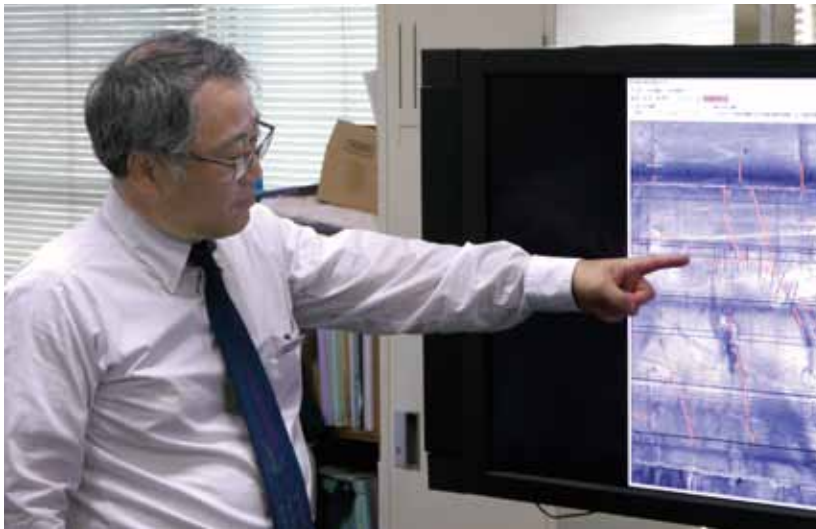


Deep Learning Finds Tunnel Cracks



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Introduction

Since maintenance and inspection services for railway structures depend on visual inspection, we have inherent problems in terms of work efficiency and accuracy of inspection. In the efforts to find a solution to these problems, image processing technologies are being highly anticipated to be practically implemented in maintenance and inspection services as soon as possible as an alternative to visual inspection.

So far, RTRI has proposed methods to detect cracks and other deformation based on shading and contours observed in a target image. However, the approach taken in such development efforts is basically a trial and error process to find an optimum

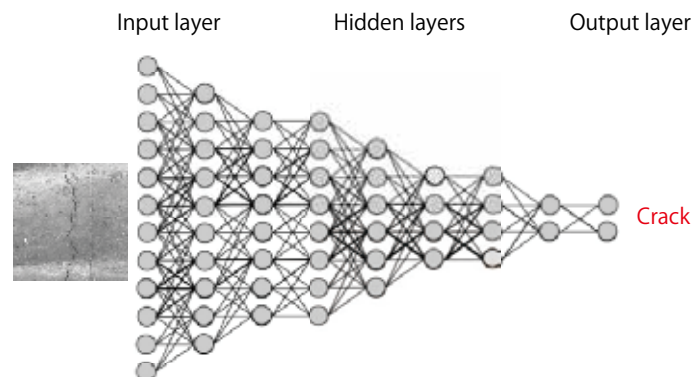
algorithm, which is based on experience. To overcome this issue, deep learning might be applied to detect cracks, which is recently attracting much attention. By

combining deep learning with the image analysis techniques so far developed, an improved method could be developed that can provide a crack detection capability comparable to that of human judgment.

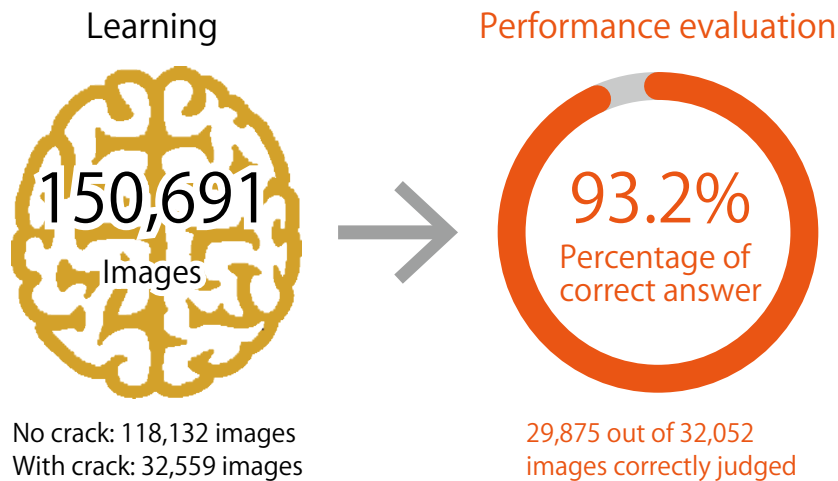
Overview of the proposed method

In conventional image processing programs, it takes significant effort and know-how to adjust the parameters. In addition, it is difficult in image processing to remove noise images, such as those of cables and joints, that look like cracks. A deep learning structure with multiple intermediate layers of the neural network is, thus, applied to create a discriminator that can determine the presence of cracks in each area.

This method mainly consists of “learning” and “deduction” processes. In the learning process, a large number of labeled images are iteratively studied to find out specific characteristics such as regularities and common patterns to eventually create an identification model. To provide training data for the learning process, a tunnel lining surface is meshed and classified each mesh segment (cell) into either “crack (with cracks)” or “none (no cracks),” according to the presence of crack. Any cell that contains a cable or joint, or both, was classified as



Deep learning is a machine learning method using deep neural network which consists of multiple layers between the input and output layers.



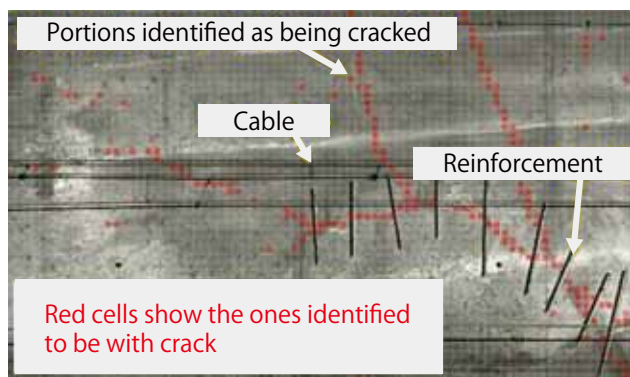
Evaluation of correct answer rate with verification images

“none”. Several tens of thousands of mesh segment images are prepared for each class as training data. In the deduction process, entering an unknown image to the identification model established through the learning process produces a deduction result in the form of a probability score for the labeled image. Accordingly, the computer is now able to automatically acquire an amount of characteristic through autonomous data analysis without requiring any explicit programming by humans. Our experimental results showed that the presence of cracks was correctly answered for more than 90 % cases.

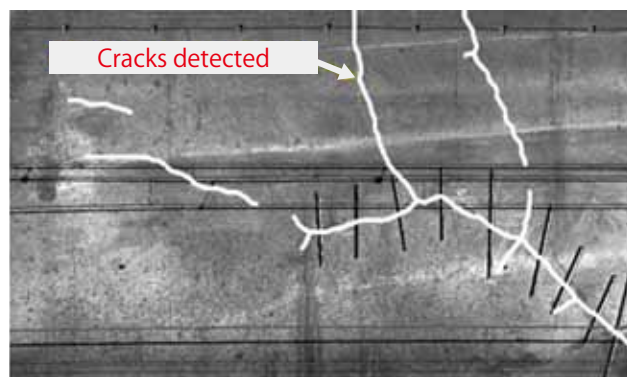
Detailed image analysis to supplement the results of deduction

To use the detection results more practically, a hybrid crack detection method is proposed to perform detailed analysis on a gray-scaled image, where the pixel value corresponds to the probability of crack presence. In this method, a bit map image is created, with each pixel value of 0 to 255 linearly corresponding to the crack presence probability of 0 to 1. The image is then analyzed to determine the position and direction of cracks. As cracks tend to be connected in the direction of

the principal axis, after performing an expanding process and connecting nearby line segments any line segment of less than a certain length is removed. Then, the remaining areas are contracted, smoothed, and skeleton extraction is made to finally detect cracks. It allows to show that the cracks behind cables and other ancillary items are correctly detected. Comparing a manually drawn deformation map with the detection results obtained from the proposed method for the same area, this detection method is practical since its results are comparable to those from human judgment.



Crack presence identified by deep learning



Eventual crack detection results after detailed image analysis on the identification results to the left

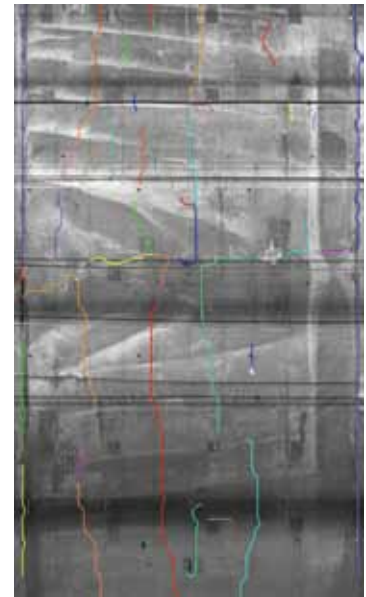
Future R & D approach

The performance of the proposed crack detection method is planned to further improve as one of the essential elemental technologies to realize automatic creation of deformation maps as well as to deal with other disturbances such as water leaks.

While the final goal of this study is to implement this method for practical use in tunnel maintenance and inspection services, our present target is to realize a trial use in the field, as a necessary step, to also enhance the sense of speed in the entire research and development activity. This system is continuously improved by receiving feedback on the usability and other comments from the field. To be more specific, the program will be released on the Web to make it publicly available so that field engineers can use a cloud-based AI system to analyze the images of tunnel lining surface taken from various locations



Manually drawn conventional deformation map



Cracks detected by the proposed method

and detect cracks. The user client program will have the functions to prepare and input training data for learning, perform

detailed analysis, perform relearning, and be customizable to the user's needs.

