ESTIMATION OF OVERTURNING RATIO OF TOMBSTONES BY IMAGE ANALYSIS OF AERIAL PHOTOGRAPHS

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ABSTRACT: As a method to estimate the seismic intensity in a strong earthquake, the overturning ratio of tombstones in a cemetery has been used widely in Japan. The purpose of this study is to estimate the overturning ratio of tombstones due to an earthquake based on image analysis of aerial photographs. It is expected to be an alternative of field survey to grasp seismic intensity widely and densely. In image processing, the edge, which is the outline of an object, is extracted because displaced tombstones are considered to be detected through the distribution of the edge direction. Firstly, the experiments with a model tombstone were conducted under various conditions such as the different displaced-state of tombstone, the position of spotlight, and the resolution of images. Removing noises by a threshold of edge intensity is found to be necessary to extract only notable edges. The examination based on the ratio of vertical and horizontal edge directions shows that not only the state of tombstone but also shadow affects this ratio largely. Hence the direction of sunlight and the shape of shadow should be considered properly. An estimation formula for the overturning ratio of tombstones will be proposed in the near future..

1. INTRODUCTION

Recently aerial photographs have been widely used in disaster management because of their high resolution and the mobility of aircraft. After the 1995 Kobe Earthquake and the 2004 Mid-Niigata Earthquake, many aerial photographs were taken and employed in grasping damage to buildings (Ogawa and Yamazaki, 2000), roads and other infrastructures.

Field surveys of overturning ratio of tombstones in a cemetery have been conducted in Japan to estimate the seismic intensity of a disaster area (Midorikawa and Fujimoto, 1996). According to Japan Meteorological Agency (JMA) intensity scale many tombstones in a cemetery may be overturned or displaced if the JMA intensity exceeds 4.5 or so. Although many seismometers are deployed all over Japan today, the field survey of cemeteries is still important since they exist more widely and densely than seismometers do.

The purpose of this study is to estimate the overturning ratio of tombstones based on image analysis of aerial photographs. The result is expected to be used in grasping the seismic intensity widely and densely. Although it is relatively easy to distinguish “standing upright” and “overturning” of a tombstone by visual inspection, the inspection is short of objectivity and needs much time for precise decision. On the other hand, image analysis is quantitative and has objectivity, and thus it is considered to be more useful for the estimation of seismic intensity than visual inspection. In this study, aerial photographs taken over the affected area of the 2004 Mid-Niigata Earthquake by Geographical Survey Institute of Japan are used.

2. EDGE DETECTION BY IMAGE PROCESSING

In order to recognize an object, extracting an outline of the object is one of important ways in image analysis. In this study, we use “edge”, which is a part of changing brightness and a series of same tone. Such ways of extracting and analyzing spatial characteristics are called “filtering”. Various edge filters have been proposed. In this study, an edge detector with 3 × 3 window is used. Generally a color image is composed of RGB colors. First, an image is transformed from RGB to HSI (hue, saturation, intensity) space, and only the intensity (gray scale image) is used hereafter. The intensity image is then converted to 8 bits so that it is easily applicable for the edge detector.

In this study, Differential Edge Detector designed by Sobel is used. This operator shown in Fig. 1 calculates differential values of direction x (→) and direction y (↓) to a pixel, and each value is expressed by Eq. (1). Then the edge intensity is calculated by Eq. (2), and the edge direction is calculated by Eq. (3). We standardize the maximum value of the edge intensity as 1.0. Note that the direction obtained by Eq. (3) means that of edge line, not the direction of brightness’ gradient. These two directions are perpendicular each other (Fig. 2).

-1	0	1
-2	0	2
-1	0	1

fx

-1	-2	-1
0	0	0
1	2	1

fy

Figure 1. Sobel’s 3×3 template

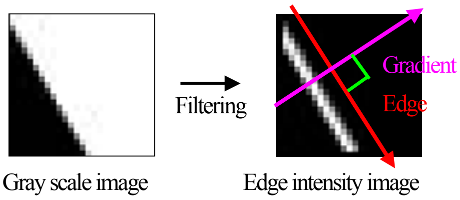


Figure 2. Edge direction and gradient direction

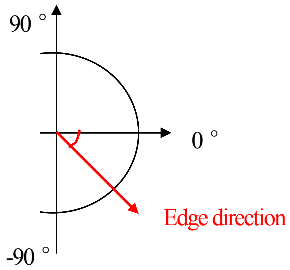


Figure 3. Image of an edge direction and its range

$$G(x,y) = (f_x, f_y) \tag{1}$$

$$|G(x,y)| = \sqrt{f_x^{\,2} + f_y^{\,2}} \tag{2}$$

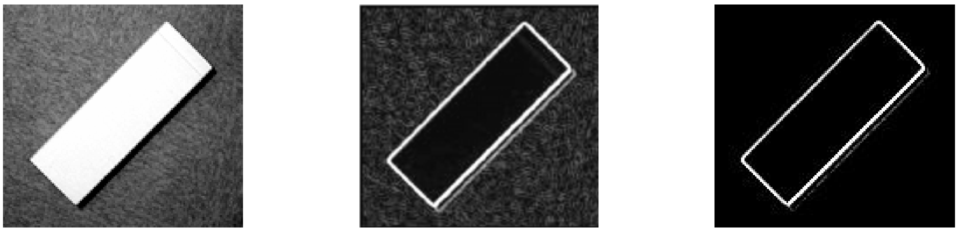
$$\theta = \tan^{-1}(f_x / f_y) \quad -90° \le \theta \le 90° \tag{3}$$

Typically, a tombstone is composed of rectangular parallelepiped stones and lines parallel to the front line. Hence, from a filtered top view of normal, upright tombstones, many edges of horizontal (x) and vertical (y) directions may be extracted. On the other hand, from the filtered image of overturned or displaced tombstones, the edges of oblique angles to the x and y directions may be detected. Therefore the condition of overturned or displaced tombstones can be estimated by means of the randomness of the edge directions. As the first step of the study, indoor model experiments are carried out and the parameters affecting the edge direction are investigated before applying the method to aerial photographs.

3. REMOVAL OF NOISE FROM THE FILTERED IMAGES

In filtered images, not only the notable edges, such as tombstone’s outline, but also noises of weak intensity may be extracted. Because such noises are thought to affect the edge direction largely, the method to remove noise and extract only notable edges is investigated. First, using a digital camera, a photo of a rectangular parallelepiped model shown in Fig. 4(a) was shot. Figure 4(b) shows the edge intensity calculated from the gray scale image. From Fig. 4(b), the edge directions properly extracted are only 18.2% of all the edge directions, and thus the weak intensity edges are considered to affect the edge directions largely as noise. Using the cumulative distribution of edge intensity shown in Fig. 5, the proper threshold value for weak edge removal was sought. Using the value shown in Fig. 5, most of the noises was removed.

From the edge intensity image after noise removal (Fig. 4(c)), 77.2% of the extracted edges were found to be to the notable edge directions.



(a) Gray scale (b) Edge intensity (before removal) (c) Edge intensity (after removal)

Figure 4. Images of the experiment for removing noises

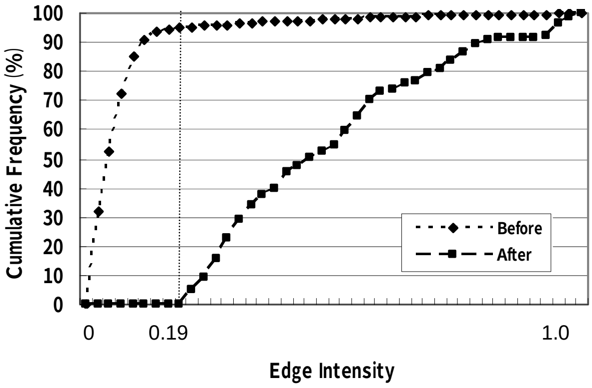


Figure 5. Cumulative distribution of the edge intensity for the indoor experiment in Figure 4

Table 1. Comparison of properly extracted edge direction before and after the noise removal

Removal of noises	Before removal	After removal
-50° - -40 °	7.4%	13.9%
40° - 50°	10.8%	63.3%
Total	18.2%	77.2%

Next, the method of removing noises was applied to aerial photographs. In order to compare the randomness of edge directions, the edge direction ranges of -90° – -75°, -15°– 15°, and 75°– 90° were used to calculate the ratio of horizontal and vertical (H-V) edge directions. This ratio was compared for three areas shown in Fig. 6(a). By visual inspection, the tombstones in the red and light blue-lined areas seem to be standing normally considering the shape of shadow and the surrounding conditions. On the other hand, the tombstones of the yellow green-lined area are apparently overturned. However, a little difference can be seen in the H-V ratio between the normal and overturning tombstones before removing noises (Fig. 6(b), Table 2). Similar manner as the indoor experiment, a threshold of weak edges was selected in the cumulative distribution of the edge intensity (Fig. 7). Consequently, the H-V ratios for the normal and overturning tombstones showed a clear difference (Table 2). Therefore, the noise removal is considered to be a necessary step before getting information on notable edge directions from aerial photographs. This

(a) Gray Scale with compared areas (b) Edge intensity (before removal) (c) Edge intensity (after removal)

Figure 6. Images of an aerial photograph for removing noises

Table 2. Comparison of the ratio of horizontal and vertical edge directions

The ratio of H-V edge directions	Red-lined area	Light blue-lined area	Yellow green-lined area
Before removal	41.7%	39.7%	37.4%
After removal	51.4%	49.6%	38.8%

method was applied before extracting edge directions in the following experiments.

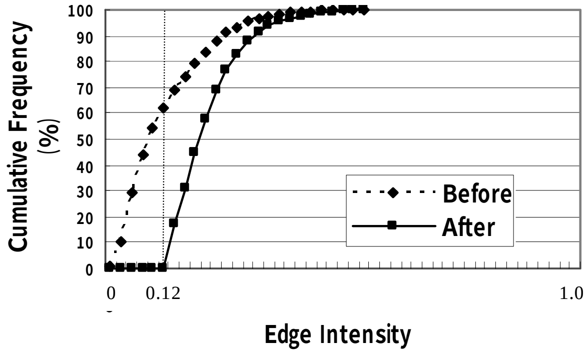


Figure 7. Cumulative distribution of edge intensity (Aerial photograph in Figure 6)

4. EFFECT OF SHADOW'S EDGE ON FILTERD IMAGES

In order to examine the effects of shadow in detail, an indoor experiment using a model tombstone was conducted under several conditions. In Japan, the styles of tombstone are roughly classified into two groups; Japanese style and Western style. Japanese style is still more popular than Western style. Thus a model tombstone was made by expanded polystyrene in Japanese style, which is composed of *Saoishi*, *Uedai*, *Nakadai*, *Shitadai*, *Hanatatedai*, as shown in Fig. 8. The size of the model is about one-third of real one. Note that a difference in the overturning mechanism between Japanese and Western style tombstones has been studied by Furukawa et al. (2005).

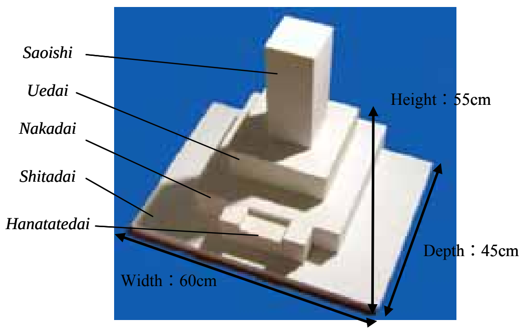


Figure 8. Model of Japanese style tombstone

Figure 9. Scene of indoor experiment

Using this model and a digital camera, digital photos were taken in various conditions in the state of tombstone, the position of light, and the resolution of an image. In the experiment, a spotlight simulating sunlight was used in a dark room. The number of patterns of tombstone and light are six as shown in Table 3: the state of tombstone (upright or overturning), the height of light (high or low), and only for the low light case, the direction of light (vertical and oblique).

First, the ratio of H-V edge directions was compared for high resolution images in Fig. 10. As seen in Table 3, the case (A) and (B) show high H-V edge ratios because the edges of tombstone and shadow extend to either horizontal or vertical direction. Although the tombstone in (C) is upright, the ratio for (C) is nearly equal to that for (D), an overturning case. Shadow's diagonal edge in (C) is considered to reduce the H-V ratio. Based on this observation, it is indicated that the edge of tombstone's shadow affects the ratio largely.

Next, the resolution of gray scale images (Fig. 10) was lowered to the same level as that of aerial photographs and then the edge intensity was calculated. Generally, *a saoishi* is about 30 cm square in the top view, which means if the resolution of an aerial photograph is 10 cm, *a saoishi* is composed of 3×3 pixels. Based on this consideration, the resolution of images was reduced as *a saoishi* model is composed of the same number of pixels. This resolution shown in Fig. 11 is about as one-tenth of the images in Fig. 10.

As seen in Table 3, the ratio of H-V edge directions was reduced by reducing the resolution because some pixels were converted to a *mixel*, which includes various components together. The cases (A) and (D) show comparatively high ratio values. It is considered that the positions of light in the two cases were high and the effect of shadow hardly affected the edge directions. On the other hand, the positions of light in the cases (B), (C), (E) and (F) were low, and the shadow's edges appeared more clearly and largely than the cases (A) and (D). In these images, the ratios were much lowered compared to theses of the images before reducing the resolution. Hence the resolution of an aerial photograph should be considered properly as well as the extent and direction of shadow in the image.

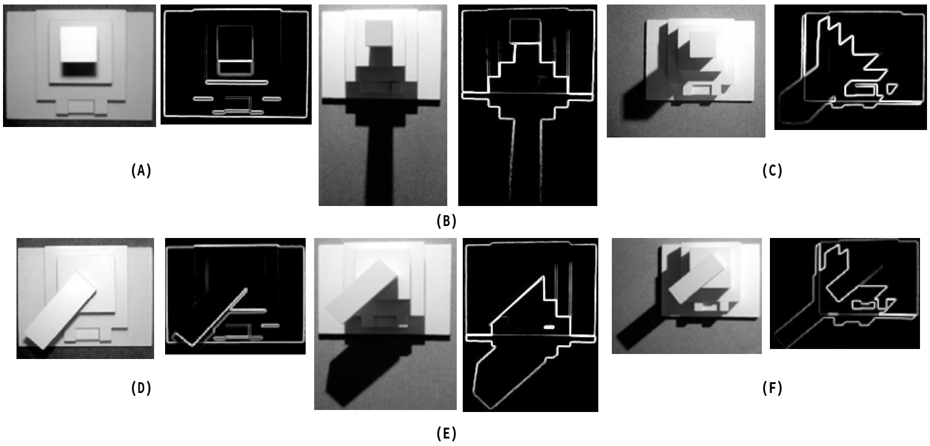


Figure 10. High-resolution images of the model tombstone and calculated edge intensity
(Left: Gray scale image, Right: Edge intensity, respectively)

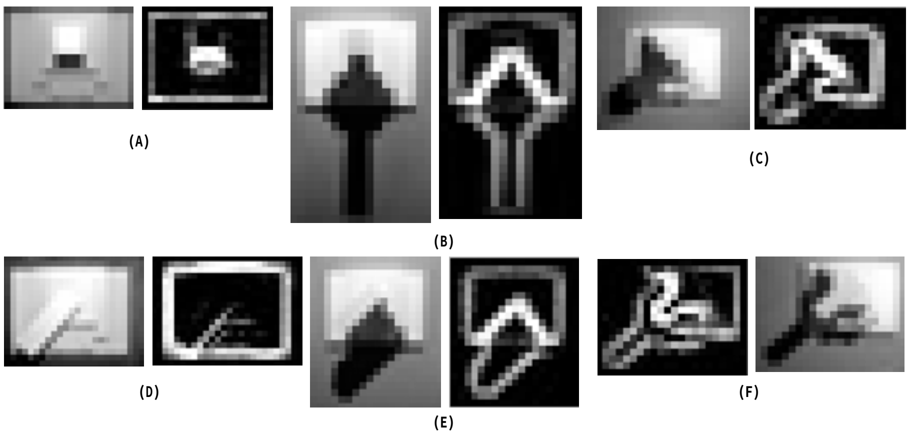
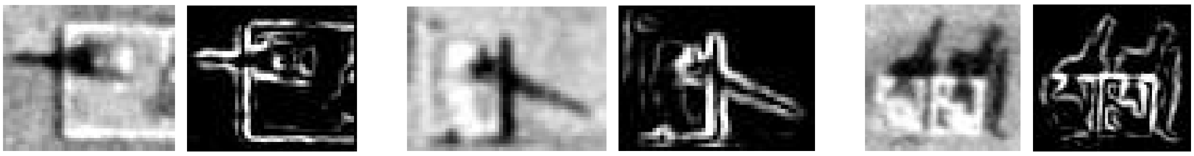


Figure 11. Low-resolution images of the model tombstone and calculated edge intensity
(Left: Gray scale image, Right: Edge intensity, respectively)

Table 3. Ratio of H-V of edge directions under various conditions

Study case	A	B	C	D	E	F
Condition of tombstone	Upright	Upright	Upright	Overturning	Overturning	Overturning
Hight of light	High	Low	High	Low	High	Low
Direction of light	—	Vertical	Diagonal	—	Vertical	Diagonal
Ratio of H-V (High resolution)	93.8%	91.8%	73.3%	73.1%	70.1%	60.1%
Ratio of H-V (Low resolution)	74.8%	50.2%	48.1%	65.1%	43.7%	38.5%

As a result of the previous indoor experiment, the edge of shadow was shown to affect the H-V edge ratio largely. Thus this effect should also be considered when using real aerial photographs. Three images of tombstones, which look upright visually, were selected as shown in Fig. 13. The edges of shadow for image (a) extend horizontally, and those for images (b) and (c) extend obliquely. As a result, the ratio for (a) is 55.9%, that for (b) 44.0%, and that for (c) 46.2%. Although all the tombstones in these images look like upright, the H-V ratios differ much due to shadow edges. The shadow's direction for case (b) is -25° and the range between -30° and -20° accounts for 6.9 % of the edge direction ratio. Similarly, the shadow's direction for case (c) is 65° and the range between 60° and -70° accounts for 6.2 % of the edge direction ratio. Therefore in order to distinguish upright or overturned state of tombstones, it is insufficient to use only the H-V edge direction ratio. The extent and direction of shadow as well as environmental conditions of the graveyard should be properly introduced in an estimation formula.



(a) (b) (c)

Figure 12. Effect of the ratio of H-V edge direction by shadow on aerial photographs
(Left: Gray scale, Right: Edge intensity, respectively)

5. CONCLUSION

An attempt to estimate the overturning ratio of tombstones due to an earthquake was carried out in this study based on image analysis of aerial photographs. The edges from a gray scale photo including tombstones were extracted because displaced tombstones may be detected through the distribution of the edge direction. As the first step, the experiments using a model tombstone were conducted under various conditions, such as the different displaced-state of tombstone, the position of spotlight, and the resolution of the image. Removing noises by a threshold of edge intensity was found to be necessary to extract only notable edges. The examination based on the ratio of vertical and horizontal edge directions shows that not only the state of tombstone (upright or overturned) but also shadow and photo resolution affects this ratio largely. Thus the direction of sunlight and the extent of shadow should be considered properly. As an extension of this study, an estimation formula for the overturning ratio of tombstones will be proposed in the near future.

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