Analysis of the features of rust on weathering steel by means of AI

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1. Introduction

Weathering steel is a steel made by adding alloy elements to an ordinary steel, thereby forming a minute rust layer (called protective rust) on the surface of the steel and suppressing the progression of rust thereafter, to suppress the amount of decrease of the plate thickness during a long period. It is widely used in the construction of road bridges as well, and depending on the conditions of bridge construction, a reduction of the life cycle cost is expected by implementing maintenance and management appropriately.

However, in cases where the steel is put in a wet state, or the like, no minute rust is formed, and flaky rust (E) and swelling and laminated layers of rust (F) occur as shown in Photo 1, and the progression of rust is not suppressed. Even if the rust does not become flaky, protective rust may remain in an ungrown state for a long period in some cases, and attention needs to be paid to the maintenance and management in such a case as well. Therefore, during inspection, etc., the minuteness of rust and the speed of corrosion should be distinguished from appearance to a certain extent. Therefore, in this study, it was investigated first based on what kinds of features AI grasps the appearance of rust, by making AI learn the images of multiple types of rust using the AI technology that is widely used in the classification of images. As compared to the observation of rust by a human and the consideration of its features, AI might characterize the appearance of rust from different viewpoints, and the classification of rust obtained as a result of such characterization may also provide more appropriate association with the speed of corrosion. The investigation was carried out in anticipation of such possibility.

2. Classification of rust that is used in current inspection

Studies that classify the features of rust from appearance and provide association with the speed of corrosion thereafter have also been conducted heretofore, and the results of such studies are used in actual inspection as well. It is stated that the condition of rust can be evaluated in 3 to 7 stages, by focusing on the fact that there are differences in rust particle size and differences in color tone and color unevenness according to the minuteness of rust. However, the ways of occurrence of individual types of rust on weathering steel that is used under various conditions are actually varied. Therefore, in this study, the features of the appearance of rust will be classified by the deep learning model based on the architecture called the Residual Network (ResNet).

Photo 1: Types of rust

3. Classification of images by means of AI technology

The deep learning model enables, when an image has been given, the features of such image to be learnt, to be extracted, and classification to be done based on the extracted features. The images of the appearance of rust to be learnt by the model are the 120 sets of anaglyph images contained in Technical Note of NILIM No.828[1)]. An anaglyph image is to produce a stereoscopic effect when viewed with glasses pasted with a red film on the left and a blue film on the right, and is a two-dimensional image in which the dents and projections as well as height of rust are reflected. Making the model learn a simple photo may also be acceptable on the precondition that the features of rust shall be capable of being classified properly by the particle size and color tone. However, in this study, from the standpoint that there could be useful appearance information besides the particle size and color tone, it has been determined that images in which information on three-dimensional shape is also reflected shall be learnt by the model.

4. Results

Firstly, AI was made to learn an image data set and the results of classification by a human in the existing method of classification (7 stages) for each image. It is

the so-called learning with teachers. Fig. 1 shows the results of classification by AI of different types of rust that appear to have no conspicuous difference in shape or dents and projections of rust within the range visible to the human eye, although the color tones are obviously different. Of the rust images that were input during such classification, which points were focused on by AI are shown in pairs, by creating a heat map (redder areas are focused on more strongly by AI) of the points by means of a technique called the Grad-CAM. The orange and brown rusts on the left in **Fig. 1** are classified into ungrown rust, and the heat map has sparse warm-colored (red, etc.) portions, and they are mixed with cold-colored (blue, etc.) portions as well. The dark brown and light brown rusts on the right in Fig. 1 are classified into protective rust, and they have been classified differently from the rusts on the left, but the heat map shows wide warm-colored (red, etc.) portions in the entire image. It is suggested that if there are no great features in the particle size, the color tone may have affected the classification by AI as well.

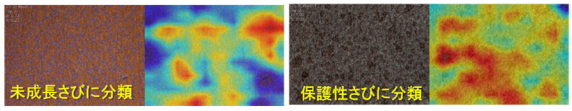

Fig. 1: Analysis of the effects of color tone of ungrown rust and protective rust

Fig. 2 shows the results of classification of rust in the same place classified by a human as protective rust, by inputting an anaglyph image and a simple two-dimensional image before synthesizing the anaglyph image (which shall be called a non-anaglyph image herein), which was done by AI, respectively. The anaglyph image in which the height information is reflected (Fig. 2, left) is classified correctly by AI as protective rust, and it appears from the heat map as well that the entire image is focused on without omission, and that the image is regarded as an image having homogeneous characteristics. On the other hand, the non-anaglyph image (Fig. 2, right) was classified erroneously as flaky rust. From the heat map on the right in Fig. 2, it can be seen that AI focuses on specific areas. A photo showing an enlargement of such areas is also shown in the figure. When a human looks at the photo as well, the areas appear as though there are dents and projections from the shade and others. Based on the foregoing, the analysis by AI shows the possibility that dents and projections should be taken into account when a human characterizes rust as well.

Secondly, AI was also made to learn the same data set consisting of 120 sets of images without teachers. In the first place, it was investigated, by classifying rust into several patterns, whether the features are reflected well in the classification. As a result, interestingly it appeared that classification into 6 types or so was good, with the result being close to the classification of the features of rust by a human into 3 to 7 types.

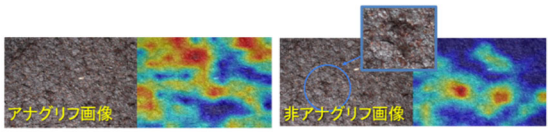

Fig. 2: Example of distinction by means of AI of an anaglyph image (left) and a non-anaglyph image (right) of the same protective rust

Actually, AI was made to classify the learning data set of 120 sets of images into 6 by learning without teachers. The rust considered to be representative of each classification is shown in Fig. 3. When the classified results are viewed by human eyes, it appears that information on the color tone and the dents and projections of rust is reflected in the classification. In future, we plan to look for the possibility of advancement of the inspection method for weathering steel by taking measures such as conducting an analysis of a certain rust by associating the classification by AI with the chemical components of rust and the speed of degradation thereafter.

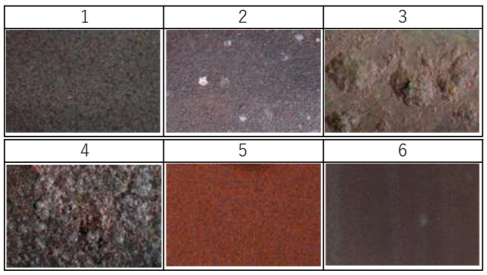

Fig. 3: Example of distinction of rust by learning without teachers

5. Conclusion

Although the Bridge and Structures Division has been conducting studies of the method of inspection concerning the functions of corrosion prevention for weathering steel until the present, it appears that a new development of studies can be expected by utilizing AI technologies as well. In future, we would like to make efforts in the advancement and speedup of studies by utilizing the cutting-edge technologies in various studies.

Note that an app for classifying the anaglyph images of any rust is available on the website[2)] that uses a model that underwent learning with teachers, which has been created in this study. Although its accuracy is not clear, readers having interest in it are welcome to test it.

☞For detailed information, refer to the following:

1) Technical Note of NILIM No. 828 Study on Evaluation of Rust by Appearance Properties for Weathering Steel Bridge (February 2015)
https://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0828.htm
2) https://www.nilim.go.jp/lab/ubg/index.htm