MVA '98 IAPR Workshop on Machine Vision Applications, Nov. 17-19, 1998, Makuhari, Chiba, Japan

8—24 Intensity calibration for stereo images based on segment correspondence

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Abstract

It is necessary to calibrate the intensity between stereo images correctly to find their correct correspondence when using a correlation method. The authors propose a method of automatically calibrating the intensity from the image data, using segment-based correspondence results, which are robust against changes in intensity. The effects of this method are explained through experiments.

1 Introduction

It is necessary to calibrate the intensity between stereo images correctly to find their correct correspondence. Especially, the adjustment of intensity is indispensable for the correlation method based on the intensity. There are two kinds of correlation methods, one using a normalized evaluation equation and the other a difference evaluation equation[1, 2]. The former method is effective for regions, such as the texture shown in Figure 1(a), where intensity remarkably changes in a correlation window. It is possible to obtain correct disparity even if the intensity is uneven absolutely between the images because of the normalization. The correspondence may shift, however, in regions, such as the shaded regions shown in Figure 1(b), where intensity changes smoothly. The latter method is effective to calculate the correct disparity in shaded regions. Thus, it is necessary to calibrate the intensity between the images to calculate the correct disparity for such shaded regions.

On the other hand, the structural analysis stereo method that uses higher-order features of an image is comparatively robust against some changes in intensity. An effective method of calibrating intensity

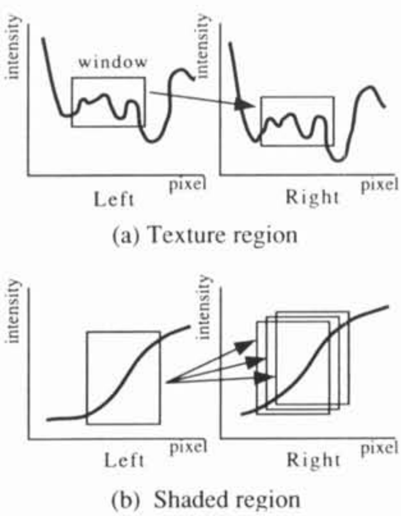

Figure 1: Correlation method

using the intensity information of the corresponding points between images is the segment-based stereo method[5, 6, 4], which is a kind of structural analysis method. The procedure is explained next, and the experimental results follow.

2 Processing procedure

The processing procedures shown in the Figure 2 flowchart are explained in sequence. First, the edges, which are higher-order features, are detected in each image. Each section is defined as a segment by dividing the edges using some characteristic points such as turning, wiggle, inflection, transition, etc.[3]. This data is converted into B-Rep (Boundary Representation) which has a winged-edge structure[4]. The intensity information consists of an intensity and a derivative at the point, which is not just the point on the edge but the point where the derivative is the smallest point in the neighborhood in the

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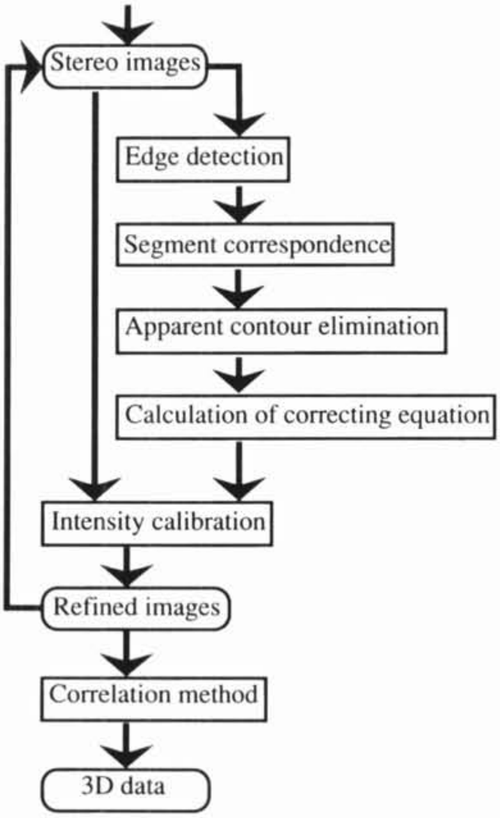

Figure 2: Flowchart of 3D reconstruction

direction of the normal in the region. In short, the intensity information at the point on the segment is data of the regions to which it belongs (see Figure 3).

The segment is a boundary edge, which divides the regions with the different intensity. Therefore, even if correspondence in absolute intensity does not exist between the images, the edge is detected at almost the same place. This is the reason why the segment-based stereo method that uses these features is robust against changes of intensity.

A standard image (an image whose the intensity is not corrected) I_1 is decided. The correspondence of the segments between I_1 and an image to be corrected I_2 is obtained using the segment-based stereo method[5, 6]. This method is based on finding similar boundaries to I_1 from I_2. The algorithm is as follows.

- Some candidates for correspondence pairs consist of two segments in I_1 and I_2 under epipolar condition, direction, and intensity. Local similarity in each pair is calculated.
- The connectivity of two pairs is decided by their distance, intensity, and angle, based on each boundary in I_1.
- The similarity of paths, which are sequences of pairs, is evaluated and recalculated by summing the local similarities.
- Multiple correspondence between pairs is removed using this similarity, and correspondence segments between I_1 and I_2 are obtained.

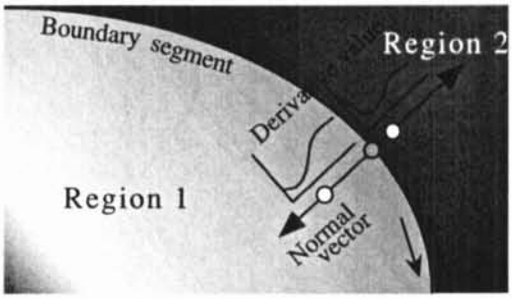

Figure 3: Intensity information

Apparent contours are correspondence candidates because of the evaluation based on segment connectivity in the segment-based stereo method. However, the correspondences of apparent contours may be incorrect and should not be the correspondences used to calibrate the intensity. It is therefore necessary to use only the segment correspondences of fixed edges. The derivative value of the intensity information at each point may be large, because intensity changes in the apparent contours are large. The correspondence candidates are removed by using this feature. In multi stereo images, they can be removed by using images from other viewpoints as verification images.

Next, because the correspondence between the points is obtained from the segment correspondences, we can find the intensity correspondences between images. The intensity calibration equation between images (I_1, I_2) is derived from the distribution. If the correspondence is correct, the points are distributed on a straight lines, and a straight line is fitted:

$$I_2(0) = a\ I_1 + b$$

a, b: coefficients

$I_i(n)$:image after the nth iteration

The image $I_2(0)$ is calibrated based on this equation, and a refined image $I_2(1)$ is calculated. This same process is repeated using subsequently refined image, until $I_2(n) \cong I_1$ (see Figure 2).

Finally, the correlation method is carried out on the refined images using evaluation methods such as SAD (Sum of Absolute Difference) or SSD (Sum of Squared Difference), the disparity is calculated, and the 3D shape is obtained. In this case, the correlation is calculated efficiently, using the corresponding points obtained previously from the segment-based stereo method, as the initial values of the corresponding search.

3 Experimental results

The experiment results of this method are described next. Figure 4 (a) shows the input stereo images. The right image was taken with the iris closed more than the left image. The left image was processed as a standard image. Thin lines are the detected edge segments, and bold lines are the corresponding segments found by the segment-based stereo method in (b). The result after elimination of apparent contours is (c), which shows that the segments in a ball and a column are removed. These images are the results for the standard image. The number of corresponding points used for calibration is 1,649. The intensity map is shown in (d), where the x-axis is the intensity of the left image and the y-axis that of the right image. Corresponding points are almost distributed on a straight line. This graph shows that the right image is a little darker than the left image. A straight line is fitted to this distribution, and the intensity calibration equation is as follows:

$$I_{right}(0) = 0.809555825\, I_{left} - 2.007559123$$

The intensity of the right image is refined by this calibration equation. The refined image is then used as the input image, and the same process is repeated until $I_{right}(n) \cong I_{left}$. The process converged after six iterations in this image and its intensity map is (e).

$$I_{right}(6) = 0.998365274\, I_{left} - 0.209307580$$

The iteration process for coefficients a, b in the calibration equation is shown in (f). The calibration equation finally obtained is as follows:

$$I_{right} = 0.802038090\, I_{left} - 1.645289688$$

The result of intensity calibration using this equation is (g).

The disparity only in the part with the intensity change is calculated by the correlation method using SAD for image (g). The reconstructed result is (h). For instance, the correct 3D shape of a ball was obtained. The result of reconstructing (a) of the original image which is not calibrated by the same method is (i). The curved surface parts that are shaded regions were not reconstructed correctly, and so the effectiveness of this method was proven.

4 Conclusions

We have described an intensity calibration algorithm for stereo images that do not have complete intensity correspondence. The intensity calibration is automatically carried out using features that are robust against changes of intensity. The effectiveness of this method was verified through experiments. In the future, we will develop a method of automatically selecting of a standard image using intensity dynamic range.

References

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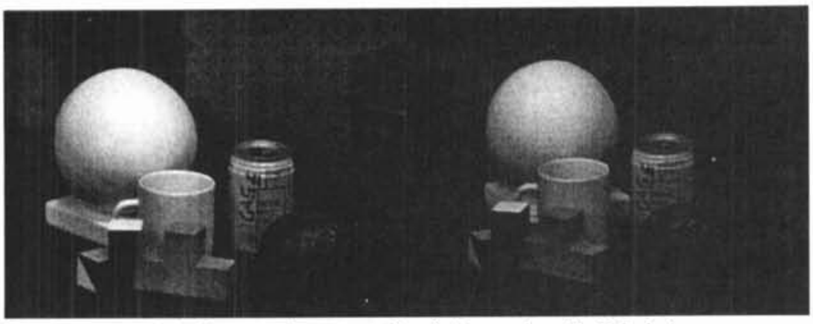
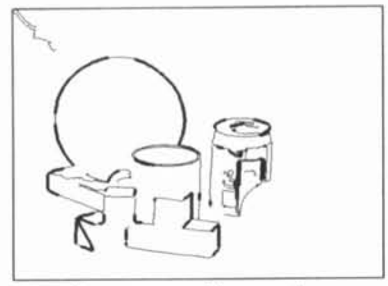
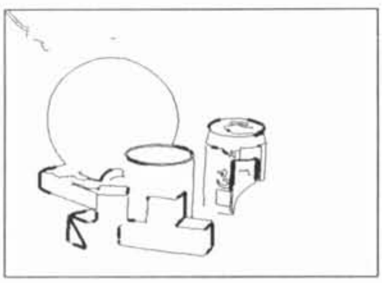


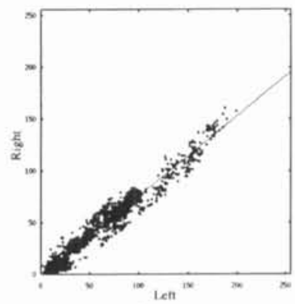
(a) Stereo images (Left [standard], Right)



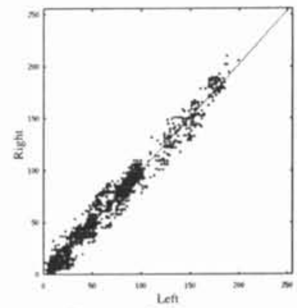
(b) Corresponding points
using segment-based stereo



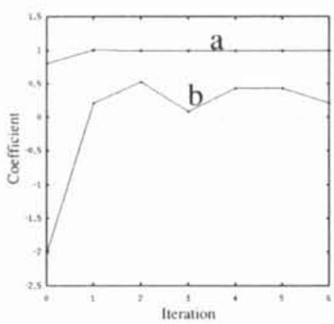
(c) Corresponding points
after elimination of apparent contours



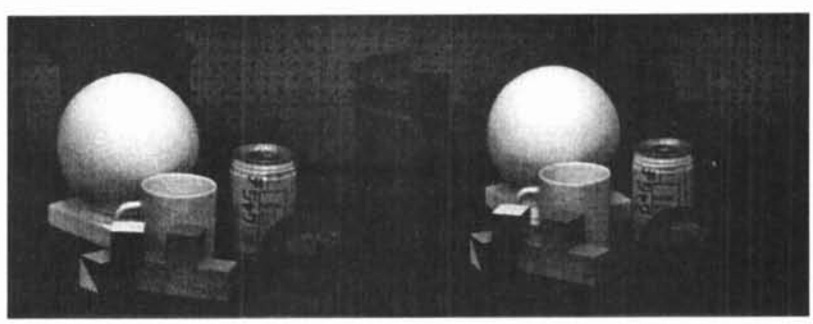
(d) Intensity map
(before iteration)



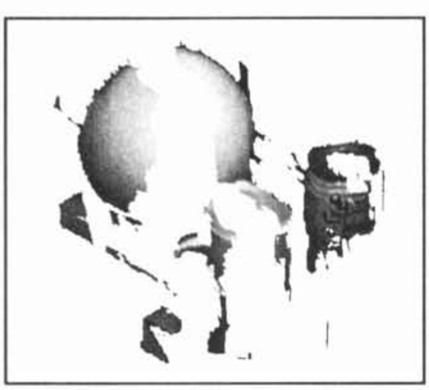
(e) Intensity map
(after iteration)



(f) Iteration process



(g) Refined images



(h) Reconstructed result
(after calibration)

(i) Reconstructed result
(before calibration)

Figure 4: Experimental results