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Image Inclination Measurement Based on Edge Directions and an Analysis of Relation between Visual Inclination

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Abstract

This paper proposes a method to measure the inclined angle of an objective image based on the most frequent edge direction. This paper also describes a relation between the measured inclined angles by the proposal method and the visual inclined angles. An edge direction is changed according to the inclination of an objective image. The most frequent edge direction is supposed to show the global inclination of the image. The proposed method measures the inclined angle of an image by detecting the edge direction with the peak in the histogram that represents the distribution of all edge directions in the image. The experimental results show that the measured inclined angles by the proposed method were similar to the visual inclined angles evaluated by experimental subjects.

1. Introduction

A captured image may often decline visually by the position of a camera and the condition of a shooting location. A technique to measure the visual inclination of an image is required to translate the inclined image to the straight image automatically. This paper proposes a method to measure the inclination of a captured natural scene image on the basis of the distribution of edge directions included in the whole image. The visual inclinations of the experimental images were also measured to evaluate the appropriateness of the measured inclination by the proposed method.

2. Distribution of edge directions

When an image rotates around the optical axis, directions of all edges in the image supposed to be changed by the inclined angle as shown in Fig.1. The directions of all edges in an image are measured at edge pixels as shown in Fig.2(a), and the edge directions histogram is generated that represents the number of edge pixels by each edge direction as shown in Fig.2(b). Fig.3(a) and Fig.3(b) show the examples of a straight image and an inclined image. Fig.3(c) shows the edge directions histograms that are obtained from the straight image Fig.3(a) and the inclined image Fig.3(b). Fig.3(d) shows the magnified peaks in the edge directions histograms. The position of the peak in the edge directions histogram obtained from the inclined image is shifted to the position of the peak obtained from the straight image.

In a general straight image, the distribution in the edge directions histogram has a tendency to collect near the inclined angle 0 degree or 90 degree. This is because various objects included in a general scene image have many edges that have near the horizontal or the vertical direction.

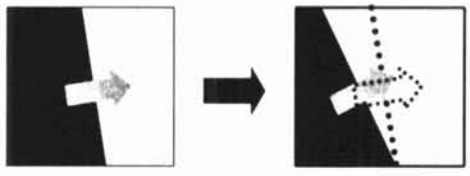

Fig.1 Change of edge direction by inclination

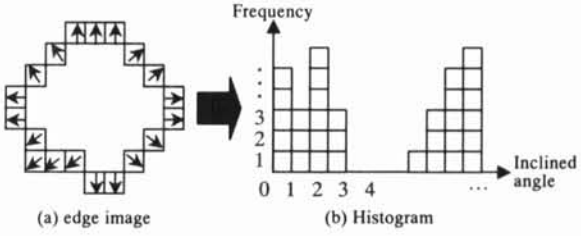

Fig.2 Edge directions histogram

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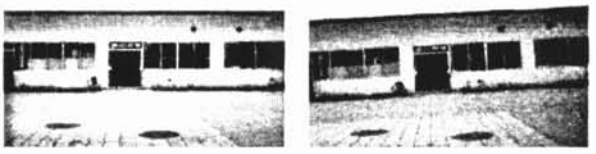
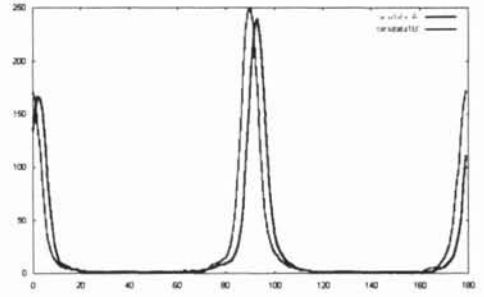
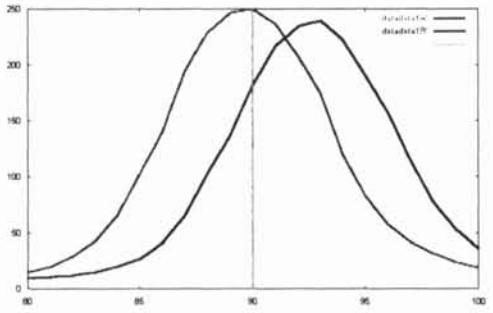


(a) Straight image (b) Inclined image



(c) Edge directions histogram



(d) Circumference of the peak

Fig.3 Edge directions histograms of straight image and inclined image

Thereupon, the proposed method measures the inclination of an image by the position of the maximum peak in the edge directions histogram. The reliable position of the peak is obtained in the proposed method through the non-maximum suppression[3] of the edge strengths and the symmetrical check of the frequencies in the edge directions histogram.

3. Method to measure inclination of image

Fig.4 shows the flow-chart of the proposed method to measure the inclination of an objective image. The following sections describe the processing steps sequentially.

3.1 Edge extraction

The Sobel operator is applied to an objective

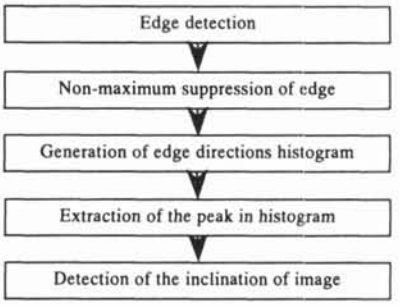


Fig.4 Flow-chart of the proposed method

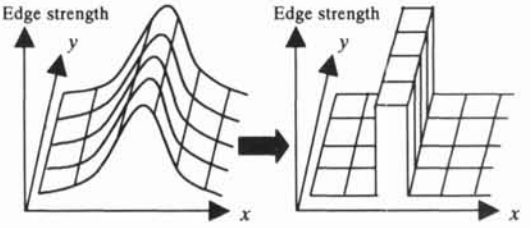


Fig.5 Non-maximum suppression of edge

gray-scaled image and edge pixels that have the larger edge strength than the threshold are extracted. The threshold is determined by the discriminate analysis method[2].

3.2 Non-maximum suppression of edge

Edge lines extracted by the Sobel operator and the thresholding method have the wide width generally [1],[3]. The edge directions of edge pixels with lower edge strengths supposed to be not so accurate. The non-maximum suppression process is applied to extract only edge pixels with the maximum edge strength in the width of an edge line as shown in Fig.5[3].

3.3 Generation of edge directions histogram

The edge directions histogram is generated using the extracted edge pixels by the non-maximum suppression as shown in Fig.2. The resolution of the angles of the edge directions histogram is set to 1 degree.

3.4 Extraction of peak in edge directions histogram

The stable edge directions histogram may be obtained when an objective image has a clear visual direction and includes many strong edges. On the other hand, the edge directions histogram often has noisy peaks when an objective image is a natural scene. To extract the proper peak in the edge directions histogram, the symmetry is checked around the candidates of peaks as shown in Fig.6. The position that has the maximum symmetrical

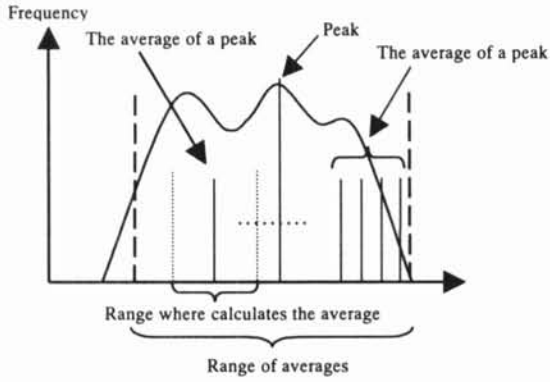


Fig.6 Extraction of the peak in Edge direction histogram

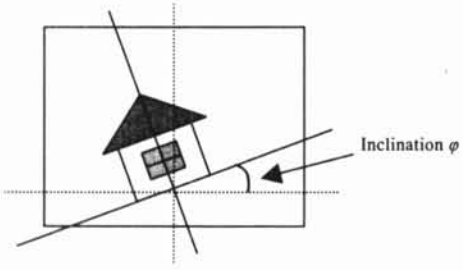


Fig.7 Inclined angle of image

Fig.8 Overview of visual experiment

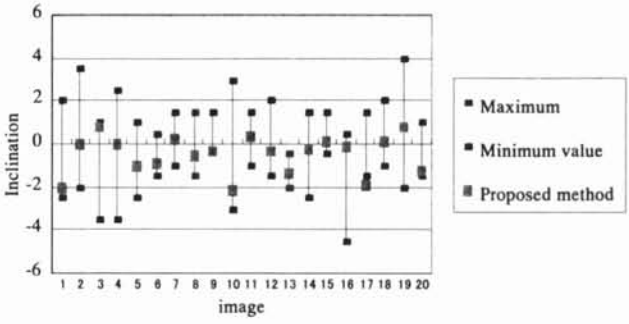


Fig.9 Relation of measured inclinations between by the proposed method and by experimental subjects

degree is extracted as the proper peak near the position with the maximum frequency in the edge directions histogram.

3.5 Measurement of inclination

The extracted peak means the inclined angle of the objective image. The inclined angle is measured as the decimal value by averaging the frequencies around the peak. The inclination of an objective image means the inclined angle based on the horizontal line in the image as shown in Fig.7

4. Experimental results

4.1 Relation between measured inclination and visual inclination

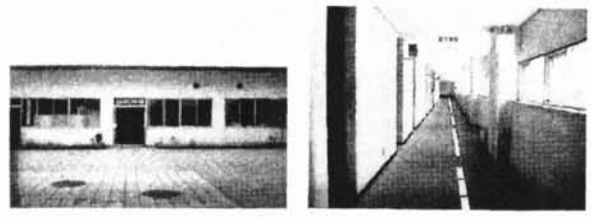
The inclinations of twenty experimental images were measured by the proposed method. The visual inclinations of the images were also measured by ten experimental subjects. Fig.8 shows the situation of the visual experiment by a subject. An objective picture that is straight to the gravitational direction is mounted on the mechanical rotation stage, and the image of the picture is displayed in the display by using the camera that is located on the vertical position of the stage. An experimental subject rotates the stage manually to the position that the subject percepts the straightness of the image in the display. The rotated angle of the stage to the position is measured as the visual inclination.

As shown in Fig.9, the measured inclinations by the proposed method were almost included in the ranges between the minimum inclinations and the maximum inclinations that are measured by all experimental subjects.

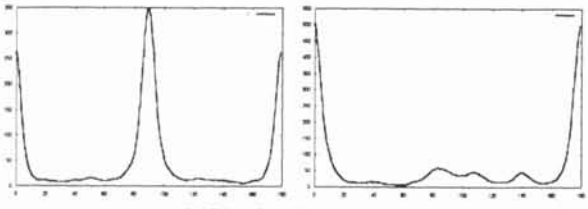
4.2 Classification of experimental images

The twelve experimental images were classified to the higher correlated images that had the small differences of the measured inclinations between by the proposed method and by the subjects. On the other hand, the eight experimental images were classified to the lower correlated images that had the large differences of the measured inclinations between by the proposed method and by the subjects. The averaged difference of the measured inclinations between by the proposed method and by the visual experiment was 0.9 degree about all experimental images. The difference of the measured inclinations was only 0.41 degree about the higher correlated images. On the other hand, the difference of the measured inclinations was larger 1.63 degree about the lower correlated images.

Fig.10 shows the examples of the higher correlated images. Many images in the higher

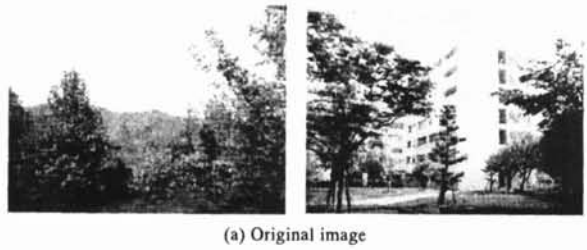


(a) Original image

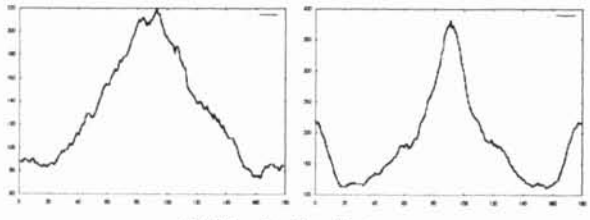


(b) Edge directions histogram

Fig.10 Examples of the higher correlated images



(a) Original image

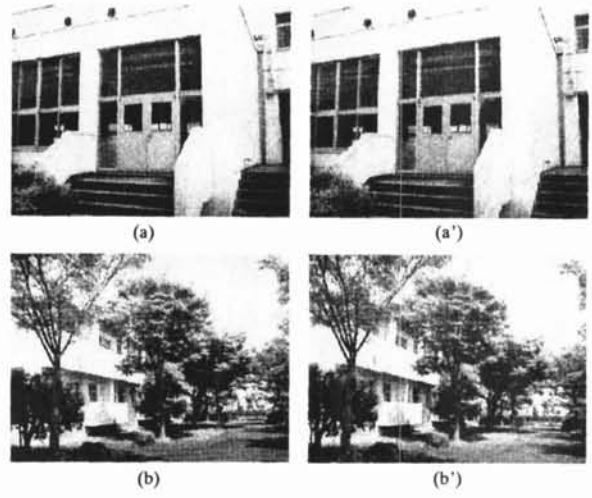


(b) Edge directions histogram

Fig.11 Examples of the lower correlated images

correlated images included artificial architectures and the distributions of edge directions tended to concentrate to near the horizontal and the vertical directions in the edge directions histograms. Fig.11 shows the examples of the lower correlated images. Many images in the lower correlated images were natural scenes that included such as trees or mountains and the peaks in the edge directions histograms tended to dull and to spread.

Fig.12(a) and Fig.12(b) are the examples that are rotated to the straight images using the measured inclinations by the proposed method. On the other hand, Fig12(a') and Fig.12(b') are the rotated images according to the averaged inclinations measured by the visual experiment. Fig.12(a) and (a') are one of the higher correlated images and Fig.12(b) and (b') are one of the lower correlated



(a) (a')

(b) (b')

Fig.12 Examples of the straight images using the proposed method ((a) and (b)) and using the averaged inclinations by the subjects ((a') and (b'))

images. It is found that the obvious difference is not perceived between Fig12(a) and (a') and between (b) and (b'). The above experimental results show that the proposed method can measure the similar inclinations of images to the inclinations by the averaged visual sense.

5. Conclusions

A method to measure the inclination of a captured natural scene image on the basis of the distribution of edge directions is proposed. The proposed method measures the inclination of an image by the position of the maximum peak in the edge directions histogram. The visual inclinations of the experimental images were measured to evaluate the appropriateness of the measured inclinations by the proposed method. The experimental results show that the measured inclined angles by the proposed method were similar to the visual inclined angles evaluated by the subjects.

References

[1] L.Kitchen and A.Rosenfeld : "Edge Evaluation Using Local Edge Coherence", IEEE Trans. on SMC, Vol.11, No.9, pp.597-605 (1981).

[2] N.Otsu : "A Threshold selection Method from Gray-level Histograms", IEEE Trans. on SMC, Vol.9, No.1, pp62-66 (1979).

[3] A.Rosenfeld and M.Thurston : "Edge and Curve Detection for Visual Scene Analysis", IEEE Trans. on Comput., Vol.20, No.5, pp.562-569 (1971).