CAMERA CALIBRATION FOR IMAGE PROCESSING

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ABSTRACT:

This paper presents some methods concerning the calibration during image digitization to get accurate information about surfaces. The stereo vision technique with the double human eyes system is inserted while all problems, related to image purification are treated. The principle of transformation of the 3D objects into double 2D images is accounted. An automated calibration model is installed in a dark room as well as mathematical constraints are developed. It leads to a high rate of accuracy. The effect of cut off level is investigated.

1. Introduction

The measurement process of any physical dimensions for an object requires a calibration relative to the standard values where its description is usually given by diagrams or look-up-tables. This procedure can be stored individually for each measuring sensor through the operations of filing. The image processing needs such a calibrating three-dimensional (3D) system when the digitizers will have a multiplication unit as well as a sensor head. The analytical principle is a target for simplicity when a complex system is concerned.

Therefore, the coefficients of a calibration model under the automation consideration must be deduced initially before processing applications and consequently, a non-skilled operator will be able to calibrate through a small quantity of information [1]. This information may be images by camera or sometimes a mathematical knowledge. It could be more difficult when the work is implemented for objects (not plane) as a model must be based for such purpose.

Thus, the calibration body should be installed for exact results through the charge coupled camera (CCD) which will become a difficult way with stereo vision due to the non-coplanar points of calibration. Otherwise, this is related to
the automated system of imaging, depending on the double camera system as the human eyes, as one will be the right (R) and the other is the left (L).

2. Model

A vision concept with an image processing hardware has been developed inside a dark room where two black / white cameras, expandable in even numbers, are attached to an analogue / digital converter frame grabber. An analogue monitor displays the image with a host computer Intel-486-DX-4/100-16 MB RAM, 540 MB disks. The software (C language) is implemented to operating system OS/2.

The calibration model (white top pins 28/x and 25/y mm apart where z coordinate varies between 15 and 70 mm, with black background) is illustrated through their projection as shown in Fig.1 to find transformation matrix elements for each eye ([T]L, [T]R) automatically to raise the accuracy of measurement according to the constraints (Fig. 1) [2]:

\[
\{ x, y \}_i < \{ x, y \}_{i+1} < \{ x, y \}_{i+2} < \{ x, y \}_{i+3}
\]

(1)

where \(x_i\) and \(y_i\) are images of a point \((i)\) in x, y coordinates, \((i = 1, 5, 9)\) but for \(x_i < x_j < x_{i+1}\), then \(y_j\) must be \(< y_i\).

If these constraints are considered the calibration will be completely correct but if they are not, a test algorithm would be necessary for check and to ensure that the calibration results are correct. This may be created in 3 cases as: firstly,
when the number of points (Fig. 1) is small with low light intensity for imaging, although secondly, for enormous number of points but with high illumination. Thirdly, if the number is suitable but there is no matching to constraints [3].

However, these conditions can be controlled by adjusting the number of points and light intensity while as the model plate should be rotated slowly in one direction for multi readings correction. Then, a dark room for calibration is built with the possibility of rotation of the model although the camera set must be in the place without movement. This helps the automatically definition for image coordinates in both cameras whenever the high accuracy reached (less than 0.4 mm) at reduced time (15 s) for both images, scanning and generating the two transformation matrices.

This depends on converting the image into a binary shape [4] through a suitable dynamic threshold as the origin is taken at the bottom of left edge. This conversion helps only as a guide to allocate the first point of calibration in the image and so, this point will be needed to get the center point \((x_c, y_c)\). Three different approaches are used for this calculation [5, 6]. Nevertheless, the binary image usually contains a little information where the algorithm, used for detection of the center point for the calibration procedure, may be implemented to find the middle points in both \(x\) and \(y\) coordinates depending on the first approach by:

\[
(x_c, y_c) = \{(x_R + x_L)/2, \ (y_R + y_L)/2\} \quad (2)
\]
3- Cutoff level

The above results of equation (1) may not be the accurate because of either any distortion or the high intensity so that the second method would be introduced based on the resulted approximated center for the detection of the original image. It can be considered as a generalization for the first one where this center will be accounted as the point of high intensity (I). If there are many points fulfilled for such a condition, their center should be obtained to continue the process as:

$$(x_c, y_c) = \{(x_R + x_L)_{\text{max}}/2, (y_R + y_L)_{\text{max}}/2\} \quad (3)$$

Thus, in the third method the center of gravity will be deduced to reduce the effect of any noise or extreme illuminations leading to exact values as a function of the relative coordinates (ij) and light intensity. Then, the number of high intensity pixels (a typical number of 10–400 pixels) belong to pins (Fig. 1) inside the typical test window will be introduced for operation raising highly the computational effort and time. The concept of cut off should be applied to minimize the appeared phenomena as shown in Fig. 2 for the case of cut off leveling. Fig. 3 presents the effect of filtering relative to the condition without it.
This removes noise and non-adjusted light and consequently the low pass filters treat the high frequency components. This leads to a more accurate value for the aimed center of gravity. The third approach (center of gravity) consumes more time but its results are normally accurate.

Three different concepts (without-, with-, fixed, and dynamic cutoff) are included although the center of gravity is always shifted to the center of the computation window in the first concept because of the illumination difference on the value required. The dynamic method is applied through four different means: the first is based on the maximum left top point but the second considers the lowest intensity illumination.
Contrary, the third one takes the highest illuminated point, and the last used the average of the intensity values inside the window. Typical values of intensity are shown in Table 1 during one of the experiments done where all given methods would be sequentially introduced for accuracy. This application is given in Fig. 4 during cut off selection for calibration [7].

Table 1: The intensity values for a typical 20 x 20 window

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With small values in first two method the computed center of gravity will be shifted to the center of image window but for zero value in the second approach the case will be the same as without cut off consideration. Moreover, with high value a good accurate calculation must be appeared. Inversely, the third concept where the offset value is subtracted from the value of highest intensity leads to a good measurement. The results of experiment are shown in Fig. 5 where a minimum offset value is deduced to represent the maximum accuracy.

An algorithm is developed to verify the pre-specified error according to the calculated coordinates of points in the model. It depends on the feedback principle as it can remove the noise and the problems of illumination. This is reflected to the resolution of measuring device, 400 - 800 pixel as a standard and the computed coordinates are integer opposite the real case causing a difference. Thus, the process can be controlled, and the computational time will be reduced.
4. Conclusion

1- The proposed calibration model for stereo vision raises the accuracy with reduced computational time and effort.
2- Simple calibration can be integrated with the practical techniques.
3- The given concept can be recommended for image processing.
4- The problems of noise and image intensity can be removed easily.
5- Smoothing and detection of images can be achieved with low-high filters.

5. References

Acknowledgment

The authors wish to express their great thanks to Prof. Dr. Eng. Robert Massen, The Dean of The Transfer Center for Image Processing, Constance, Germany, for his High support during the experiments in this research. They also would like to appreciate the help of Prof. Massen and his staff members relative to the preparation and work.

ماعتراة آلة التصوير للعمليات التشغيلية للصور

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ملخص:

يقدم البحث بعض الطرق المتعلقة بالمعايير التصويرية أثناء عمليات التصوير الرقمي للحصول على دقة معلوماتية عن الأسحاب التي يتم تصويرها. تقنية التصوير المجمد التي تنتهج أسلوب الرؤية البشرية والتي تعتمد على زوجين من العيون البشرية تحترمها في هذا العمل بينما جميع المشكلات المتعلقة بتنقية الصورة قد تم علاجها. تم إتباع الواقع الفعلي لطباعة الصور على الورق المسطح ولذا تم الاعتماد على مبدأ التحويل الرقمي للأبعاد الثلاثية التصويرية إلى ثنائية الشكل. يقدم البحث نموذجاً آلياً للمعايرة حيث وضع في حجرة مظلمة ثم تم التحليلات الرياضية لتحديد حدود الصلاحية والتي أكدت على دقة عالية في نتائج التصوير ثم تم دراسة الحدود الفاصلة التي تمثل الإطار بالنسبة للصور لرفع كفاءة العملية التشغيلية والحصول على النتائج الموضحة بالبحث.