Camera Calibration with Varying Parameters Based On Improved Genetic Algorithm

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Abstract: - In this paper, we propose an approach based on improved genetic algorithms for the camera calibration having the varying parameters. The present method is based on the formulation of a nonlinear cost function from the determination of the relationship between points of the image planes and all parameters of the cameras. The minimization of this function by a genetic approach enables us to simultaneously estimate the intrinsic and extrinsic parameters of different cameras. Comparing to traditional optimization methods, the camera calibration based on improved genetic algorithms can avoid being trapped in a local minimum and does not need the initial value. The proposed technique to find the near optimal solution without the need for initial estimates of the cameras parameters. Tested on several cases, the proposed method proved to be an effective tool to determine the camera parameters necessary for various applications, such as the images rectification, the analytical photogrammetry and 3D reconstruction from 2D images.

Key-words: - Camera calibration, computer vision, improved genetic algorithms, varying parameters, non-linear optimization.

1 Introduction

The camera calibration is a crucial step in the vision stereo and the 3D reconstruction [1], it consists of estimating the intrinsic and extrinsic parameters of the cameras. Different techniques of the calibration exist in [2, 3, 4 and 5] they are generally based on the pinhole model and use of images of an object reference with of known dimensions (Calibration pattern).

The mathematical optimization methods used may have some problems (stability of the method, the initial point of optimization), and this has prompted researchers to test approaches based on genetic algorithms [6, 7]. These approaches can be classified as methods of nonlinear stochastic optimization.

The optimization algorithms, and specifically those based on the evolutionary approach are widely used in the field of computer vision for various applications [8, 9, 10] their success in the field of the camera calibration and the stereoscopic vision is that they are capable to minimize the non-linear function for the calculating the cameras parameters. The minimization of nonlinear cost functions is not an easy task to achieve, as this function is not convex and contains of many the local minima complex.

The genetic algorithms have a significant contribution for the camera calibration relative to conventional methods, because they have no constraints vis-a-vis the model and can explore all the solutions of search space in order to optimize the result. Compared to conventional methods, the genetic algorithms offer the following advantages:

The importance of this type of mutation is to use a largest interval to maintain a diverse population in the first generation for performing a global search and avoid rapid convergence of the algorithm. This mutation interval gradually decreased during the iterations for to focus on local search of the solution.

3.3.3 Crossover

The crossover of our approach is the follows: Suppose v_i and v_j two potential solutions to a generation $l(i \# j)$. A generation $l+1$ two son individuals v_{1a}, v_{2a} can be generated by crossover by next formulas:

$$\begin{cases} v_{1a} = v^{+}(1-\eta) + max(v_i, v_j)\,\eta \\ v_{2a} = v^{-}(1-\eta) + min(v_i, v_j)\,\eta \end{cases} \quad (14)$$

Where $\eta \in [0\ 1]$ is a weight, $max(v_i, v_j)$ is the vector of each element obtained by taking the maximum between the corresponding elements of v_i and v_j. The same $min(v_i, v_j)$ denotes the vector obtained by taking the minimum values.

We executed the IGA under the following parameters (Table 1).

Table 1 Parameters of IGA

Population size	Crossover probability P_c	Mutation probability P_m	Number of iterations T
200	0.80	0.1	120

4 Experimental results

4.1 Synthetic data

In this section, a sequence of 512 × 512 images of a 3D grid is simulated to test the performance and robustness of the present approach. After the detection of control points by the Harris detector [24, 25], the matches between each pair of images are determined by the correlation function ZNCC [23, 24]. The 3D grid is projected in images plan taken from different views with Gaussian noise of standard deviation σ. The determination of a relationship between the points of the 3D grid and their projections in the images plan can define a non linear cost function. This cost function is minimized by our IGA, finally the intrinsic and extrinsic parameters are obtained.

The table 2 show the relative error of the focal length (for example) of the left camera used depending on Gaussian noise of our approach compared with other methods Tsai's two step calibrations technique [2] to be implemented and executed on our test images.

Table 2 the relative error (%) of the f_g according the noise

Noise (σ)	0	0,5	1	1,5	2	2,5	3
Our approche	0,01	0,07	0,09	0,098	0,13	0,16	0,23
Tsai's	0,09	0,2	0,3	0,52	0,67	0,93	1,1

The figure 3 shows the graphical representation of the relative error on the focal length of the left camera.

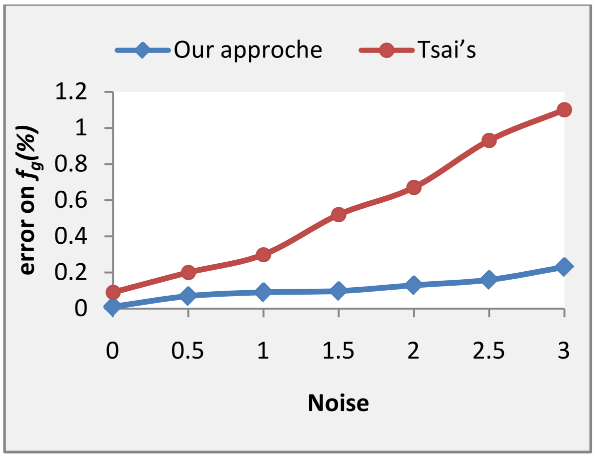

Fig. 3 Relative error of f_g according the Gaussian noise

A Gaussian noise with a standard deviation (so that $\sigma \leq 3$ pixels) is added to all image pixels to show the performance and robustness of the present method. A simple reading of Fig. 3 and Table 2, we ignored the results of the Tsai's method, because from $\sigma \geq 1$, the errors of the cameras parameters enlarge , we can conclude that the Tsai's method gives results accurate when the images are not noisy or slightly noisy. Unlike, in our approach the error of the camera parameters is approximately constant for various noise values up to $\sigma = 2.5$, but these errors increase slowly if σ exceeds 2,5 pixels. This shows that the presented approach is more accurate and robust to noise.

4.2 Real data

This section deals with the experiment results of the different algorithms implemented by the Java object oriented programming language. We use the 512x512 images (Fig. 4), in which we know the locations of interest points on the image pair and their corresponding 3D object coordinates. Based on

CCD camera which is characterized by varying parameters. Two images are show in Fig 4. The interest points and matches between these two images are shown respectively in Figs. 5 and 6, the intrinsic and extrinsic parameters estimated by two methods (the present method and Tsai's [2]) shown in table 3.

Figure 5 shows the interest points obtained by the Harris detector in the two images. 46 interest points were detected in the first image, and 46 interest points were detected in the second image.

The interest points detected by the Harris algorithm are matched between two images by the correlation function ZNCC. Figure 6 shows the 32 matches obtained by this correlation.

Fig. 4 two Images of 3D scene

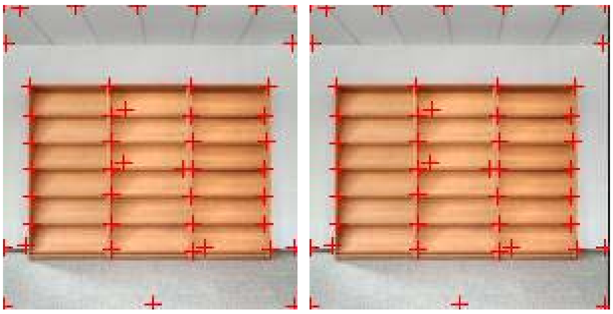

Fig. 5 the interest points are shown in red in the two images

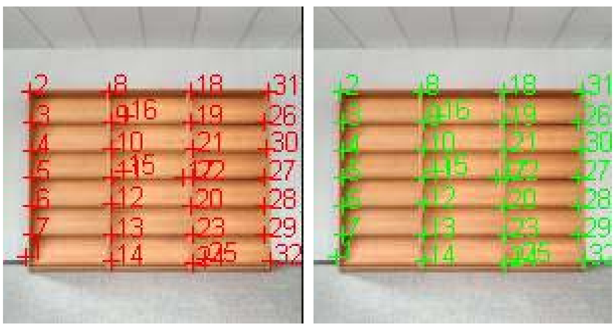

Fig. 6 The matches are shown in the two images

In order to obtain the good values of the intrinsic and extrinsic parameters of two cameras, we gives to the algorithm the initial bounds for the parameters to be estimated which limiting the search space for the optimal solution. The large bounds (table 3) can be defined for the unknown parameters to obtain a good accuracy. Table 3 shows the optimal solution of the parameters of cameras used obtained by our method and Tsai's [2].

Table 3 The results of the cameras parameters estimated by the two methods

Our method				Tsai's (single camera)
Parameters of two cameras		Large Bounds $[v^-, v^+]$	optimal value by IGA	
Left camera	f_g	[10,100]	64.00	63,94
	k_{xg}	[50,90]	69.00	67,32
	k_{yg}	[50,90]	70.25	63,01
	x_{0g}	[200,280]	252.00	257,00
	y_{0g}	[190,220]	210.00	206,00
	t_{xg}	[-400,400]	-93.00	-102,00
	t_{yg}	[-400,400]	-88.00	-94,10
	t_{zg}	[700,2000]	1802.00	1793,00
	ω_g	[-π, π]	0.500234	0,41003
	$\emptyset_g$	[-π, π]	0.020134	0,02965
	θ_g	[-π, π]	0.043671	0,01784
Right camera	f_d	[10,100]	61.50	
	k_{xd}	[50,90]	68.20	
	k_{yd}	[50,90]	70.00	
	x_{0d}	[200,280]	250.00	
	y_{0d}	[190,220]	201.00	
	t_{xd}	[-400,400]	-96.50	
	t_{yd}	[-400,400]	-80.00	
	t_{zd}	[700,2000]	1841.46	
	ω_d	[-π, π]	0.512679	
	$\emptyset_d$	[-π, π]	0.024671	
	θ_d	[-π, π]	0.046237	

After comparing the results on the synthetic data, the results of the present approach on real data (the two images shown in Fig. 4) are compared to those obtained by Tsai's [2]. The reading and the analysis of the camera parameters presented in Table 3 show that the results of the present approach are a little different from those obtained by Tsai's [2], this is logical because the impoved genetic algorithm has less chance to generate values far removed from the optimum and helps avoid the local minima of the cost function. Therefore, this approach provides a robust performance and accuracy. In addition, this method has several advantages: the use of free cameras with varying parameters this which make the calibration process more robust without no constraints on the cameras used, the use an IGA to optimize the cost function, this algorithm converges to an optimal solution without initial estimates of the parameters and helps avoid the local minima of the cost function.

5 Conclusion

In this article, a robust method of camera calibration with varying parameters based on improved genetic algorithms is presented. This new approach is based on determination of a relationship between points in 3D scenes and their projection in planes of images, this relationship give a non linear cost function and the minimisation of this function provides the intrinsic and extrinsic of the cameras used. The importance of our approach of calibration manifested in two points, the first is the use of free cameras with varying parameters this which make the calibration process more robust without no constraints on the cameras used. The second point is the use an IGA to optimize the cost function, this algorithm converges to an optimal solution without initial estimates of the parameters and helps avoid the local minima of the cost function. The robustness of this method in terms of simplicity, accuracy, stability, and convergence is shown by the results of the experiments and the simulations conducted.

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