# Evaluation of Paint Film Deterioration on Steel Bridges Using Image Processing Technology

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## ABSTRACT

An automatic inspection system using computer image processing technology has been jointly developed by Japan Highway Public Corporation (JH) and Ishikawajima-Harima Heavy Industries Co. Ltd. This has already been used to assess deterioration of painting film used on steel bridges, enabling detection of deteriorated parts and quantitative evaluation from photos of painting film. It automatically detects deteriorated parts fairly well from outdoor images with a shaded background. The system fully evaluates deterioration detected from various parts of a bridge. In this report, an overview of the system and its future development is described.

Keywords• Paint View, Steel Bridge, Paint Film Deterioration, Data Base,
Image Processing, Morphology Method, Automatic Inspection System

# 1. INTRODUCTION

Steel bridges and other steel-frame structures are painted to prevent corrosion and preserve scenic beauty. The paint film deteriorates over the years by rusting, cracking and peeling off. This deterioration is inevitable. Because the life of the paint film can be prolonged by repainting• • partial or full repainting is normally performed. By determining the most appropriate time to carry out this repainting, substantial reductions in cost are possible.

In the inspection of the external appearance of paint film, which is conducted as part of a steel bridge maintenance program, the visual inspection method is mainly used. Visual inspection, however, has a problem in that differences in judgment between individual inspectors are unavoidable. This is because observers have different experiences and their subjective viewpoints vary. Therefore the reliability of the results provided by visual inspection tends to be inferior in spite of the great amounts of time and labour used in such inspections. In consideration of this situation, from 1992, we have been developing an evaluation system for paint film deterioration ("Paint View") which enables inspectors to quantitatively evaluate deterioration phenomenon in paint film, irrespective of the extent of their knowledge or experience in the paint and painting field, through the use of image processing technology. This system is expected to make a great contribution to the control of structures' remaining lives, reduce repainting costs, and enable streamlining of the inspection of the external appearance of bridges.

As the first step in the development process, an automatic evaluation system for paint film deterioration has been developed. This system extracts parts of the paint film that have changed and quantitatively measures the degree of paint film deterioration, based on information about the paint film surfaces obtained from pictures and videotapes of steel bridges. It is capable of comprehensively and objectively evaluating paint film deterioration by inspecting the degree of paint film deterioration at multiple points on a bridge. In this report, we give an overview of this system and its future development.

# 2. OUTLINE OF THE SYSTEM

Based on image data such as pictures and videotapes of the paint film surfaces of a bridge, this system compares rusted, cracked and peeled parts with normal parts. Specifically, it distinguishes parts whose brightness differs from that of the surroundings in images so that it can identify and inspect deteriorated parts. We named the system “Paint View”.

## 2.1. System Configuration

**Figure.1** shows the appearance of “Paint View”. This system is installed in the Expressway Research Institute of JH, and consists of the four main components described below• :

### (1) Engineering workstation

The engineering workstation controls the entire system, calculates various geometrical characteristic and statistical values, evaluates the degree of deterioration, receives commands from the operator, and displays the results of processing. The operator can execute tasks in an interactive manner by pressing icon buttons displayed on the menu screen of a monitor.

### (2) Image processing unit

The image processing unit is used to extract deteriorated parts of the paint film from image information for the paint film surface. This unit is equipped with a high-speed parallel vision processor. It is capable of executing a variety of filtering operations at high speed.

### (3) Image acquisition unit

Using a CCD camera and an 8-mm VCR, this image acquisition unit imports image information recorded as photographs and 8-mm Videotapes into the system. The 8-mm VCR

can be controlled by the engineering workstation; it can automatically search for and input image data to be inspected by referring to index signals.

### (4) Display and recording units for inspection results

Images to be inspected and images obtained after being subjected to various processing routines are displayed on a monitor screen of the engineering workstation. The results of inspection are also displayed as a chart or graph on the screen. The inspection data can be stored on a re-writable optical disk.

In addition, as shown in **Figure 2**, this system uses the JH' Intranet. It enables Head Office, Regional Bureaus, Operation Offices and other offices to easily do research on and to refer to the inspection data and images.

## 2.2. Inspection Procedure

**Figure.3** shows an inspection flow chart for this system. The paint colour is the only parameter required to automatically extract deteriorated parts. By designating this parameter at the start of inspection, a series of processing routines can be automatically executed simply by inputting images, thus reducing the inspectors' workload that will lead to an improvement of work efficiency.

## 2.3. Basic Functions

Here we describe the basic functions of this system along with the steps performed in the inspection procedure.

### (1) Input of images

Image information on the paint film surfaces at multiple points of a bridge can be imported into the system successively from photographs or 8-mm videotapes which are made available ahead of time by on-site photograph. Using 8-mm videotapes that have index signals, it becomes possible to import these multiple inspection images into the system automatically.

### (2) Setting the target area

When images of a bridge are recorded using a camera or a camcorder, various bridge components are usually included in the images along with the paint film surfaces of interest. In such images, there are considerable differences in brightness between the painted surfaces of interest and intersecting other bridge components. This allows both deteriorated and intersecting parts of bridge components to be detected at the same time. In order to prevent intersecting parts of bridge components from being extracted mistakenly, the painted surface area to be evaluated is established as a target area and the extraction operation is performed on the deteriorated parts of this target area.

### (3) Calibration of actual size units

In order to evaluate the degree of paint film deterioration correctly, the area of the deteriorated parts, their circumferences and other geometrical characteristic values must be calculated in terms of actual unit size. This system uses an image calibration method that associates pixel unit measurements obtained from image information with actual unit size by specifying bridge components of known dimensions in the image or by specifying the scale of a ruler placed in the image. This image calibration method enables the characteristic values of deteriorated parts to be evaluated in direct relation to actual measurements.

### (4) Extraction of deteriorated parts

By using the gray-scale morphology method, the deteriorated parts will be extracted. The morphology method is an image processing technique, which have been designed to extract portions where brightness values are greatly different from those of surrounding areas such as deteriorated parts. One of the features of this method is that deteriorated parts can be extracted

flawlessly and automatically without being affected by the non-uniformity in lighting that is caused by outdoor photography.

### (5) Evaluating the degree of deterioration

Area, circumference, circularity and other geometrical characteristic values are calculated based on the deteriorated parts extracted. The degree of paint film deterioration is evaluated for each image in accordance with judgment criteria established by paint-film inspection experts. After the extent of deterioration is evaluated for each bridge component, an overall evaluation is made for the entire bridge structure.

### (6) Display of inspection results

The results of inspection are displayed on the monitor of the engineering workstation in the form of images, tables and graphs. The original images for inspection, images of deteriorated parts of the paint film and other output images obtained during inspection are also displayed on the monitor.

**Figure.4** shows an output image.

### (7) Storing the results of inspection

Inspection results and inspected images are stored on a re-writable optical disk as an image database which can be referenced later to obtain necessary information, including information on changes over time. Using this image database, the operator can retrieve past inspection data by specifying information about the bridge name, date of inspection, extent of the paint film deterioration and other items, thus allowing the results of system inspection to be effectively applied in the functions to manage the paint film's remaining service life. The information on the results of inspection contains the various parameters used during inspection. Therefore additional tests can be performed later by using these parameters.

## 3. EXTRACTING DETERIORATED PARTS WITHOUT BEING AFFECTED BY NONUNIFORMITY OF LIGHTING

### 3.1. Processing by the Gray-scale Morphology Method

The image of a deteriorated part usually looks darker than that of the normal paint surface. Because the objects inspected are outdoor structures, the photographic images are affected by non-uniformity in lighting in most cases. This makes it difficult to only extract deteriorated parts alone with a high level of accuracy especially if the brightness of the threshold value is fixed at certain value. Regarding this problem, the gray-scale morphology method is effective.

**Figure.5** illustrates the principle of gray-scale morphology. From this figure, if an image taken under uneven lighting conditions is processed by ordinary binarizing processing, a situation often occurs where deteriorated parts are extracted imperfectly or non-deteriorated parts are extracted along with deteriorated parts. Using gray-scale morphology, the deteriorated parts can be extracted satisfactorily. This system employs the gray-scale morphology method of extracting parts that only look darker locally than the surrounding area. Therefore, using this system, deteriorated parts can be extracted stably even under uneven lighting conditions.

## 4. HOW TO EVALUATE THE DEGREE OF DETERIORATION

### 4.1. Criteria for Evaluating the Degree of Deterioration

In the case of conventional visual inspection methods, paint film deterioration criteria are mainly given by the area ratio of deteriorated parts. Therefore, if the area ratio method is used for all target areas inspected, it is inevitable that the same results of judgment will be obtained even if the sizes, shapes or distribution of deteriorated parts are actually different.

However, since our recent studies have determined the relationship between grain diameter of rusts on paint surface and corrosion of steel (corrosion depth), this system was configured to judge the necessity of repainting directly referring to the corrosion of steel, instead of global assessment. The larger the grain size of rust on the paint surface, the greater the corrosion degree of material. Based on this fact, the system was so designed that rust is classified by grain diameter, and the occupying area ratio of each grain size class is weighted to evaluate the deterioration degree of paint film. Therefore, depending on the Paint View System, the same occupation area of rust does not necessarily represent the same corrosion degree of steel, but existence of larger grain sizes means a greater corrosion degree. This is the typical feature of this system.

## 4.2. Overall Evaluation Using Multiple Images

Evaluation of the degree of deterioration in a paint film will be biased if only one picture taken of part of paint surface is used. Also, if pictures are taken under different conditions, variations may occur in the results of deteriorated parts extraction and deterioration evaluation. To solve this problem, sets of multiple pictures are taken of the paint surface. By evaluating these multiple pictures and reviewing the results of each evaluation in a comprehensive manner, it is possible to make correct judgments. Specifically, first each image is evaluated to find out the degree of deterioration of each bridge component. Then the results of evaluating each bridge component are reviewed so that a correct overall judgment can be made. Because the degree of deterioration is evaluated for each bridge component, this procedure is applied to the case of partial repainting.

# 5. APPLICATION STATUS AND FUTURE DEVELOPMENT

We have applied this system to the nationwide expressway in Japan since 1999. Initial evaluation of steel bridges in Japan, managed by JH, is almost finished. Bridges evaluated in earlier stages have been repainted, on the basis of the judgments of the evaluation results obtained by the system. The final goal of this project is to develop a management system to support and determine a method, whereby a reasonable and cost effective timing of repainting can take place.

With this management system; (1) objective and quantitative evaluation will be possible, (2) it will be unnecessary to use scaffolds and other equipment for investigation, due to the fact that the evaluation will be conducted through the use of photos and video tapes, (3) data and statistics can easily and quickly be analysed because the system is centralized with a database, (4) the change over time of paint film deterioration can be effectively analyzed, (5) it will be possible to predict the future paint film deterioration and estimate its remaining life, (6) a long-term repainting plan that minimizes the lifecycle cost by evaluating the cost, frequency, and method of repainting can be efficiently established.

Up to now, items (4) and (5) above have just started. The immediate tasks are as follows; implementing analysis of evaluation results of bridges stored in the database, and continuous monitoring of bridges, a deterioration degree curve will be made for different conditions such as the environment, paint type, member, and position: referring to the deterioration degree curve, the estimation accuracy of paint film remaining life will be improved.

# 6. CONCLUSION

In conclusion, application status and future development of a diagnosis system of steel bridge paint film deterioration has been discussed. It is JH's mission, as a road administrator, to operate present road asset efficiently. This system that objectively and quantitatively evaluates the paint film deterioration, and determines the timing for re-painting, will greatly assist efficient management and appropriate use of maintenance cost of not only JH, but also other bridge administrators.

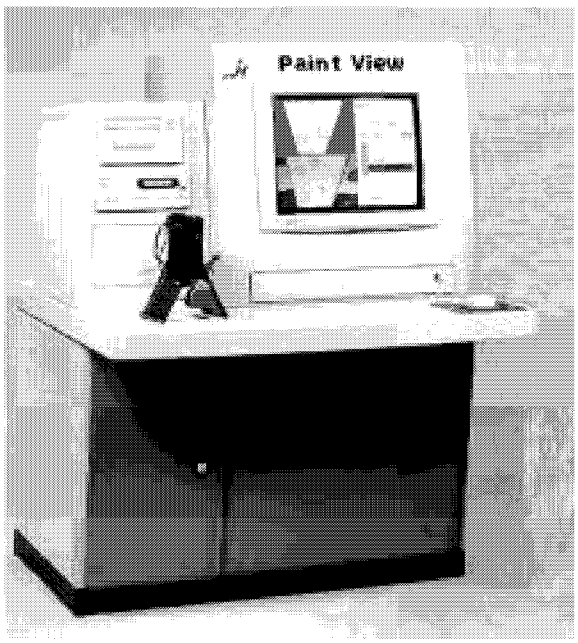


*Figure.1 Appearance of Paint View*

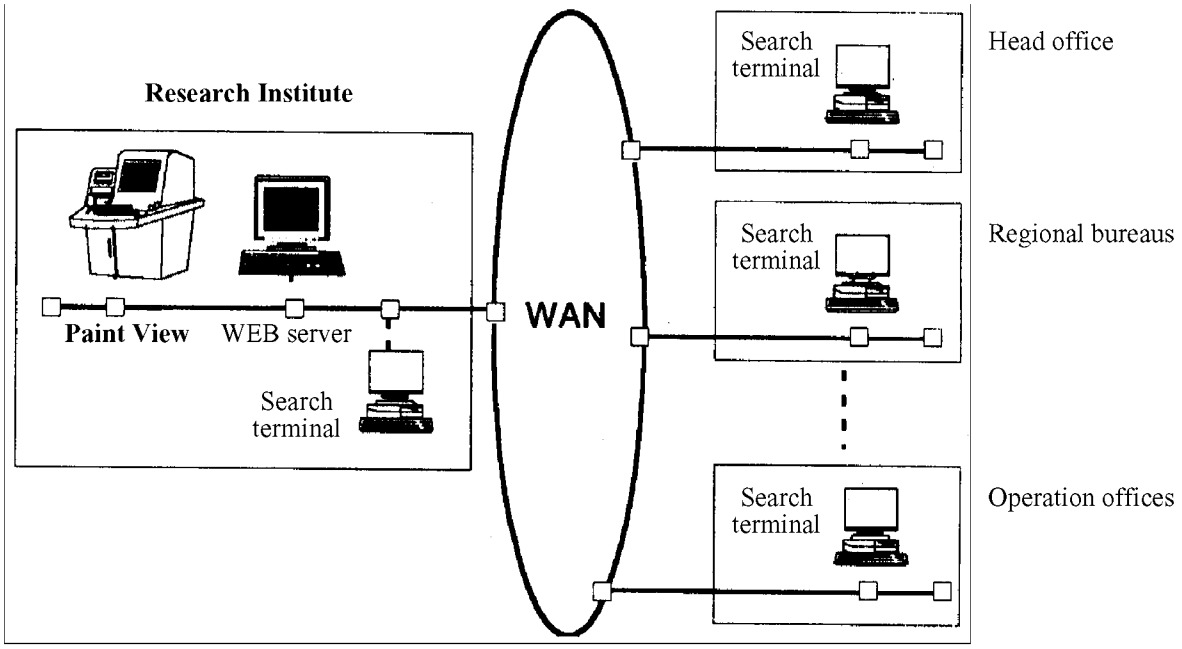


*Figure.2 System configuration*

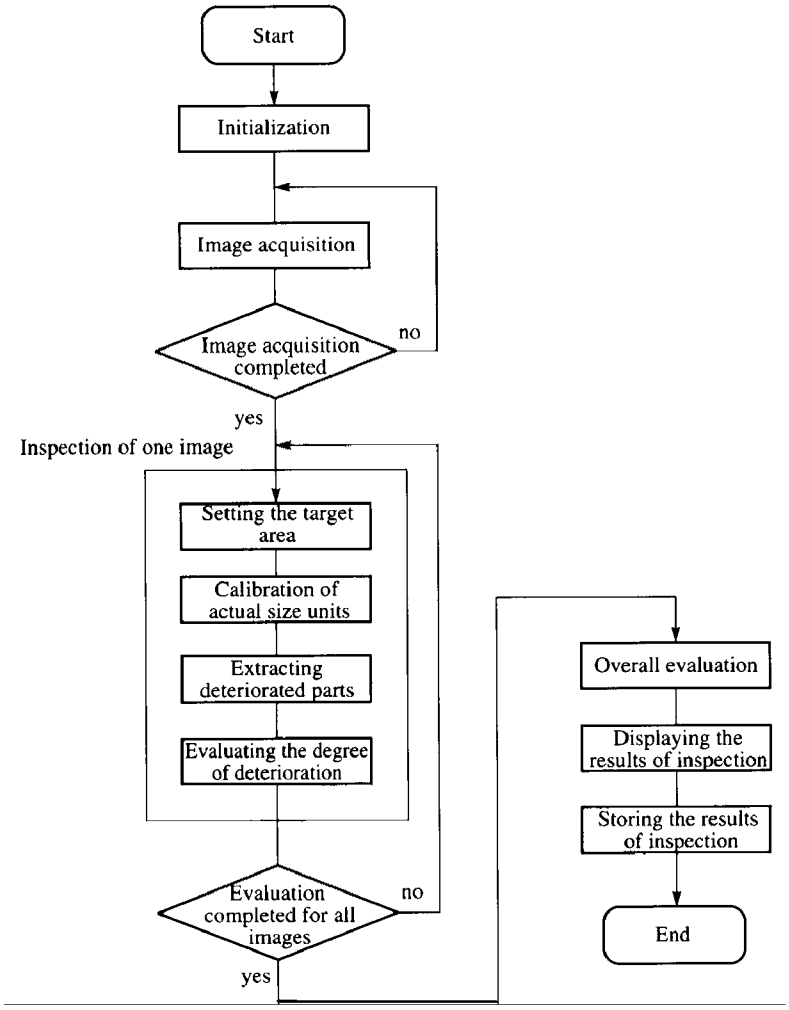


*Figure.3 Flow of inspection*

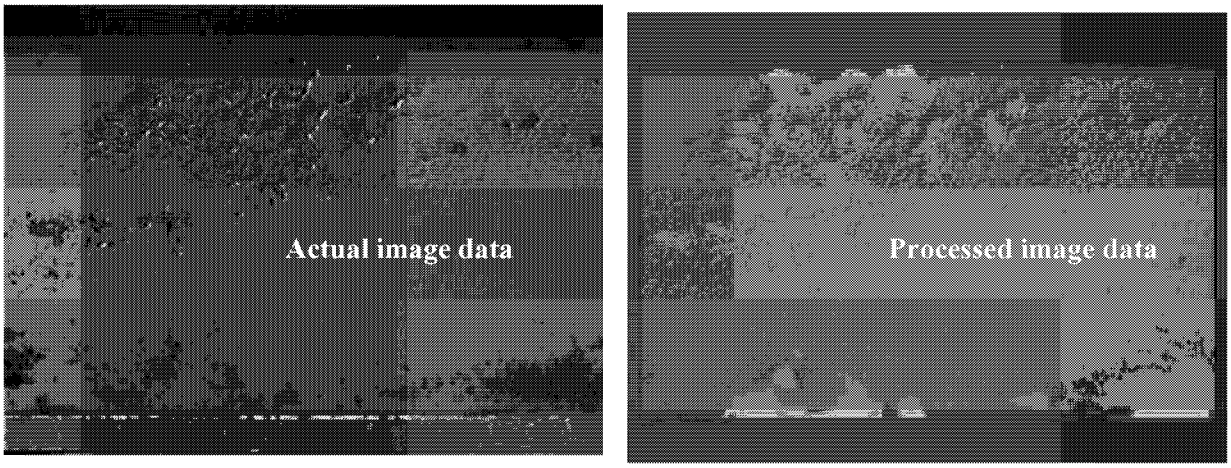


*Figure.4 Output imaged*

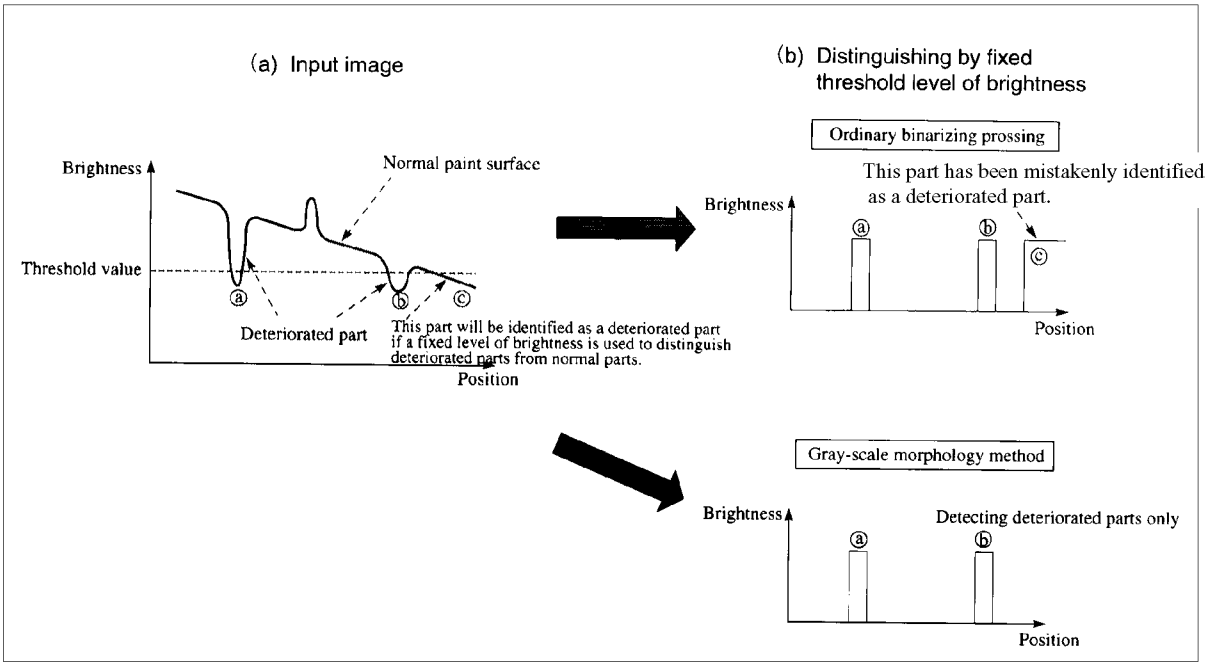


***Figure.5 Principle of morphology***