Preliminary Study on Digital Images for Automated Identification of Structural Damages by Edge Detection

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1. Introduction

The primary importance of urban earthquake disaster evaluation is to achieve the quickness, i.e., the time to complete the estimation must be of the order of ten minutes. The object is to carry out the preliminary study of utilizing observation cameras for quick evaluation of urban earthquake disaster, see Table 1. The major concern is the examination of the accuracy and quickness in measuring displacement by means of image analysis. The content is as follows: the properties of the pixel data taken for building edges are quantitatively analyzed. The applicability of GIS to set a window for image analysis is proposed to reduce the computation cost. Also an experimental evaluation of sub-pixel edge detector is performed.

Table 1 Outline of urban earthquake disaster evaluation system

target area	a few hundred meter square (maximum a kilometer square)
target	RC buildings
analysis	displacement due to earthquake accuracy is order of a few centimeter so that relative deformation can be measured
key issues	accuracy of measuring displacement quickness of image analysis

2. Digital Image of Building Edge

Digital images are taken for buildings with some time shifts to examine the stability of the image by a cooled CCD camera. As a typical example, two-dimensional distribution of the pixel data in gray-scale for captured parts a in Fig. 1 is plotted in Fig. 2. The data change non-smoothly across the building edge. The change, however, is not uniform along the building edge. In statistical way, the mean is computed for the pixel data along the edge direction and the results are summarized in Fig. 3, based on which further edge detection is done. Almost negligible difference between the graphs of image 1 and image 2 shows the stability of the pixel data respect to time.

3. Utilization of GIS to find Analysis Window

For usual edge detection method, choosing a threshold or a suitable function for the target image requires some practice. And in building edge image analysis, the background could be sky or another building, and building images might be overlapped with each other. Based on these considerations, the authors are searching a pre-setting of an analysis window for a digital image in which the building edge possibly appears, by taking advantage of GIS which stores three-dimensional configuration data for buildings and structures the aid of aerial photo and laser scanning. Choosing a small size for the window, the computation needed for the advanced image analysis is drastically reduced. It is a straightforward task to construct a virtual structure model for each building using the 3D configuration data. However, the difficulty arises regarding to the development of a virtual digital image which mimics an actual digital image taken by observation cameras.

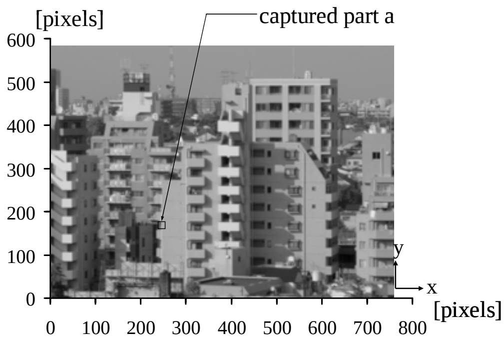

Fig.1 Examples of digital image taken by cooled CCD camera

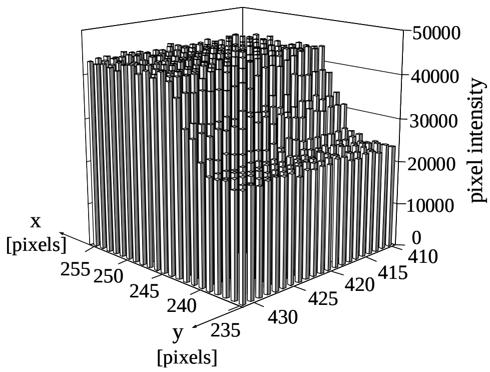

Fig.2 Two-dimensional distribution of pixel intensity

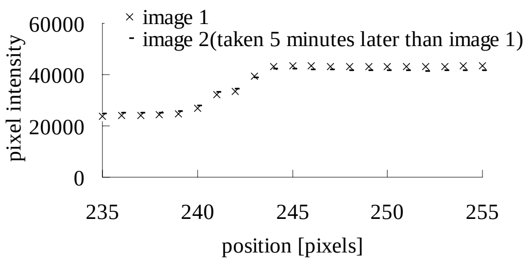

Fig.3 Mean value

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Since the location and orientation of the camera is precisely given, the virtual digital image can be made very close to the actual digital image. The difference in the box configuration shown in Fig.4 is a few pixels.

(a) virtual digital image

(b) actual image

Fig. 4 Example of virtual digital image

4. Edge detection in sub-pixel scale

How and on what degree we can measure the shift of the building is the key issue in automated identification of structural damages. To realize it, a relative object in the digital images such as a line or a point with high accuracy position has to be identified, which makes edge detection in sub-pixel scale important. Automatic accurate edge detection requires low computational cost. Since the images taken by cooled CCD camera has the strong stability about the pixel intensity, the simplest way to get the sub-pixel edge position is taking advantage of the mean value before and after the edge, then with the average of those two value the cross pixel position can be detected using linear approximation.

In the experiments, the cooled CCD camera used to take photos only moves in one direction step by step automatically on the automated optical stage. In our experiments, the camera moving distance is from 1 cm to 15 cm. For each step, 30 images are taken at the interval of 2 seconds by the cooled CCD camera automatically. Fig. 5 and Fig.6 shows the digital images and pixel intensity corresponding to the edge in the images. For outdoor image, one pixel corresponds to 35.59 mm. Table 2 shows the comparison between observed edge shift and the shift of the camera. The maximum error is 0.473 pixels (16.821mm).

Since the high-speed and high accuracy of the edge detector is the key problem in proposed automated identification system. If we can detect the edge shift of the structure before and after earthquake with high accuracy, for example 0.1 pixels or perhaps 0.01pixels, the accurate displacement can be obtained and other analysis can be done based on that.

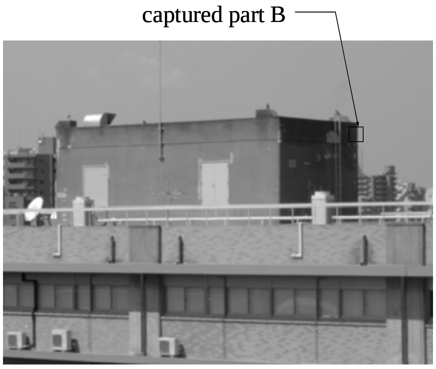

Fig.5 Outdoor digital image

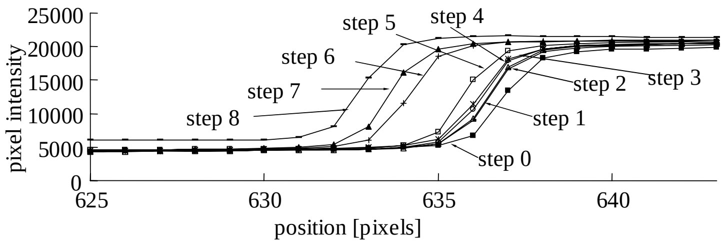

Fig.6 Pixel intensity of captured part B in Fig.5

Table2 Comparison of edge shift in sub-pixel scale of outdoor case

camera shift (um)		10000	20000	30000	40000	50000	100000	120000	150000
(a)corresponding edge shift (pixels)		-0.281	-0.562	-0.843	-1.124	-1.405	-2.810	-3.372	-4.215
(b)experimentally identified edge shift (pixels)		-0.382	-0.398	-0.562	-0.651	-1.119	-2.645	-3.231	-4.053
error =(b)-(a)	(pixels)	-0.101	0.164	0.281	0.473	0.286	0.165	0.141	0.162
	(mm)	-3.590	5.832	9.992	16.821	10.165	5.876	5.013	5.754

5. Conclusions

This paper carries out a preliminary study on utilizing observation cameras to meet the demand for the quickness in evaluating urban earthquake disaster. The key issue is the examination of the high-accuracy and high-speed in measuring displacement by means of image analysis. The properties of the digital images of the edge of the structure under different weather conditions are analyzed in listing the images taken by two kinds of CCD camera, low-noise cooled CCD camera and common camera. The proposed consideration of pre-setting of an analysis window including the edge of the structure can drastically reduces amount of computation with a help of GIS data. Sub-pixel edge location is the key issue in the proposed method. Automated identification with high-speed and high-accuracy is needed.

References

1) David A.Forsyth and Jean Ponce, *Computer Vision: A Modern Approach,* Prentice Hall, USA, 2003.
2) Yi Ma, Stefano Soatto and etc, *An Invitation to 3-D Vision,* Spring, USA, 2005.