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# Application of vision-based displacement measurement to KTX railway bridge

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## ABSTRACT

Displacement is an important indicator of structural safety. Displacement measurement of large civil structures with conventional displacement measurement devices such as the linear variable differential transformer is challenging due to difficulty in finding device installation locations. Displacement measurement using a camera has been recently developed to replace such conventional devices, providing sufficiently accuracy for infrastructure monitoring purposes. The vision-based method offers a practical solution for measuring the displacement of large civil structures by means of image processing algorithms such as blob detection and homography transform. This paper presents a practical application of the vision-based method to a railway bridge for Korea Train Express (KTX). Displacement is measured when a train is running at different speeds and directions. The measured displacement is compared with the reference obtained by laser Doppler vibrometer (LDV).

## 1. INTRODUCTION

Displacement of the civil structure provides important criteria for structural maintenance and inspection as displacement responses reflect the load carrying capacity of large civil structures. In the design process, the structural displacement acts as a key design factor for assuring structural safety. Hence, monitoring the displacement is crucial for structural health monitoring (SHM).

Displacement measurement for the large civil structures is challenging due to difficulty in finding a stable reference point. Conventionally adopted displacement measurement devices, such as the linear variable differential transformer (LVDT), often restricts applicability due to unavailable reference points. For example, imagine the

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devices must be located at the bottom of the bridge to measure displacement at the mid-span. However, environmental barriers such as rivers and roads under the bridge prevent the sensing devices from being installed. Hence, conventional measurement methods are challenging for full-scale structures.

The vision-based displacement measurement systems (VDMS) are developed to offer a practical solution for measuring the displacement of the large civil structures. The camera captures the movement of a target marker attached to the structure, of which image frames are processed to obtain displacement. To reduce the error caused by camera location, the homography-based mapping method is introduced by Lee in 2014 that allowed the camera to be arbitrarily located.

This paper presents a practical application of the vision-based displacement measurement technique using the homography transform. The test bed is selected to be a railroad bridge for KTX trains. The homography mapping enables arbitrary selection of the camera position. Displacement from the vision-based method is compared with reference displacement measured by LDV.

## 2. VISION-BASED DISPLACEMENT MEASUREMENT SYSTEM

In general, the vision-based displacement measurement systems using target markers consist of video acquisition and displacement calculation as shown in Fig 1. Movement of a point in the target structure is captured by a camera. Herein, for the accurate displacement measurement, a user-designed planar marker is attached to the target point in the structure. Once video is acquired, pixel scale movement of the marker in the video is detected and tracked by feature detection algorithm. The feature detection algorithm can be a blob detection or a corner detection algorithm depending on the marker pattern. The pixel scale movement is then mapped into the metric scale displacement by a coordinate transform such as affine transform and homography transform. Homography transform can map two different planes in the same projective space as shown in Fig 2. Thus, this paper adopts homography transform to enable the camera to be positioned at an arbitrary point.

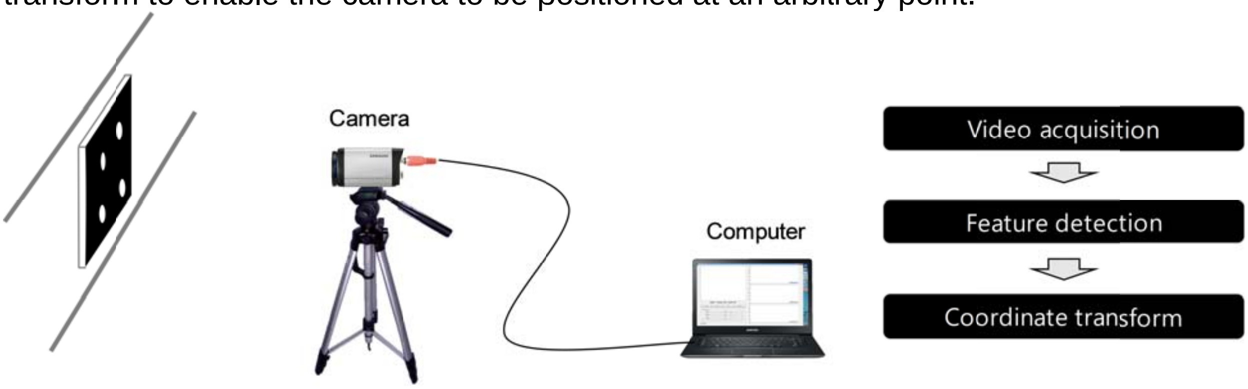



Fig 1. Vision-based displacement measurement method

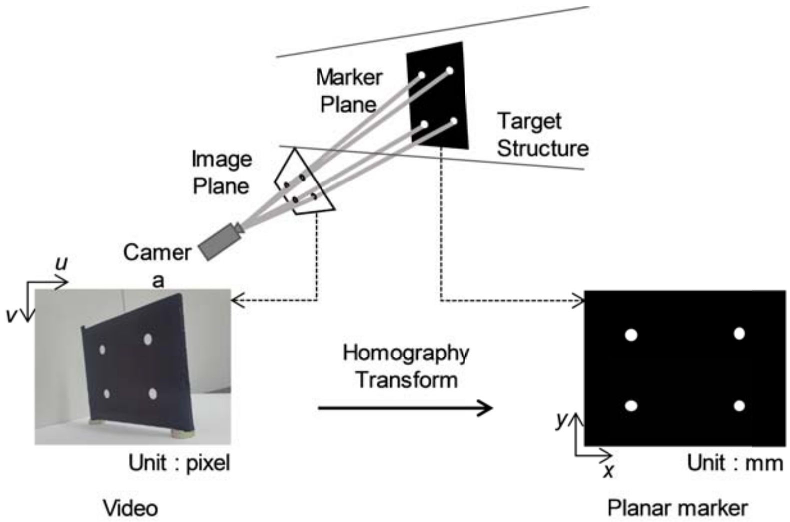
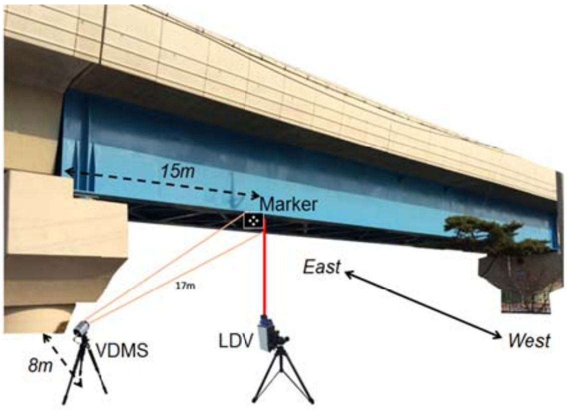



Fig 2. Homography relationship

## 3. FIELD TEST RESULT

A field experiment was conducted in Yeonjeong railroad bridge located in South Korea. The bridge was steel composite bridge with 40m span length. As shown in Fig. 3-(a), measurement point was at Western rail with 15m apart from the pier. Camera with NTSC camera interface (640×480 resolution, 29.97Hz) was installed 8m apart from the pier. LDV, which has 3nm resolution was also installed right below the bridge. Displacement was measured when KTX train was running at a different rail, direction, and speed as described in Fig 3-(b).



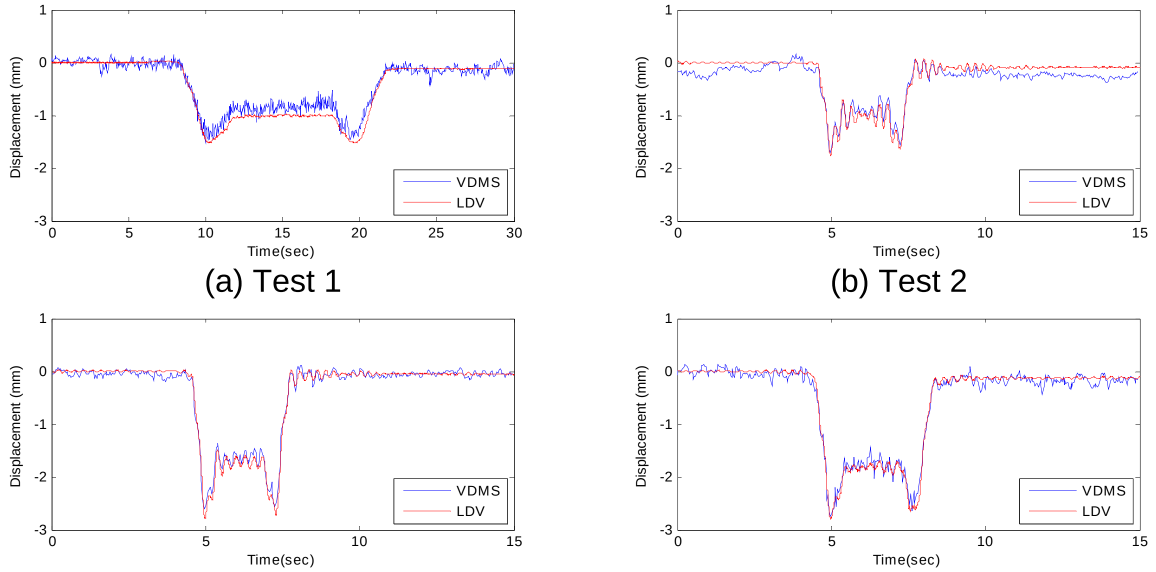

(a) Experimental setup

| | *Rail* | *Direction* | *Speed* |
|---|---|---|---|
| **Test 1** | East | Southbound | 60km/h |
| **Test 2** | East | Northbound | 300km/h |
| **Test 3** | West | Northbound | 270km/h |
| **Test 4** | West | Southbound | 230km/h |

(b) KTX scenario

Fig 3. Field experiment

The results of field test are listed in Fig. 4. In this comparison, vision-based method results show good agreement with LDV. However, 0.1mm drift was measured in Test 1 as the camera was moved due to the wind. For reliable measurement, the camera must be rigidly fixed on the ground.




(a) Test 1 (b) Test 2

(c) Test 3 (d) Test 4

Fig 4. Field scale experiment results.

## 4. CONCLUSIONS

Practical application of the vision-based displacement measurement method to the KTX railroad bridge is presented. Displacement was measured by camera and LDV when KTX was running in four difference scenarios. For each scenario, displacement acquired by vision-based method shows good agreement with LDV. The field experiment results prove the applicability of the vision-based method to large civil structures in preparation with rigid camera fixation.

## Acknowledgment

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