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Image-Based Crack Detecting using Convolution Neural Network (CNN) with Less Data

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Abstract

The maintenance of building or structure is more important problems. To keep checking the safety of structure, the periodic and accurate inspection is necessary. The conventional method to inspect structure need lots of human resources and time, so, for reducing cost, time and further efficient measurement, image-based crack detecting that could be automatically conducted is necessary.

This paper is focused on image-based crack detection method using a deep convolution neural network (CNN) with less Data. For getting well-predict model, a lot of data for train the model, delicate design of CNN-structure, and accurate image-processing. This paper specially treat the method for getting higher accuracy with less Data. With some level of trained models, predict cropped target image repeatedly, and it is the method of rating the score. Getting 1 point when predict accurately, otherwise get zero point. Theoretically, with this method, accuracy of prediction for target images is increased. As a result, as the number of models are increased, the predictions of each target images are getting accurate.

1. Introduction

The conventional method to detect crack is based on human resources, they directly inspect crack, water leak, damage, material degradation, etc. Image-based crack detection by using CNN could reduce time for examination and increase the accuracy of measurement that, in actual condition, people measure the crack's features such as length, width in person.

To conduct examination by using this technique, the image size of subject to inspection is need to same as the trained image. Actually, the part of crack in concrete-wall has a little, so model is might be biased if trained by these images, ultimately, these images affect negatively to model. Using small size of image is effect to train the model.

Research about Crack detection is proceeding, and there are already several

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models for image-based the crack detecting. However, most of models are trained with lots of data it means it took time for trained their models. And this process makes the model's accuracy to be increased. However, in some case, computer power is limited and these whole process is difficult to conduct.

This study focused on method for getting higher accuracy with less data. We observe how much increase the accuracy and changes the result of crack detecting when applied actual concrete crack images

2. Methodology

2.1. Image processing

Image consist of length, width, and layer, the layer represent color scheme. Most of layers of image are 3 that represent RGB. However these color is not necessary to detect depth, due to feature of color is not significant factor in crack detection. The darkness of crack part and difference between crack part and original concrete wall part are more important. In actual concrete surface, there are lots of noises with crack. So in this process, the classification between crack and noises is most important.

The actual images of concrete surface are not ideally neat but rough. Also, some of images have pattern not crack. These features need to be removed from the original images. For these process, several filters are used such as Gaussian Blur, binary and OTSU threshold filter. Both make original images to be ordered surface and removed unnecessary part in Crack detection.(Fig. 1, Fig. 2)

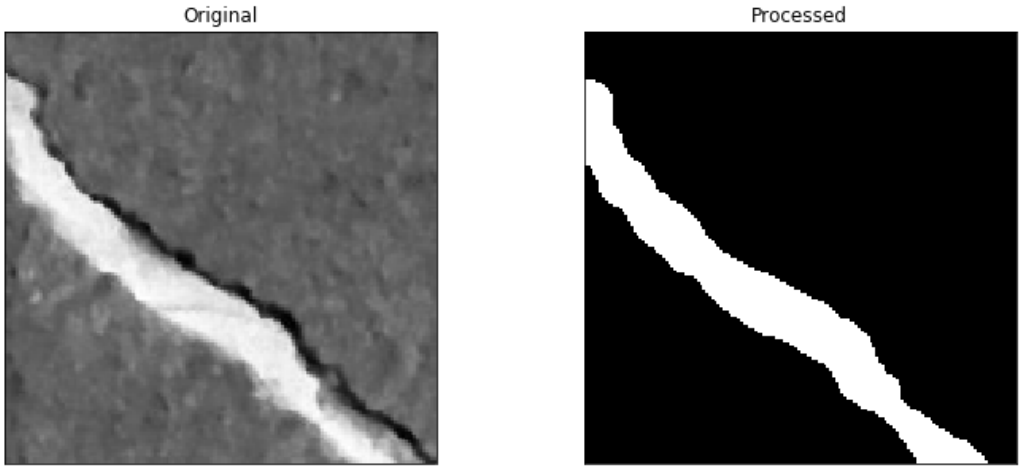

Fig. 1 Compare Original Image to Processed Image

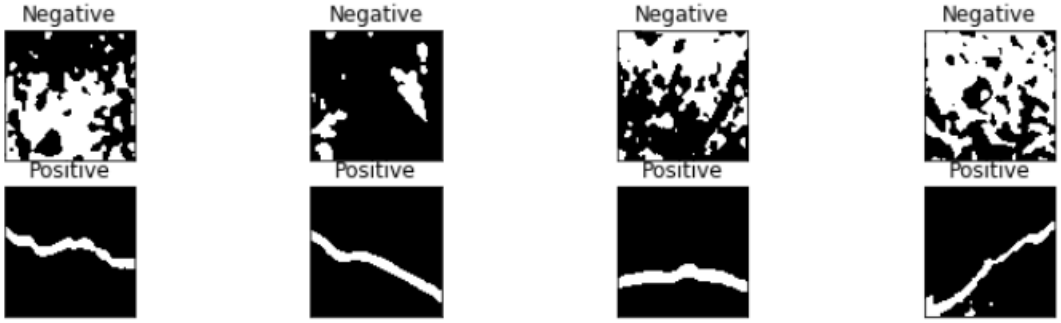

Fig. 2 Image Processing (Negative = No Crack, Positive = Crack)

2.2. Deep convolution neural network

By using proceed images, the model is trained according to the architecture of Convolution Neural Network (Fig. 3, Table. 1). In overall this project, the 5000 images respectively the crack and non-crack images are used, of which 5000 images that consist of 2500 images of crack, and 2500 images of non-crack are used in trained process. Other 1250 images (Each 1250 images of Crack and Non-crack) are used to check the accuracy of each models. Finally, rest of images are used in getting accuracy of decided model, and this accuracy is represent general accuracy because the images for test are not used in trained process and those images are randomly chosen.

In Deep-Learning process, Convolution layers mean the records of patterns information, and Pooling layers represent how many include the patterns. The values of those layers are updated according to trained process, and cost represent how difference between predicted value and actual value. As train progress, the value of cost tend to be decreased (Fig. 4).

Finally the fully connected layers act as dimension reduction. As input data pass through the convolution layers, the amount of data is large, need to be reduce to classify the data. At the final point, the result represent 0 (Negative) or 1 (Positive). Also, to prevent overfitting to trained data and reduce the error, dropout function is used, it means randomly several feature is removed in the middle of training.

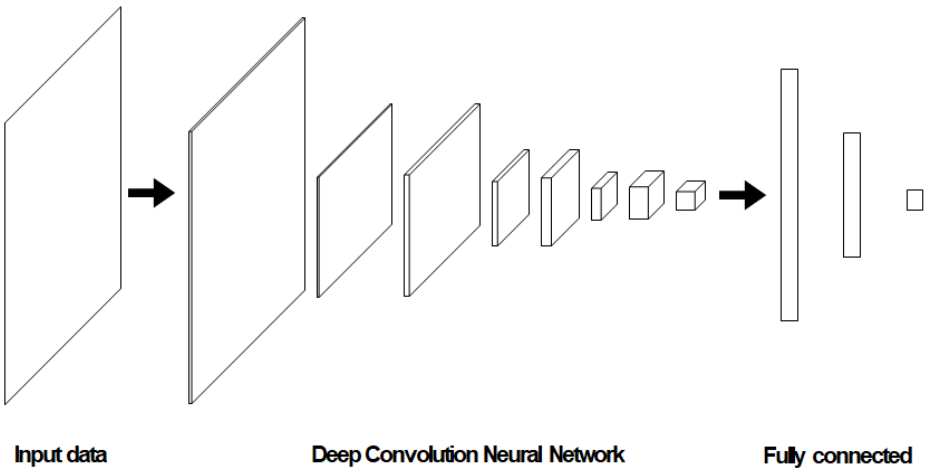

Fig. 3 Overall architecture of Convolution Neural Network

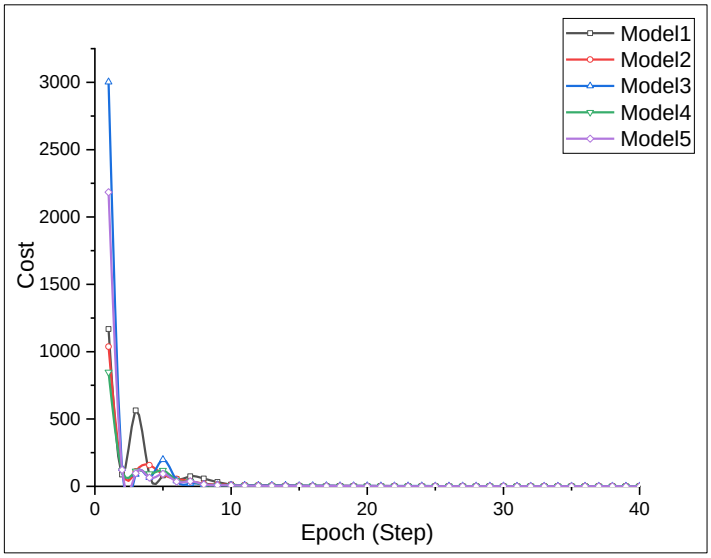

Fig. 4 Variation of Cost value in Each Model

Input data		CNN		Fully-connected	
Layer	Size	Layer	Size	Layer	Size
Input data	150×150×1	Conv1	150×150×16	Dense1	1000
		Pool1	75×75×16		
		Conv2	75×75×32	Dense2	100
		Pool2	38×38×32		
		Conv3	38×38×64		
		Pool3	19×19×64		
		Conv4	19×19×128	Dense3	2 (Softmax)
		Pool4	10×10×128		

Table. 1 Details of CNN (Conv = Convolution, Pool = Pooling)

2.3. Application to Test Image

To verify the model's accuracy, the images from open source are used to test (https://unsplash.com/search/photos/concrete). Not only these images, but also other images have different color, brightness, and difference between crack and concrete. Therefore, in image processing, it is not proper that applied the same standard to target Images. According to Detailed instructions about Safety check and precision safety diagnosis (2010), the Lowest score in crack aspect means the area of crack is larger than 20% overall area. By using this instruction, each image transformed grayscale. And then could get the histogram of target image (Fig. 5), it represent the distribution of

brightness (0 means black and 255 means 1). The shape of histograms are various. In crack images, the crack part is darker than other part. And in image processing, the crack part image changed to bright, others are dark. Therefore, could transform the original image (gray scale image) more clearly. The value of larger than some point could be changed white color and others black.

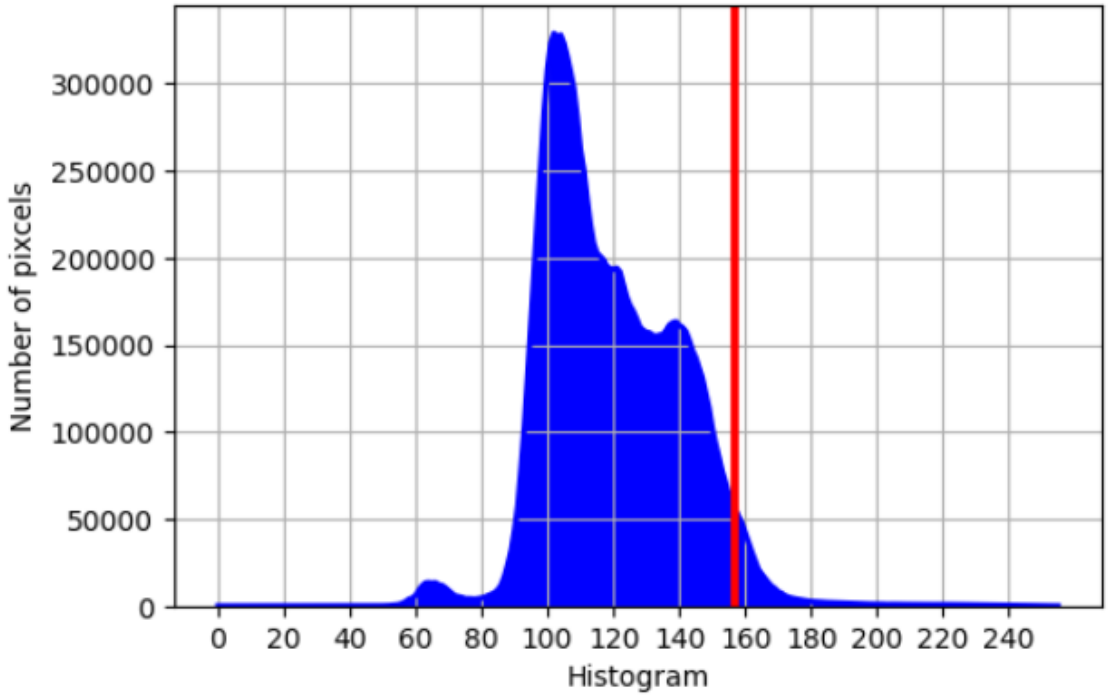

Fig. 5 Histogram of Target Image

The size that used in trained process is 150 ×150, it is cropped size. So, before passing through the deep-learning filters, divide processed target images into several pieces in size 150 ×150. In the case that is not clearly divided, the lacking parts are filled with black pixels to trained all surfaces. During the passing filters process,, the result is Positive, then output the original data, but in the case of Negative, the output is data that all pixels have zero-value it means black. After all cropped images pass the filters, combine those images. If it is crack image, could get crack image with less noises. On the other hand, if it is non-crack image, could get just black image without any noises or with less noises (Fig. 6).

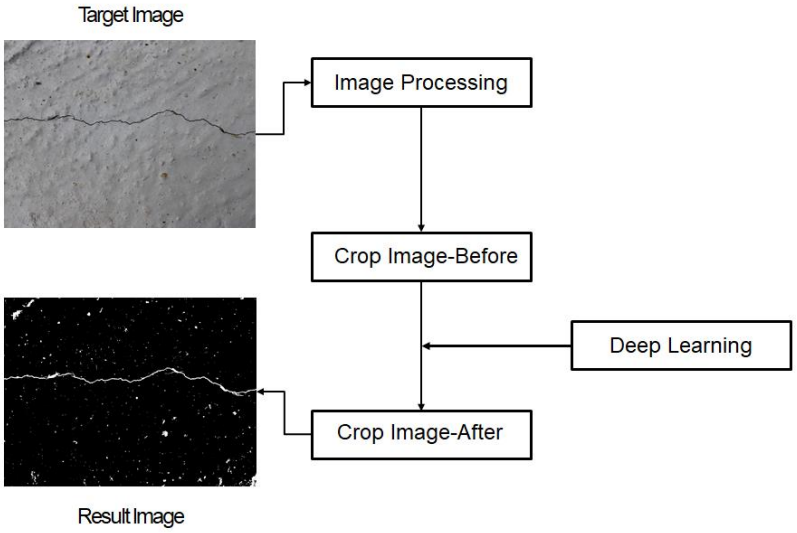

Fig. 6 Overall Crack Detection Processing

2.4 Getting Higher Accuracy

To get higher accuracy, the lots of amount of data for train are needed, also, the well-organized CNN structure is needed. The amount of data is directly related to the computer performance. There is method of overcoming shortage data in same condition. If the same data pass through the several models that are already trained, the accuracy is increase.

In theoretically, assuming the probability of an accurate prediction is 90%, the accuracy is changed depending on the number of repetitions. But the accuracy is increased compared to the case that pass through the filter once in common. Therefore, with a small quantity of data, the getting higher accuracy is feasible when there are several models that have high accuracy.

# of repetitions	Score	Accuracy	%
3	≥2	${}_3C_2 \cdot (0.9)^2(0.1) + {}_3C_3 \cdot (0.9)^3$	97.2
5	≥3	${}_5C_3 \cdot (0.9)^3(0.1)^2 + {}_5C_4 \cdot (0.9)^4(0.1) + {}_5C_5 \cdot (0.9)^5$	99.144
7	≥4	${}_7C_4 \cdot (0.9)^4(0.1)^3 + {}_7C_5 \cdot (0.9)^5(0.1)^2 + {}_7C_6 \cdot (0.9)^6(0.1) + {}_7C_7 \cdot (0.9)^7$	99.7272

Table. 2 Relation between the number of repetitions and Accuracy. (Hypothesis : The probability of an accurate prediction is 0.9.)

3. Results

3.1 Accuracy of models

In training process, because dropout function conduct differently, could make several models. Base on each model's accuracy from Validation-Data, from the highest

model, get models that need to processing. Theoretically, as the number of models increase, the accuracy is increased. However, it takes a lot of time as much to augment of number of models. Therefore, for efficient analysis, number of models should be controlled.

When choose only one model, from several models, could get accuracy in each model. Among those models, the model that has highest accuracy for validation data should be chosen, that is validation data's role. From this model, with test data, could get general accuracy. In this model, general accuracy is 91.72%. (Table. 3)

	Validation Data					Test Data
Model	1	2	3	4	5	-
Accuracy	0.8996	0.8944	0.8764	0.9216	0.9104	0.9172

Table. 3 Accuracy of model and Accuracy from the chosen model. (# of models = 5)

Along the same lines, when choose several models, choose from the highest accuracy for validation data. From each model with test data, could get accuracy of prediction about general data.

3.2 Result of Crack detection (# of model : 1)

In the case of using one – model, the general accuracy is 91.72% that means several errors occurs. From the result, we could know the crack is exist in crack-image. However, there are some blank, looks like crack is not continuous. If it gets severe, it shows some parts with being unaware of crack.

In non-crack image, there exist noise part but it does not look crack. Also, compare with crack image, it shows difference. In crack image, there are several linear lines, while non-crack image have no linear lines. (Fig. 7)

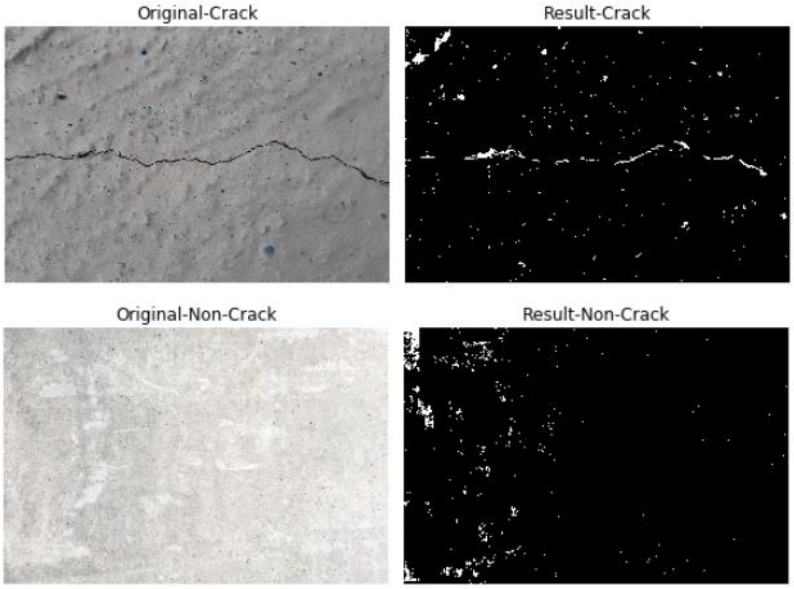

Fig. 7 Crack-Image and Non-Crack Image

3.3 Result of Crack Detection depending on Number of Models

Theoretical, as the number of model is increased, the accuracy of result should be increased (Fig. 8). And actually, from case that use one model to use nine-models, could predict target Images. When predict with one model, there are several empty space where exist crack clearly, while in nine-models case, there is no space. The last case is most similar with the original image.

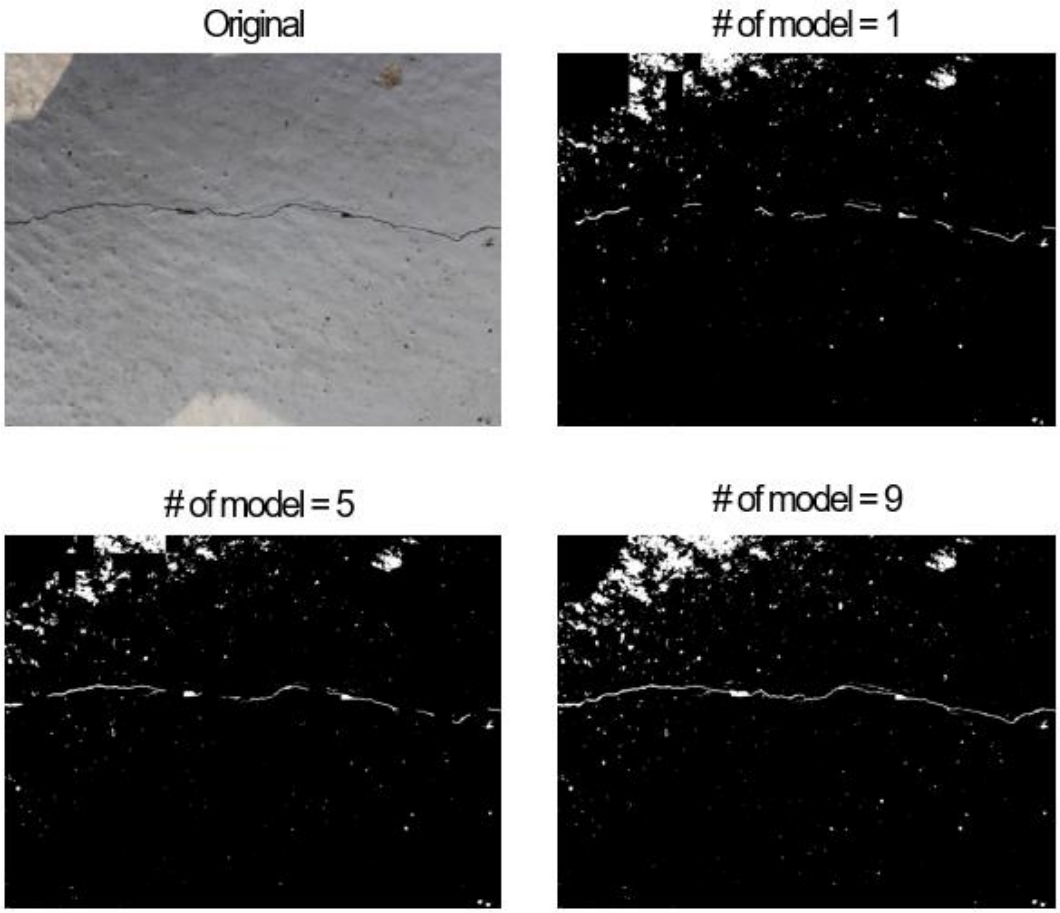

Fig. 8 The result of Crack detection depending on the number of model used.

4. Conclusions

This study proposed method for crack detection with less data using Deep Convolution Neural Network (CNN). For accurate crack detection with less data, the model should be well trained, so, before the train part, image processing need to be conducted. In this process, something like crack such as scratch, pattern and shadow are removed except for cracks.

When conduct crack detection using one-model, the low accuracy due to low data exist. And for this reason, the model predict crack part to non-crack part, target images are not predicted accurately. However, by using several models, crack detection is based on score from the frequency in correct prediction. This case present higher accuracy in comparison with using only one model.

However, exquisite image processing for train the model and effective structure of deep Convolution Neural Network are the most in need for an accurate crack detection.

ACKNOWLEDGEMENT

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