AN IMAGE REGISTRATION TECHNIQUE FOR DETECTION OF CRACK AND RUST GROWTH

Norihiko Itoh
Central Research Institute of Electric Power Industry
2-11-1 Iwado Kita, Komae-shi, Tokyo, Japan

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Abstract: To observe and record the progress of cracks and rusting, it is necessary to compare the images of the past with those of the present. The angles of surfaces of structures such as a concrete wall taken vary according to the camera position, that is the location in which they were taken. The images that were taken from different points are distorted, deformed or appear as if the actual location of the cracker rust has been shifted. So need less to say, the uses of these images are not good means of accurately detecting the progress of crack and rusting. It is first necessary to make rectifications. This can be done by using the images as a basis in determining the correct camera location and the adjustments made thereof. This paper proposes the difference of the camera angle can be detected by applying the frequency element of the whole image. Especially, this method is effective for a surface with few features such as a concrete wall.

1 INTRODUCTION

Recently with the availability on high quality digital cameras, it is now easier to record and store the progress of the cracks on the dam-gate or concrete area. The observation period is lengthy due to the slow progress of the cracks or rust and it is common to record and compare the cracks or rust on a regular or irregular basis.

The angles of surfaces of structures such as a concrete wall taken vary according to the camera position, that is the location in which they were taken. The images that were taken from different points are distorted, deformed or appear as if the actual location of the cracker rust has been shifted. Therefore, the uses of these images are not good means of accurately detecting the progress of crack and rusting. Then, presumption and compensation of inclination of those images are important. In order to grasp progresses of a crack or rust by the difference of images, it is necessary to utilize a highly registration technique sub-pixel or less.

Surfaces of structures such as dam-gate or other huge facilities have few features. Due to the surface simplicity it is difficult to compare images using feature points. It is common to use mark point to presume the camera angle. However, in the case of huge structures such as dam-gates, it is extremely difficult to set up indicators on the surface.

Many methods of presuming the camera angle from images are proposed. Most of them (e.g. Ribeiro (Ribeiro, 2000)) assume homogenous or isotopic textures.

Hwang (Hwang, 1998) proposed the method based on wavelet transform to describe more complex textures. It focuses the energy concentration at some frequency bands found by wavelet transformation. In addition, it is necessary to detect a peak of frequency spectrum stably by this method. However, such concentration does not necessarily appear in textures like the surface of concretes.

This paper proposes a high precision texture-based image registration method. This method is based on the spectrum and applicable to non-homogenous and non-isotopic texture as well as Hwang's, but this method use phase-only-correlation, which uses only the phase of spectrum representing the rich shape information. That is, the intensity of frequency spectrum is not used but carries out high registration of accuracy only using the phase.

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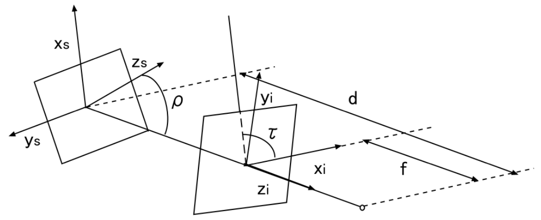

Figure 1: Location of camera and textured plane.

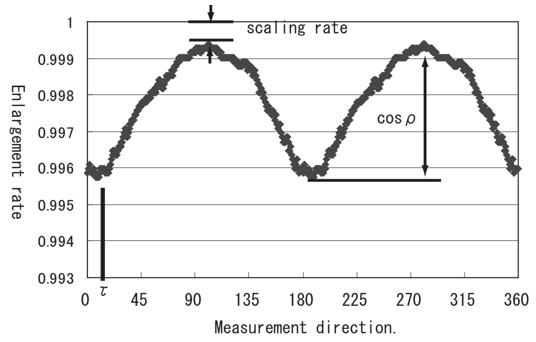

Figure 2: Scaling rate and slant-tilt angle.

2 PROPOSED METHOD

A camera projects the three-dimensional space onto a two dimensional image. The projected image is determined by 4 parameters, the distance d and the slant ρ and the tilt τ and the rotation θ. Let the coordinate systems of the object's surface plane (x_s, y_s, z_s) and of the camera's image plane (x_i, y_i, z_i) and the focal length f as depicted in Figure 1.

The slant angle ρ is defined as an angle between z_s and z_i, which takes nonnegative values between 0 and 90 (deg.). Furthermore, the angle between the x_i axis and the projection of the surface normal (z_s), onto the image plane (x_i, y_i) is defined as the tilt angle τ, which takes values between -180(deg.) and 180(deg.). The slant-tilt combination represents the orientation of a planar surface. An angle between the x_i axis and the projection of the x_s axis is defined as a rotation angle θ.

The scaling, slanting, tilting, rotation of an image all changes the power spectrum (amplitude of the spatial frequencies) of the image but their effects are different. For example, the rotation causes the rotation of the spectrum and the scaling (zooming) causes the isotopic scaling and the slant and the tilt cause anisotropic scaling. Proposed method estimates all the positional parameters including the scaling, the slant and the tilt by comparing the spectrum of two images.

The outline of the procedure is as follows:

1. **Cancellation of the shift.**
The proposed method first calculates the power spectrum of two images. This cancels the shift (translation) between images because the power spectrum of an image doesn't change by translation of the image.

2. **Estimation of a rotation angle**
Make the log-polar mappings of the two spectrums. By this mapping, the rotation angle θ and a scale factor λ is transformed to the translational displacements between two images. After log-polar mapping, the proposed method calculates the rotation angle θ of the images using phase-only correlation (Takita, 2003). The rotation angle is computed by the difference of peak coordinates in the θ-axis.

3. **The calculation of an enlargement and reduction by the difference in a measurement direction.**
The proposed method calculates the rate of anisotropic scaling between the two log-polar spectrums. After log-polar mapping, this method decides the direction of search. Two-dimensional phase-only correlation is used for calculation of the rate of enlargement. The rate of enlargement is computed from the peak coordinates of the direction of λ. The rate of enlargement is calculated repeatedly by changing the direction to search. Consequently, the enlargement for every direction is estimated.

4. **The calculation of a rate of scaling, and the slant-tilt angle ρ, τ.**
The rate of enlargement and reduction of each measurement direction changes in a shape of an ellipse. A rate of scaling is calculated from the value of a direction of a long axis, the inclination direction of optic axis (τ) is calculated from a direction of a short axis, and the inclines angle ρ is calculated from a ratio of a long axis and a short axis. The relation between rate of the enlargement and the slant-tilt angle ρ, τ is shown in Figure 2.

5. **The calculation of the amount of movements of the x, y direction.**
First, an input image is rectified using inclination direction of optic axis (τ), and inclines angle ρ. Next, the proposed method calculates the rotation angle θ of the images using phase-only correlation afresh. The input image is rectified using τ, ρ, θ. Finally, using the reference image and the compensated input image, the proposed method calculate an amount of movements of x and y directions, and image registration is completed.

A flow of the proposed algorithm is shown in Figure 3.

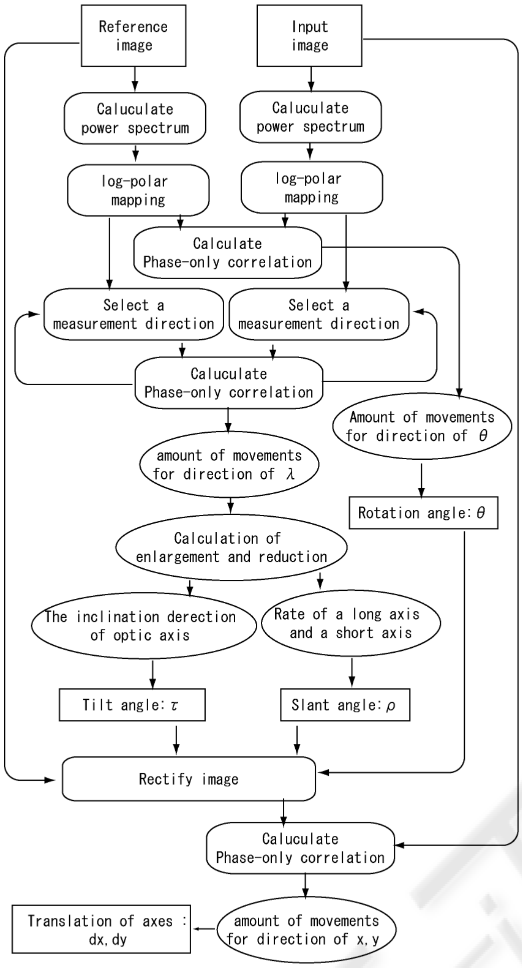

Figure 3: Outline of proposed algorithm.

3 PERFORMANCES

The images of cracks in concrete and rust in steel taken at the time of inspections are usually non-homogeneous and non-isotopic. So, two experiments were performed. In the first experiment, using the images of corkboard, which are typical non-homogeneous and non-isotopic images, the camera positions are controlled accurately. In the second experiment, the camera positions are estimated, using the images of the surface of a concrete wall taken by a camera only fixed by hands in a similar way at the time of usual inspections.

3.1 Corkboard Surface

The proposed method is applied to the images of corkboard taken by a digital camera (Nikon COOLPIX 950). The experimental environment is depicted in Figure 4.

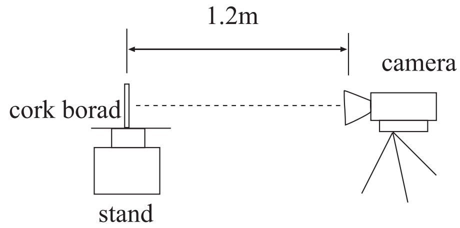

Figure 4: Photography environment.

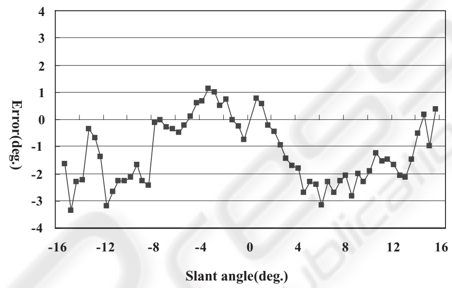

Figure 5: An example of error vs slant.

The target corkboard is set on a rotation stand and its distance from the camera is 1.2 meters. The center of corkboard and the center of the camera's lens are at the same height. The stand is rotated from -15.5 degrees to 15.5 degrees by 0.5 degrees, which correspond to the slants of surface orientation. The size of images is 512×512 pixels. The image when the slant is set to 0 is the reference image and the slant of the rest images are estimated.

The estimation errors are shown in Figure 5. The mean of absolute error was 1.44 degrees and the maximum error was 3.36 degrees. The error of 3.36 degree corresponds to 0.44 pixels because $512/2 \times (1 - \cos(3.36 \text{ deg.})) = 0.44$.

When realizing equivalent accuracy using feature points, it is necessary to detect all the feature points with a less than 0.44-pixel error.

If it is an error of this level, an error is very small. Therefore, the validity of the proposed method has been checked.

3.2 Concrete Surface

The method is applied to the images of a concrete surface of a wall taken by the digital camera next. In usual inspections of dam-gates, tripods do not always fix the cameras. So, in this experiment, the camera was fixed by hand as well, not using a tripod. The size of images is 256×256 pixels. The reference image is shown in Figure 6 and the input image is in Figure 7. The estimations by the method are that the

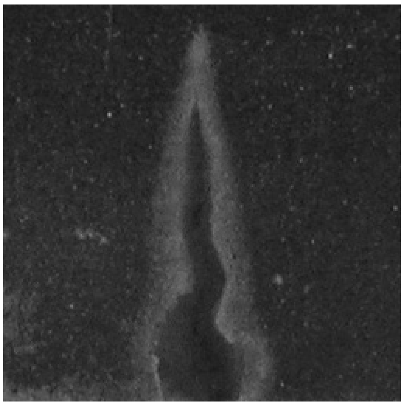

Figure 6: Reference image.

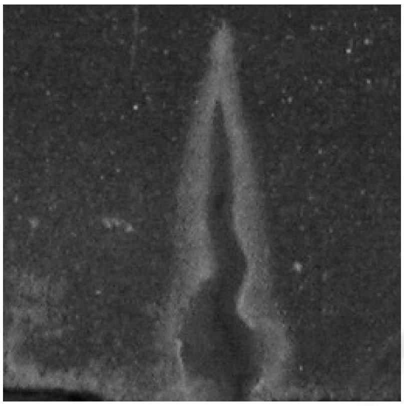

Figure 7: Input image.

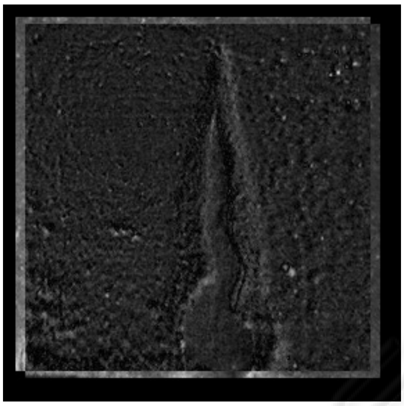

Figure 8: Difference image (no compensation).

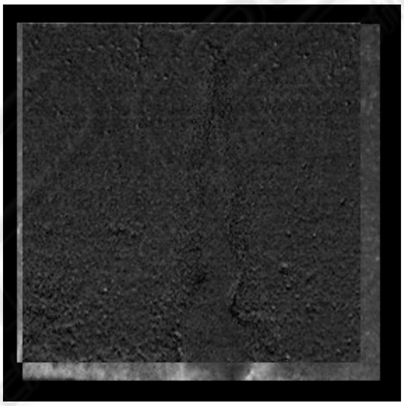

Figure 9: Difference image.

relative scaling r of the input image is 0.966, the tilt $\tau = 9.22$(deg.), the slant $\rho = 0$(deg.), and the rotation angle $\theta = 0$(deg.). Figure 8 shows the difference of the reference image and the recovered image from the input image using the estimated r, τ, ρ and θ. The whiter pixels have the larger differences. Comparing with Figure 9 showing the difference between the recovered and original input image, the differences are reduced greatly by this method. The images compensation by this method is clearly effective.

4 CONCLUSIONS

This paper proposes the method to detect the relative difference of camera positions (including the distance, the tilt and the slant) of two images of an object. In the experiments, it is showed that proposed methods can be applied to the images with non]homogeneous and non-isotopic textures, such as, the images of the concrete surface, corkboards and the steel surface. The Proposed method can detect the differences of camera positions with high accuracy. Currently we are applying this method to observe the growth of concrete cracks in an accelerated test environment.

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