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Displacement Measurement of Steel Pipe Support Using Image Processing Technology

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***Abstract*—There are two types of devices, contact and non-contact sensor, for measuring the displacement of a building during construction. The contact sensors are not easy to set up but relatively cheap. On the other hands, the non-contact sensors are easy to install but expensive. In order to consider the economic aspect, the displacement measurement technique using the image base is emerging. In this paper, displacement of steel pipe support was measured by using displacement gauges and image processing technique with pattern. Based on the experiment, the load-displacement curves and the mean error were compared and evaluated with the results of image processing. This study investigates the possibility of replacing the existing displacement gauges with image processing technology.**

***Index Terms*—displacement measurement, steel pipe support, image, pattern, color**

I. Introduction

Current equipment for displacement measurement includes Linear Variable Differential Transformers (LVDT), expensive laser equipment such as Laser Doppler Vibrometer (LDV), and equipment using Global Positioning System (GPS). These equipment are divided by two types which are contact and non-contact sensor. The contact sensors are difficult to install but cheap, while the non-contact sensors are expensive but easy to set up in a general construction site [1]. To compensate for these drawbacks, the research is underway on image-based displacement measurement, a non-contact type measurement technique. Recently, it has become easy to access with excellent video equipment such as camcorder and webcam. It can be considered that image processing technique has been able to measure the deformation of the structure such as bridges. In addition, since there is an image processing function in MATLAB [2], it is easy to install and relatively low-cost image displacement measurement is performed. This method improves the accuracy about changing of light by converting the image brightness and contrast.

This study proposes a method to measure displacement of steel pipe support by implementing two algorithms using the specific pattern and color map in the image processing technology. The accuracy of the algorithm using the pattern is compared with the result of conventional LVDT [3], and the displacement of the algorithm using color are also evaluated. Therefore, the image processing technology has been proposed as the method which could replace existing displacement gauge.

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II. Image Processing Technology

A. Image Processing Technology Algorithm Using Pattern

Fig. 1 shows the overall algorithm of displacement extraction based on image processing technology using pattern. The source image is acquired through the camera and transferred to the computer. After that, this transferred image is loaded in MATLAB program. In order to classify the pattern clearly, the image is converted to grayscale and ROI (Region of interest) is selected for the patterned area [4]. To increase the accuracy of the algorithm, adjust the grayscale values for the light changes. This pattern consists of five circles in the form of a cross, which makes it easy to calculate the displacement of each direction. The ROI keeps track of the pattern area and performs image processing only on that part, which enables a fast analysis to be performed.

When finished selecting ROI of the image, convert the frame image to extract the exact center of the pattern circle. After the image is transformed, the coordinates of the circle center corresponding to the frame are extracted and stored. It is a coordinate corresponding to a pixel as an x and y coordinate of the image of each circle [5].

If there is a next image, go to the next image and perform image conversion. If there is no next image, the process proceeds to the next step. The unit of the center circle coordinate is a pixel, and it is necessary to convert this pixel to the unit of SI unit (or mm). In order to compensate for the change in the pixel due to the camera's refraction, the distance between center circle and each direction circles are obtained. Using this distance, the pixel coordinates of the reference point are divided to obtain the ratio of distance to pixel (mm/pixel). Where, the reference point is center point of each circles in pattern and the distance of each reference points is 27.5mm.

If the task of obtaining mm/pixel is done, subtract the circle center coordinates corresponding to the reference point of the image and the next image. The x and y coordinates of the shifted pixel distance are measured. Assuming that the pattern is moved to left side and the

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number of moved pixel is measured, the *x* and *y* displacements of the reference point are extracted by multiplying mm/pixel using the reference point and the center coordinates of the left circle. This operation is continued until the next image does not exist. If this displacement extraction is done, the algorithm ends when the *x* and *y* displacements are stored and exported.

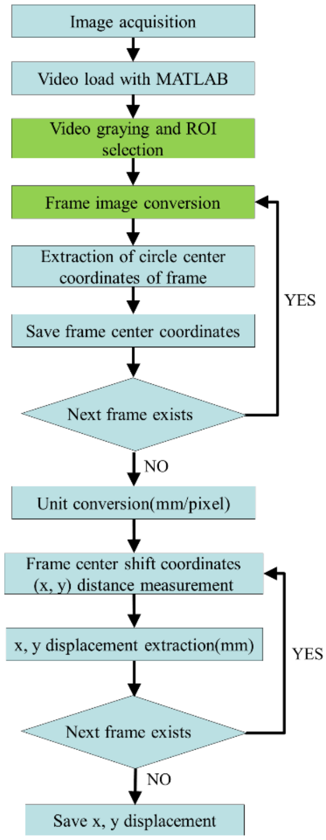

Figure 1. Image processing algorithm using pattern

B. *Image Processing Technology Algorithm Using Color*

Fig. 2 shows an algorithm that measures displacement based on the classification of specific colors. In this algorithm, the image is acquired through the camera in the same way as the image processing technique using the pattern, and then the image is loaded on the MATLAB. After that, ROI is specified to cut the image and analyze the image quickly.

In the next step, RGB image is converted a Hue-Saturation-Value (HSV) color model. The reason for doing this is because HSV is similar to what people see better than RGB, and it is easier to distinguish specific colors. In order to cope with changes in lighting, it is possible control a wide range of specific colors.

If the image is classified into a specific color, only the classified color has a value. The portion having this value is converted to black and white and converted to white. If the background color is specified as a specific color, the brightness is reversed after the black-and-white process.

Then, extracted *x* and *y*, which are the center of the area of the white portion. The edge is extracted and the distance between the point and the straight line is measured to obtain the mm/pixel necessary for unit conversion.

Thus, the distance between the point and the straight line is calculated, and it is repeated until the next image does not exist. If the next image is repeated up to the end of the non-existing, the coordinate distance between the image is measured based on the center of the area. The coordinate distance shown here is the distance between pixels, and it is necessary to convert it to SI unit. If the distance between the frames is multiplied by using the mm/pixel obtained from the above, the displacement of mm is extracted. The displacement this extracted is stored.

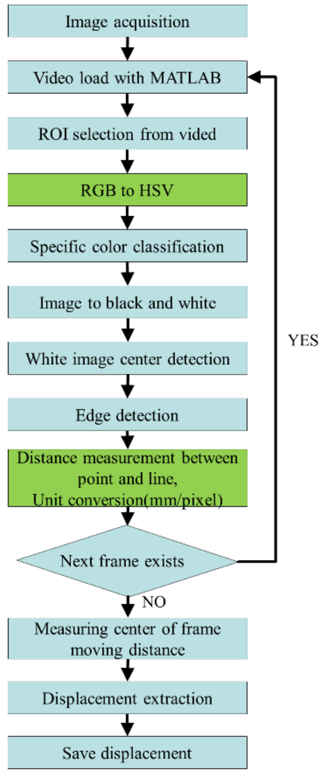

Figure 2. Image processing algorithm using color

III. Experiment

A. *Image Processing Technology Using Pattern*

Fig. 3 shows the concept of the test setup. The test specimen is generally steel pipe support using in the construction site. The displacement measured by LVDT and image processing using pattern at the center according to the length (*L*) of the specimen.

Table I shows the details for the lengths (*L*) 3,000 mm, 3,500 mm and 4,000 mm using in experiment. The distance between the pattern and the camera was set at 6,000 mm. The displacement of the steel pipe support was measured by the pattern and LVDT to the length (*L*) every 500 mm. When the pattern is installed at 3,500mm in the spacing every 500mm, the displacement at the center was not measured at the time of installation, so one additional pattern was installed to measure the displacement at the center.

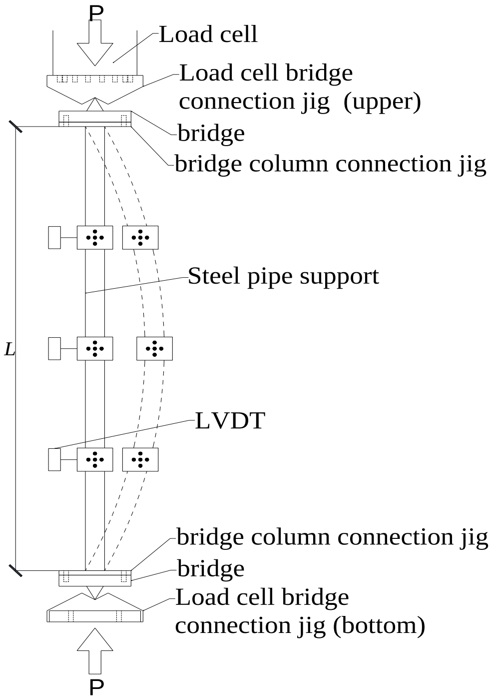

Figure 3. Experiment installation concept

TABLE I. DETAILS OF EXPERIMENTAL

Length(*L*, mm)	3,000	3,500	4,000
Number of pattern (EA)	5	7	
Distance between pattern and camera (mm)	6,000		

B. *Experimental Results and Analysis*

Fig. 4 shows the load-displacement curves of the specimen center with the length (*L*) of the steel pipe support of 3,000 mm. The maximum displacement of the LVDT was 116.9mm, and the maximum load was 26.46kN. The maximum displacement of the image processing using the pattern was 116.91mm. At this time, the error was 0.01mm. The initial displacement was very small, so the error of the image processing is too large. To avoid unreliable areas, the mean error is calculated after load of 5 kN, and it was 1.19%.

Fig. 5 shows the load-displacement curve of the length (*L*) of the steel pipe support of 3,500 mm. The maximum displacement of the LVDT was 205.9mm, and the maximum load was 17.25kN. The maximum displacement was 205.61mm using the image processing. The average error of displacement using LVDT and image processing was 0.9%.

Fig. 6 shows the load-displacement curves of the center of the specimen with the length (*L*) of 4,000 mm. The maximum displacement of the LVDT was 250.1mm, and the maximum load was 12.31kN. The maximum value of the displacement was 251.69mm using the image processing. The error was 1.59mm. The average error of the displacement using LVDT and image processing was 0.4%. Table II summarizes the results of each experiment. In the case of error, the larger the displacement, the smaller the mean error.

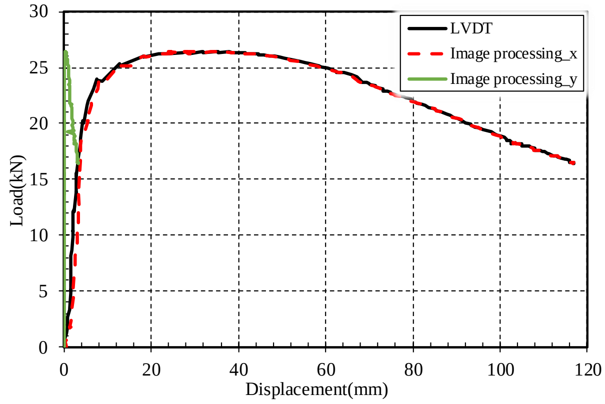

Figure 4. Load-displacement curve of steel pipe support length 3,000mm

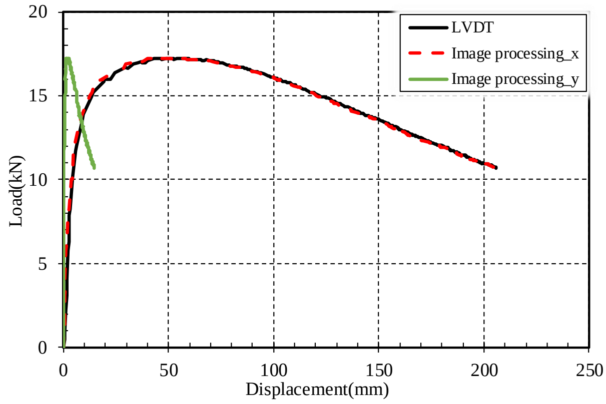

Figure 5. Load-displacement curve of steel pipe support length 3,500mm

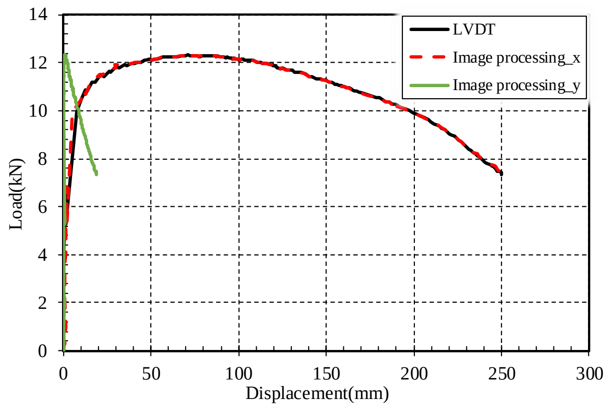

Figure 6. Load-displacement curve of steel pipe support length 4,000mm

TABLE II. RESULT OF EXPERIMENT

L (mm)	Maximum load (kN)	LVDT Maximum displacement	Image processing Maximum displacement	Mean error
3000	26.46	116.9 mm	116.91 mm	1.19%
3,500	17.25	205.9 mm	205.61 mm	0.9%
4,000	12.31	250.1 mm	251.69 mm	0.4%

C. *Image Processing Technology Using Color*

In the previous section, the error between the displacement measured by the image processing using the pattern and the LVDTs was not large. Therefore, the displacement measurement method using color and pattern were compared to evaluate the accuracy of image processing technology using color. The diameter of the pattern was 15 mm and the center-to-center distance each circle was 27.5mm.

Displacement measurements were performed when the background color was green and the color of the steel pipe support was gray. Fig. 7 shows the experimental setup image when the background color is green. ① part is a pattern serving as a reference of displacement. It means a moving displacement of ① in the result. ② part is measured with color without pattern, and the displacement of ② is calculated as a result.

The result is compared and analyzed as shown in Table III. For displacement measurement, the steel pipe support with a length (L) of 2,000 mm and a diameter (D) of 48.6 mm was moved and measured.

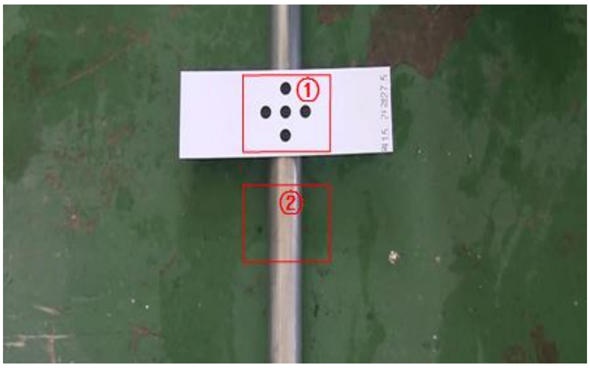

Figure 7. Experiment settings when the background color is green

TABLE III. RESULT OF EXPERIMENT

	Maximum displacement(mm)	Mean error	Time(sec)
①	198.6	3.3%	7
②	197.5		

D. *Experimental Results and Analysis*

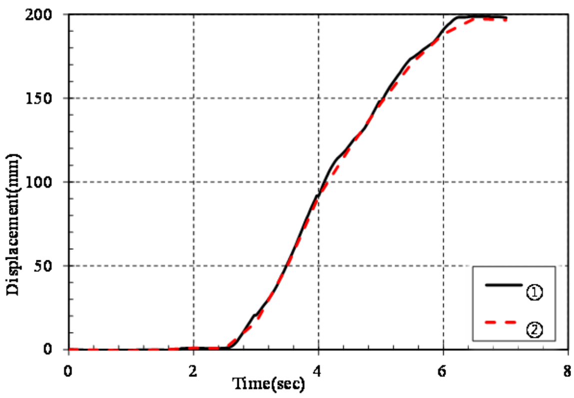

Figure 8. Time-displacement curve ① and ②

Fig. 8 is a time-displacement curve of ① and ② when the background is green. The experiment was performed for about 7 seconds. The maximum displacement using the pattern was 198.6mm, and the maximum displacement using the color was 197.5mm. The error was 1.1mm. The mean error between the displacement using the pattern and the displacement using color was 3.3%. This is because there was a shadow of the steel pipe support and background was not completely green when measuring color displacement.

IV. CONCLUSION

In this study, the displacement of the steel pipe support was measured by image processing technology using the pattern and color map. This displacement was compared with the existing LVDT to confirm the accuracy.

In the test by the bending deformation of the steel pipe support, the average error rate between the displacement using the pattern and LVDT was 1.19% in the length of 3,000mm, 0.9% in the length of 3,500mm, and 0.4% in the length of 4,000mm, respectively. It is shown that the accuracy of the image processing technology using pattern has come to be believable.

When compared the displacement measurement using the pattern and the displacement measurement using the color, the error rate was 3.3%. So it is considered that the non-contact displacement measurement is possible.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Dae-Geun Kim and Kyung-Jae Shin conducted the research; Jong-Hun Woo analyzed the data; Dae-Geun Kim and Kyung-Jae Shin wrote the paper.

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REFERENCES

[1] S. J. Cho, S. H. Sim, and E. S. Kim, "On-site performance evaluation of a vision-based displacement measurement system," *Journal of the Korea Academia-Industrial Cooperation Society*, vol. 15, no. 9, pp. 5854-5860, Sept. 2014.

[2] Image Processing Toolbox - MATLAB – MathWorks.

[3] S. H. Shin, K. J. Shin, and H. J. Kim, "Reliability verification of vision-based dynamic displacement measurement system," *Journal of the Wind Engineering Institute of Korea*, vol. 21, no. 3, pp. 135-142, Sept. 2017.

[4] J. P. Lee, J. Y. Lee, and C. H. Hyun, "Coin classification and recognition using digital image processing," *Journal of Korea Institute of Intelligent Systems*, vol. 22, no. 1, pp. 7-11, Jan. 2012.

[5] J. H. Lee, S. J. Jo, and S. H. Sim, "Vision-Based displacement measurement system operable at arbitrary positions," *Journal of the Korea Institute for Structural Maintenance and Inspection*, vol. 18, no. 6, pp. 123-130, Nov. 2014.

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Prof Shin holds the chair of the Steel Structural Society.