, & u_0 \\ 0, & f, & v_0 \\ 0, & 0, & 1 \end{pmatrix} \tag{7}$$

(3)Get camera external parameter of rotation matrix R and displacement of coordinate axis of x, y.

$$\begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \approx K(R \quad t)\begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix} \tag{8}$$

$$R = \begin{pmatrix} r_1 & r_2 & r_3 \\ r_4 & r_5 & r_6 \\ r_7 & r_8 & r_9 \end{pmatrix} t = \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix} \tag{9}$$

The result

$$x=\frac{fs(r_1X+r_2Y+r_3Z+t_1)}{r_7X+r_8Y+r_9Z+t_3}+u_0 \quad (10)$$

$$y=\frac{f(r_4X+r_5Y+r_6Z+t_2)}{r_7X+r_8Y+r_9Z+t_3}+v_0 \quad (11)$$

Then

$$\frac{x-u_0}{y-v_0}=\frac{u-u_0}{v-v_0} \quad (12)$$

The result

$$\frac{s(r_1X+r_2Y+r_3Z+t_1)}{r_4X+r_5Y+r_6Z+t_2}=\frac{u-u_0}{v-v_0} \quad (13)$$

Calculate through some corresponding points:

$$M_0=(m_1,m_2,m_3,m_4,m_5,m_6,m_7,m_8)$$
$$\approx(sr_1,sr_2,sr_3,sr_4,st_1,r_4,r_5,r_6,t_2) \quad (14)$$

M_0 divides $c=\sqrt{m_5^2+m_6^2+m_7^2}$ and get $(sr_1,sr_2,sr_3,sr_4,st_1,r_4,r_5,r_6,t_2)$

We can know s and t_1 through $r_1^2+r_2^2+r_3^2=1$

$$(r_7,r_8,r_9)=(r_1,r_2,r_3)\times(r_4,r_5,r_6) \quad (15)$$

$$(r_7,r_8,r_9)=(r_4,r_5,r_6)\times(r_1,r_2,r_3) \quad (16)$$

Choose (r_7,r_8,r_9) according to $\det(R)=1$

(4)Get t_3, f, k_1

K_1=0 as initial value, then:

$$x-u_0=u-u_0,\ y-v_0=v-v_0 \quad (17)$$

$$x=\frac{fs(r_1X+r_2Y+r_3Z+t_1)}{r_7X+r_8Y+r_9Z+t_3}+u_0 \quad (18)$$

$$y=\frac{f(r_4X+r_5Y+r_6Z+t_2)}{r_7X+r_8Y+r_9Z+t_3}+v_0 \quad (19)$$

According to (17),(18),(19) and R, t_1, t_2,

$$(u-u_0)(r_7X+r_8Y+r_9Z+t_3)=fs(r_1X+r_2Y+r_3Z+t_1) \quad (20)$$

$$(v-v_0)(r_7X+r_8Y+r_9Z+t_3)=f(r_4X+r_5Y+r_6Z+t_2) \quad (21)$$

f , t_3 will be known through (20),(21). Then (22),(23) will be known:

$$\frac{fs(r_1X+r_2Y+r_3Z+t_1)}{r_7X+r_8Y+r_9Z+t_3}(1+k_1(u^2+v^2))=u-u_0 \quad (22)$$

$$\frac{f(r_4X+r_5Y+r_6Z+t_2)}{r_7X+r_8Y+r_9Z+t_3}(1+k_1(u^2+v^2))=v-v_0 \quad (23)$$

Simulation example

In order to verify the performance of RAC camera calibration algorithm in the computer vision automatic calibration. We use the example of actual life to measure vertical target on the ground. We measure the distance of two points on the ground and the vertical height. Calculate the distance between points in the image using the parameters of the camera, and then transform it into actual distance. Compare the actual distance and get the error.

When estimating the actual length of the grid, the average value of some case will be better. The experiment Figure 1:

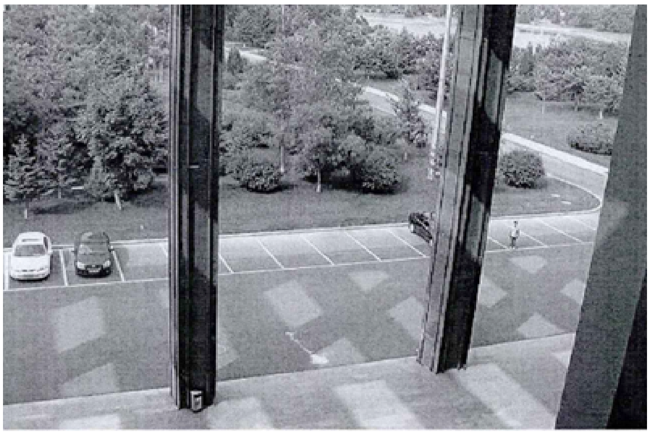

Figure 1. The experiment figure

As shown in the following table of calibration experiment the head of the human foot point coordinates and reduction of the 3 d distance from the image.

First, as a reference to vertical target coordinates objects are extracted, and the concrete as shown in table 1.

Table 1. Pictures of head foot point image coordinates

Different place	Coordinate of head/ pixel(103)	Coordinate of foot/ pixel(103)
1	（1.6190,0.7789）	（1.6061,0.8739）
2	（1.5623,0.9577）	（1.5442,1.0695）
3	（1.1780,0.9773）	（1.1651,1.0919）
4	（0.7859,0.9996）	（0.7833,1.1170）
5	（0.3784,1.1003）	（0.3861,1.2288）

Then calculate the length of the short and long frames and column in the picture, measuring a total of 6, and then use tape measure actual length, then compared with the actual length, and calculate the error, as shown in table 2, 3, 4.

Table 2. In the picture you short length

times	Effective length(cm)	Actual length(cm)	Absolute error(cm)	Relative error(%)
1	231.3438	239	-7.6562	3.2
2	235.0269	239	-3.9731	1.66
3	237.5942	239	-1.4058	0.59
4	241.2707	239	2.2707	0.95
5	231.3519	239	-7.6481	3.2
6	238.2957	239	-0.7043	0.29

Table 3. In the picture you long length

times	Effective length(cm)	Actual length(cm)	Absolute error(cm)	Relative error(%)
1	426.8301	489	-62.1699	12.71
2	421.5856	489	-67.4144	13.79
3	459.7923	489	-29.2077	5.79
4	430.1660	489	-58.8340	12.03
5	455.8640	489	-33.1360	6.78
6	445.0355	489	-43.9645	8.99

Table 4. Images of the width of the columns

times	Effective length(cm)	Actual length(cm)	Absolute error(cm)	Relative error(%)
1	111.3270	120	-8.6730	7.23
2	105.3875	120	-14.6125	12.18
3	111.3876	120	-8.6124	7.18
4	109.5504	120	-10.4496	8.71
5	114.1219	120	-5.8781	4.9
6	107.7307	120	-12.2693	10.22

In these experiments, parameters should be set up in advance and then measure the length of the object, then measure the actual length with a ruler, compare with them and get the error. In the application of the general environment, we can choose a reference which is fixed. The reference we use in this article is people. We use coordinate values of person's head and feet as coordinate reference. In order to reduce the calibration error, it`s better to get average coordinate values .

In order to analyze the error between the result we have calculated and the actual length. We use excel with statistical analysis tools, get the following data:

Table 5. Model validation regression statistics

Regressive statistics	
Multiple R	0.963802
R Square	0.928914
Adjusted R Square	0.924965
Standard error	2.243445
Observed value	6

We get the result that standard error is 2.243445 through the 6 observed value. Coefficient of determination R_2 is very close to 1. It shows the test value and the actual value is very close, and we know our camera calibration value is precision.

Conclusions

This article uses the RAC algorithm to make computer vision automatic calibration, and taking pictures for instance simulation of real life. Measure different object in the image, and then compared with the actual value, verify the algorithm performance. By this method, we can know this method is automatic calibration. Through the analysis of the goodness of fit, the error between measured value and the actual value is small. Calibration precision is high, and has certain market application prospect.

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Defects Detection Based on Deep Learning and Transfer Learning

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