Cracking Detection on 2D Concrete Images

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Introduction

Early detection on concrete cracking allows preventive measures to be taken to prevent damage and possible failure on engineering structures[1-2]. With the development of deep learning, more applications of image processing are explored in the field of Structural Health Monitoring(SHM)[3], in particular, concrete cracking detection[4-12].

A large number of image processing techniques[4-7] are proposed and applied on cracking detection. Abdel-Qader, et al.[4] provided a comparison of the effectiveness of four crack-detection techniques: fast Haar transform (FHT), fast Fourier transform, Sobel, and Canny, using a sample of 50 concrete bridge images. The results showed that the FHT was significantly more reliable than the other three edge-detection techniques in identifying cracks. Fujita, et al.[5] proposed a robust automatic crack-detection method from noisy concrete surface images, and evaluated robustness and accuracy of the proposed method quantitatively using 60 actual noisy concrete surface images. Nishikawa, et al.[6] presented a new robust automated image processing method for detecting cracks. It can be used for the accurate detection of cracks in surface images recorded under various conditions. Hutchinson, et al.[7] presented a statistical-based method for conducting image analysis, specifically for the purpose of evaluating concrete damage (cracks, spalling, etc.).

Furthermore, study on application of deep learning on crack detections has gained extensive interests [3, 8-12]. Cha, et al.[8] designed a CNN which is combined with a sliding window technique to scan any image size larger than 256 × 256 pixel resolutions. Comparative studies are conducted to examine the performance of the proposed CNN using traditional Canny and Sobel edge detection methods. Dung, et al.[9] proposed a crack detection method based on deep fully convolutional network (FCN) for semantic segmentation on concrete crack images. Jiang, et al.[10] proposed a real-time crack inspection method based on CNN to address the difficulty of quick deploy. Li, et al.[11] designed a CNN through modifying AlexNet and then trained and validated with the highest accuracy of 99.06%. Reza, et al.[12] discussed on varying CNN implementation on civil structure crack detection. Dong, et al.[13] proposed a hybrid model to detect cracks without using large datasets.

In this project, to practice the knowledge gained in Computer Vision class, different image process techniques are employed to an example image of cracking concrete. Then a CNN model is built to classify 1000 images into two categories, namely cracking and non-cracking.

Framework

The project consists of the following four steps:

1. Image enhancement
2. Edge/crack detection
3. Use high-level API (i.e. OpenCV)
4. Build CNN model

Image enhancement

For image enhancement, first the image is converted to gray scale, and then used different approaches, including histogram equalization, linear stretch and brightness mapping.
Compared to the original image, gray scale image looks brighter, while histogram equalized image looks darker. Linear stretch and brightness mapping did not improve the image significantly. So the gray-scale image is used in the next steps to detect cracks.

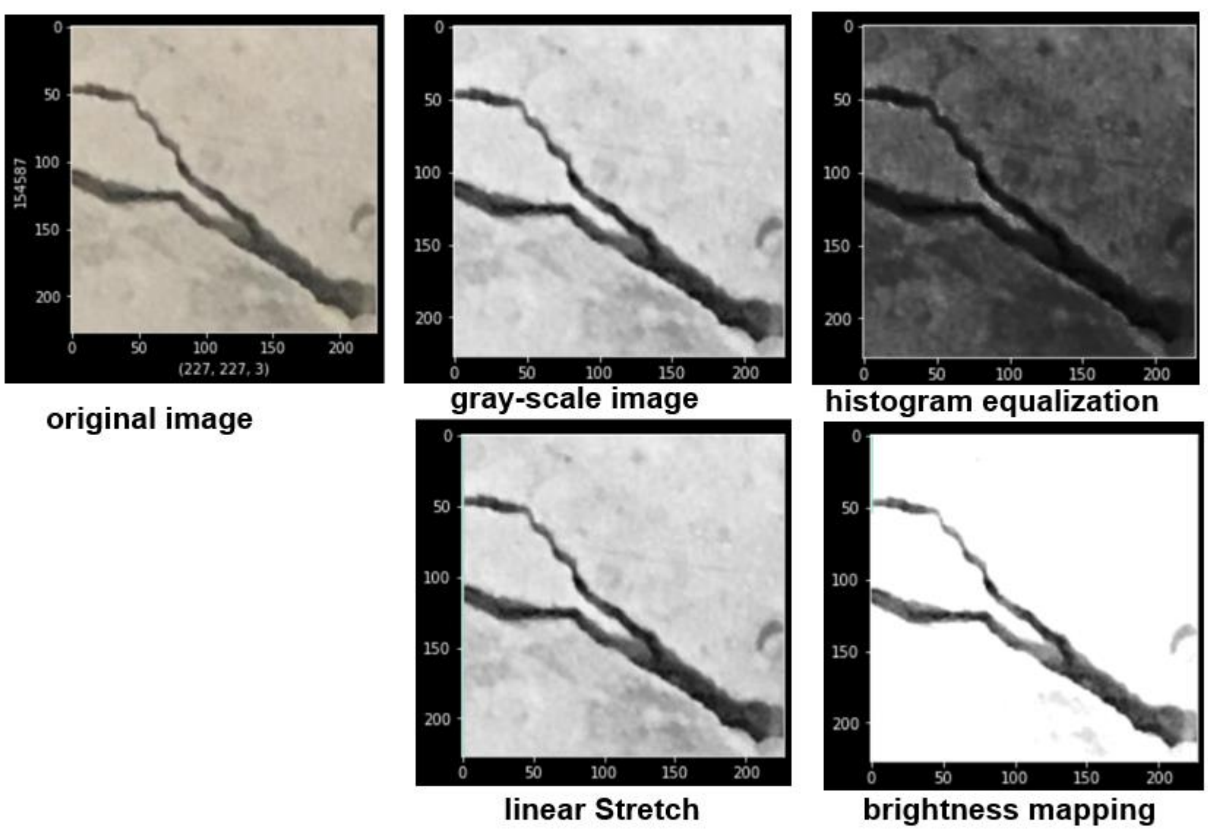

Fig.1 Comparison on Different Image Enhancement Approaches

Edge/crack detection

For edge detection, firstly the thresholding approach is conducted. The histogram is checked, we can see from the Fig.2, there are one sharp peak and one slight valley as well as one low plain. The valley is ranged from 0.45 to 0.6 which should be a good range for thresholding.

Fig. 2 shows results of varying thresholding. It is noted that the image with threshold of 0.6 shows not only cracks but also other stains on concrete surface. With threshold of 0.45, we can clearly distinguish the cracks.

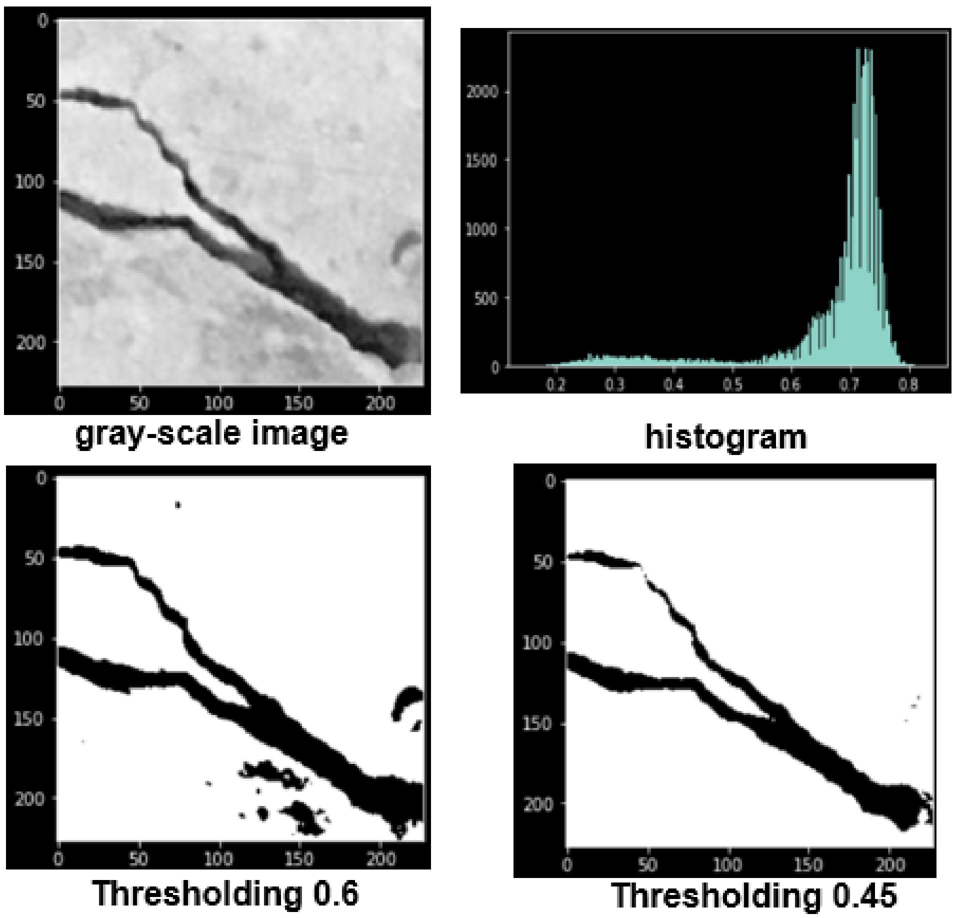

Fig.2 Thresholding Results

Next, Sobel kernels with three different direction are used to filter the image. As shown in Fig.3, the horizontal, vertical and combined Sobels are applied on the gray-scaled image, respectively. And it represents indirectly the horizontal, vertical and inclined gradient components. The combined Sobel has the best performance and shows the crack most clearly, since this crack is inclined and perpendicular to the Sobel. The horizontal Sobel performs the worst, as the angle between the crack and the Sobel is small.

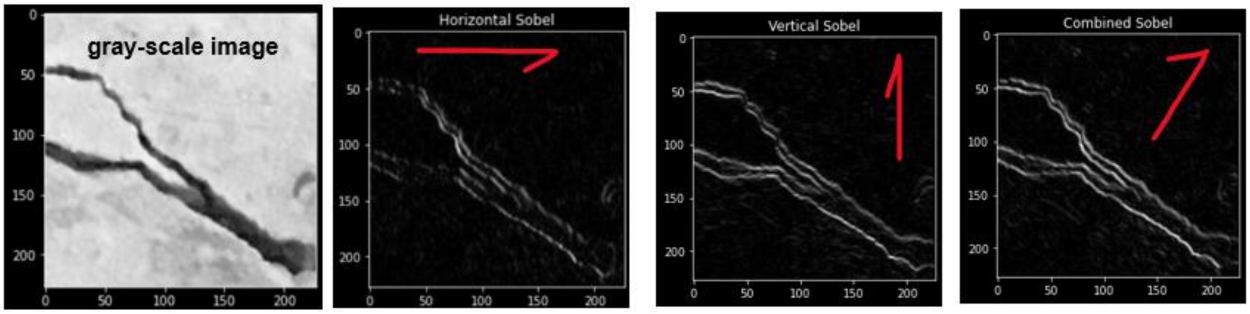

Fig.3 Sobel Filter Results

Last, a certain percentage of pixels with the highest gradient values is kept in the each subplot of Fig.4. It shows the higher percentage of the highest gradients left, the more detailed edges.

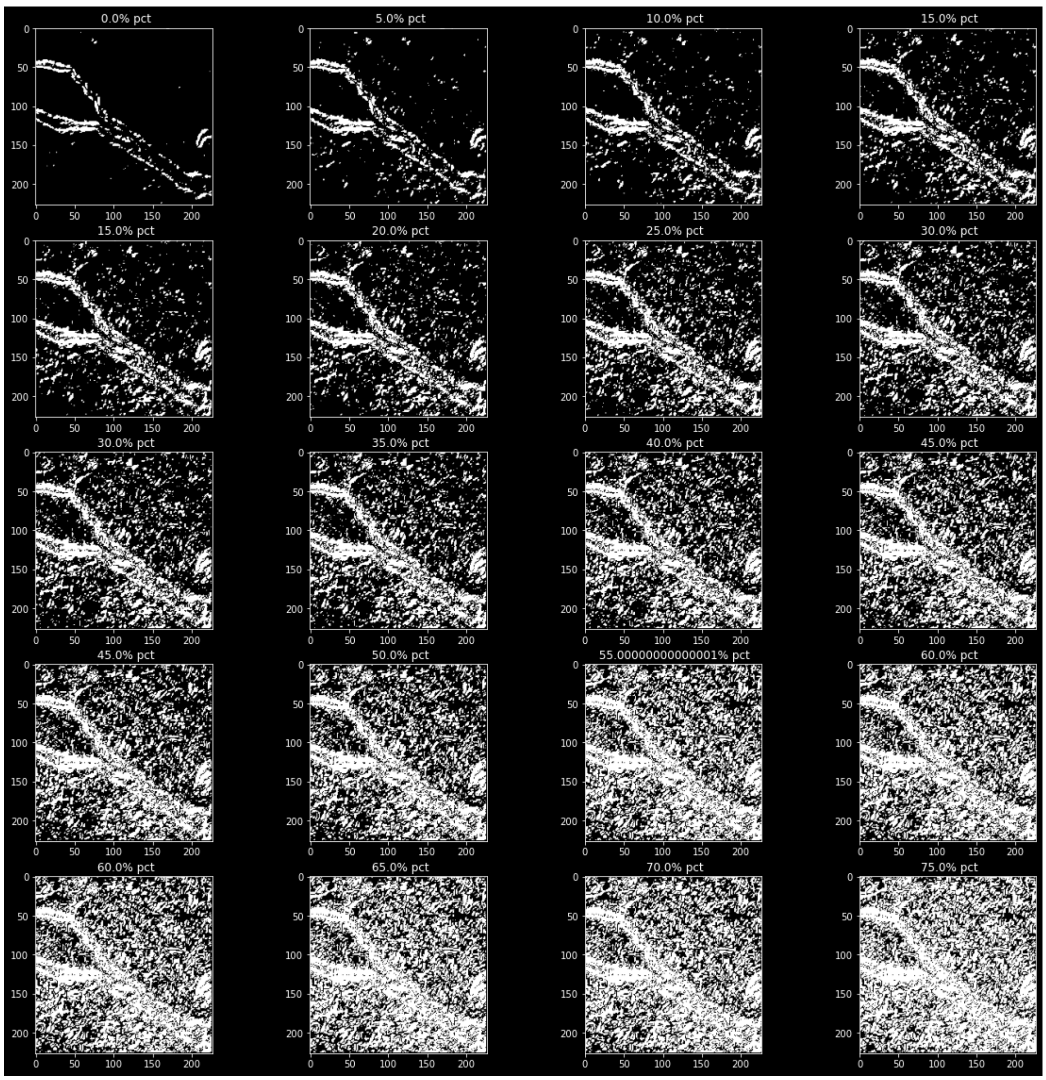

Fig.4 Effect of Filtering Varying Percentage Pixels of Highest Gradients

Crack detection using high-level API

For comparison, Canny edge detector and threshold modules in OpenCV are used, and the results are plotted in Fig.5. Compared to Fig.2, it also shows clearly concrete cracks.

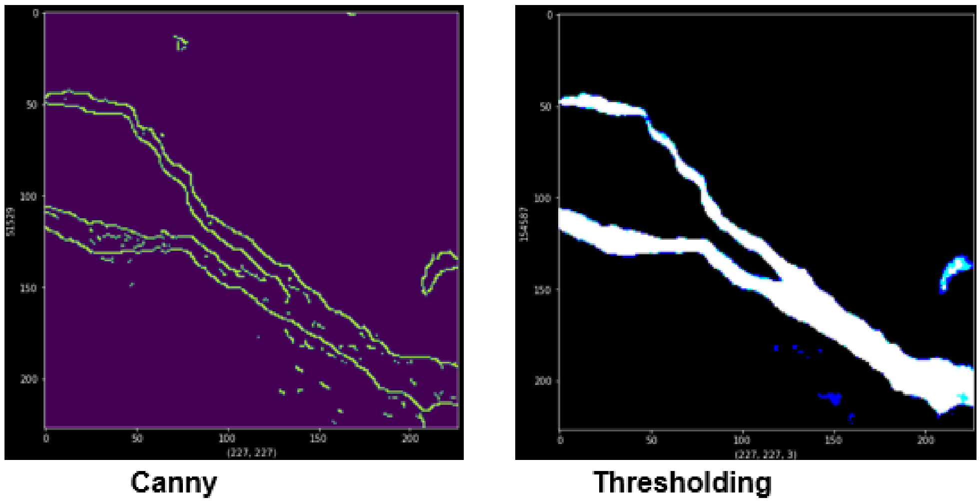

Fig.5 Results from OpenCV

Build CNN model

In this section, a CNN model is built to conduct a classification task. Given 1000 images of concrete as input, the model classifies the images into cracking or non-cracking as output. It consists of 1 input layer(120x120x3), two conv2D layers(118x118x16, 57x57x32) followed by two max_pooling2D layers respectively, one globel_averager_pooling2D, and a output dense layer.

The model performs good, the test loss is 0.057 and it has high accuracy of 97.91%, and it is not overfitting or underfitting from the learning curving plotted in Fig.6.

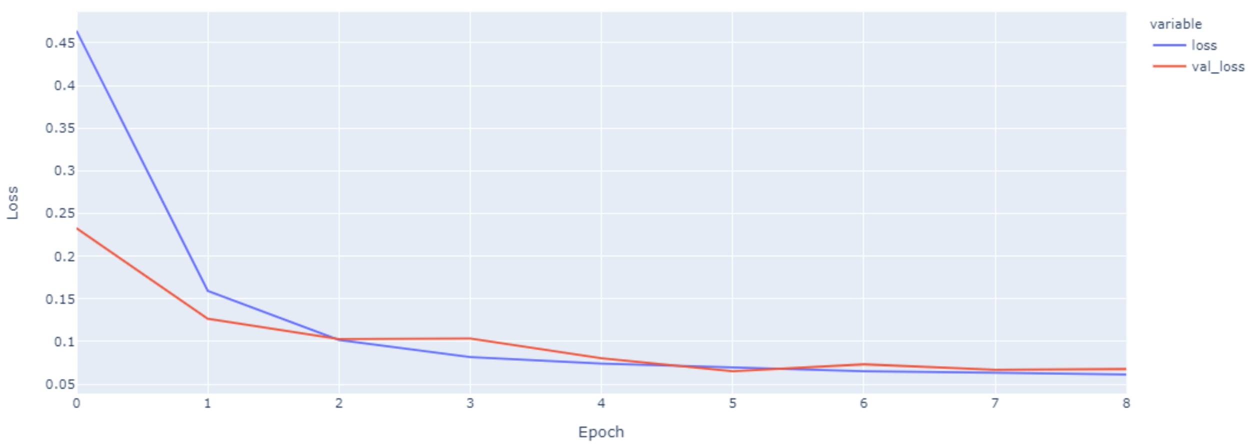

Fig.6 Training and Validation Loss Over Time

Conclusion and future work

In this course project, different approaches are employed to process concrete cracking images.

Generally, the thresholding and canny approaches have a good performance on identifying cracks.

Sobel kernel is also good for detecting cracks in a particular direction, which could be used to identify potential failure modes of engineering structures.

The application of cracking detection is promising in the field of SHM. The future effort should be exerted on not only whether cracking or not, but also measurement on the width, depth and prediction on the direction of cracking propagation.

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