DEVELOPMENT OF IMAGE PROCESSING TECHNIQUE FOR CRACKED RC STRUCTURES

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1. INTRODUCTION

The earthquake and environmental conditions are the major causes for damaging the concrete structures and inspection of these structures is necessary to estimate the damage. Visual inspection to evaluate the degree of deterioration of the damaged concrete structures is possible but takes time and requires experience. A method to determine the degree of deterioration in an efficient way is image processing. This method is used to extract digital data as crack pattern and crack width from the images of damaged structures. Using the crack pattern and crack width the degree of deterioration of damaged concrete structures can be determined[1)].

Accuracy of the results will be achieved if the resolution of the analyzed images is high. Assembling local images having high resolution is a solution to solve the resolution problem. To obtain the global image continuity of local images must be satisfied. During the assembling procedure the local images must have continuity in vertical and horizontal directions.
The cracks are the starting points in the damage estimation process. The extraction of cracks is done using vectorization where pixels are defined by its position and its intensity. The pixels that have the color darker than a predefined threshold represent the crack and whiter than the threshold, the uncracked region.

From image processing, density index, direction and distribution indices to characterize the cracks can be obtained and used in the damage analysis[2)].

2. METHODOLOGY

In case of vertical structures as a bridge pier, the continuity on vertical direction of the local image can be ensured by a special guide system. Along this system the camera slides and images are taken at predefined points. **In Fig. 1** the method to take the images is described. The position of the camera at which the images must be taken is given by d_p that is a function of height of the image d_c and overlapping distance d_l necessary to stitch the images together. The height of the image d_c depends on the camera angle, distance between camera and structure, and is also a function of zoom of the camera used to take the image.

After determining the predefined points the positions are marked on the linear guide and the local images are taken. Assembling the local images into the global one can be performed by a software that stitches all the photos together.

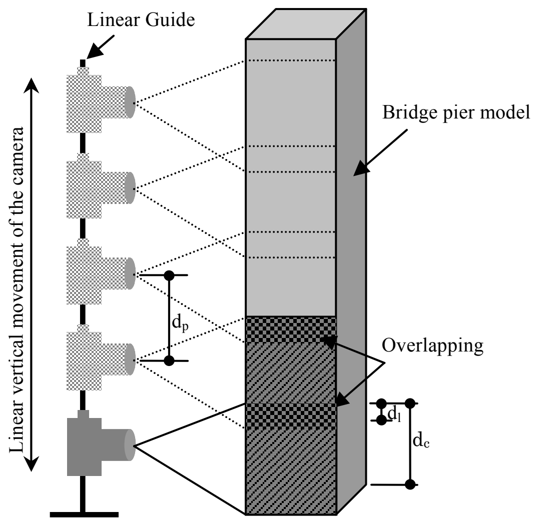

Fig. 1 Methodology for obtaining local images

3. INDICES FOR CRACK CHARACTERIZATION

3.1 Density index

The density index is defined as the density of the pixels of an image with the color darker then a predefined threshold. Density of cracks is an important feature of cracks. Knowing the density of cracks of structure the failure mode is predicted.

3.2 Indices for direction

There are two indices for direction that refer to long runs emphasis LRE and edge gradient emphasis EGR of the pixels with darker color corresponding to cracks.

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These indices can describe the direction of cracks and it will complement each other. From image processing, values of the indices are obtained. Each value corresponds to a certain direction (0, 45°, 90°) as given in **Fig.2.**

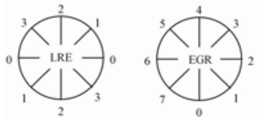

Fig.2 Directions for LRE and EGR

3.3 Distribution index

The distribution index is determined by projecting and then summing up the darker pixels, pixels that represent the crack, on x or y directions. The obtained distribution presents some peaks as it can be seen in **Fig. 3**. The image is rotated with 5° pitch and distribution is determined for the each rotation until the maximum peak is obtained that represents the distribution index.

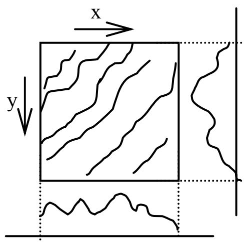

Fig. 3 Distribution of pixels

4. APPLICATION OF INDICES

The local image data from **Fig. 4** corresponds to an experiment where six RC columns have been subjected to reversed cyclic loading[3]. For the same zone of interest flexural cracks at the beginning of the loading can be seen and in the later stages shear cracks. Image processing indices are obtained for these to images. Density index is presented in **Table 1** where Hand D refer to horizontal and diagonal cracks and R, L refer to the cracks from left and crack from right.

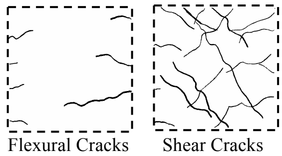

Fig. 4 Local images

The direction indices LRE and EGR are calculated for the flexural cracks and shear cracks from the left and from the right and are shown in **Fig. 5** and in **Fig.6** distribution index is shown for flexural and shear cracks.

Table 1 Density index

Image	HR	HL	DR	DL
Density index (%)	0.8	0.48	1.79	2.3

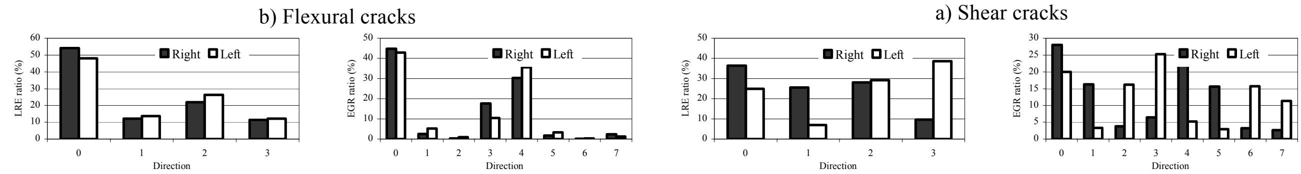

Fig. 5 LRE and EGR

5. CONCLUSIONS

Characterization of cracks by the above indices shows the potential of image processing in the analysis of concrete structures. Density of cracks can predict the failure mode, direction index gives the analytical model to be applied and distribution index shows the crack spacing.

The accuracy of these indices can be improved by the proposed methodology, and from images with high resolution, crack width can be estimated.

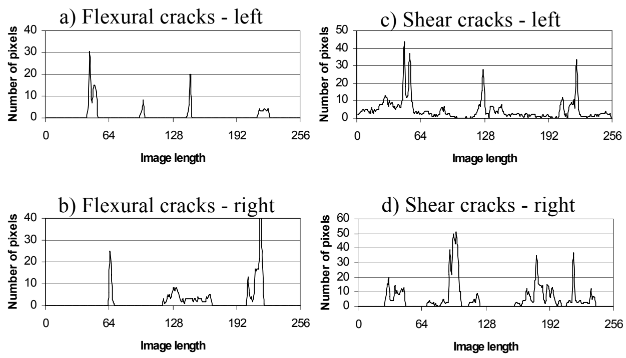

Fig.6 Distribution index

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