REMOTE BRIDGE INSPECTION USING OPTICAL METHODS

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ABSTRACT
Routine bridge inspections usually consist of visual observations. These inspections are time-consuming and subjective. There is a need to identify new inspection techniques for infrastructure that reduce traffic disturbance, and improve the efficiency and reliability of the acquired data. This study compared the performance of three different imaging technologies for the three-dimensional (3D) geometric modelling of existing structures: terrestrial laser scanning, close-range photogrammetry, and infrared scanning. Each technology was used to assess six existing concrete railway bridges. The results suggest that all methods investigated can be used to create 3D models, however, with different level of completeness.

Key words: Bridge Inspection, Optical Methods, Remote Sensing, Maintenance

1. INTRODUCTION

Routine bridge inspections usually consist of visual observations. These inspections are generally time-consuming and highly subjective. The measurements and observations are typically documented in the form of field inspection notes, freehand sketches, and photographs which are then used as inputs in transportation agencies' bridge management protocols. The procedure is highly dependent on the inspector's experience [1-2], and knowledge of the structural behavior and material properties of the system being investigated. The method is limited in that only the accessible parts of the bridge can be investigated due to the difficult terrain in which the structure is sometimes located. Therefore, there is a strong need for new infrastructure inspection and monitoring techniques that reduce traffic disruption and improve the efficiency and reliability of the acquired data. The technologies tested included terrestrial laser scanning (TLS), close-range photogrammetry (CRP), and infrared scanning (IS) tested on six railway concrete bridges.

2. THE SELECTED BRIDGES

Six bridges located in northern Sweden along the Iron Ore Line were selected for demonstration. The bridges' accessibility varied – some were readily accessible (e.g. a bridge crossing a road in a town), while others were not (e.g. a bridge in a remote area with rough terrain). Figure 1 presents photographs of the six bridges and their locations.

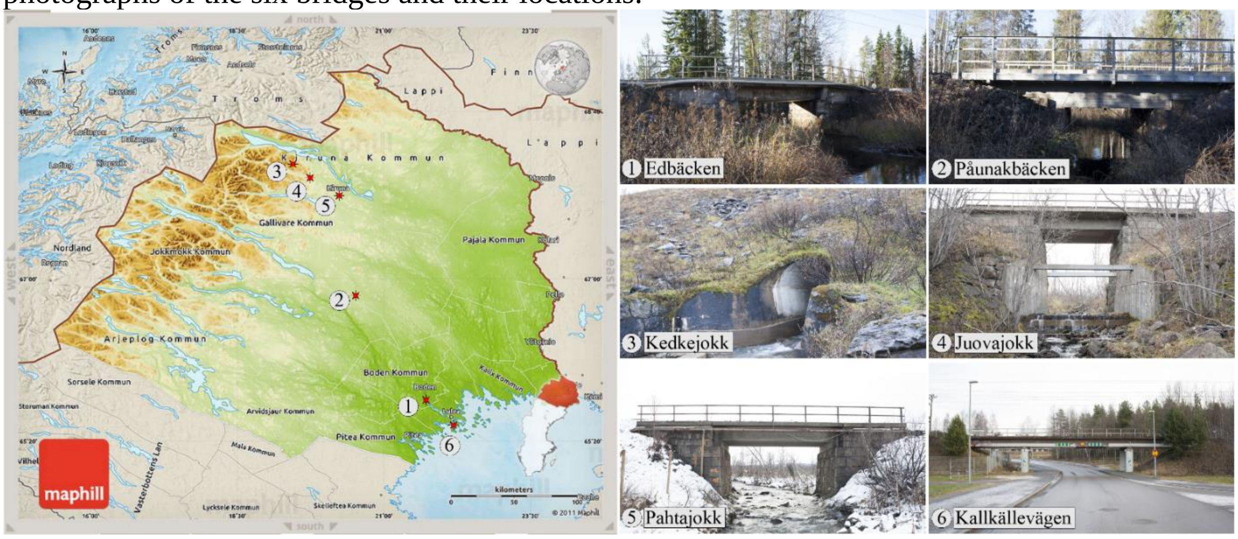

Figure 1 – Bridge locations and photos of the bridges scanned. "Map by Maphill"

3. GEOMETRIC RECONSTRUCTION: TECHNIQUES AND EQUIPMENT

Terrestrial laser scanning – TLS: In TLS, the structure's 3D geometry is obtained using light detection and ranging technology (LiDAR). The system works by emitting light and detecting its reflection to determine the distance to the object. The 3D models are created by stitching together multiple scans on a common coordinate system. The equipment used in this study was a long-range, RIEGL VZ-400, 3D terrestrial laser scanner (Figure 2a).

Close-range photogrammetry – CRP: In CRP, a series of images is recorded using digital cameras, and coordinates of points (targets), patterns, and features in the images are subsequently identified using image processing techniques. A minimum of 60% overlap between images is necessary, in both the longitudinal and transversal directions. A commercial photogrammetry software package, Agisoft PhotoScan Pro, was used to create 3D models. The equipment (Figure 2b) consisted of a Canon EOS 5D digital single-lens reflex (DSLR) camera with a full-frame CMOS optical sensor giving a resolution of 12.8 megapixels. The camera was equipped with a Canon EF 35mm wide-angle prime lens.

Infrared scanning – IS: Infrared scanning uses RGB-D cameras in combination with an infrared camera and an infrared projector to augment the still image with depth information. The sensors project a structured infrared light pattern onto the scene, and the reflected light is captured by the infrared camera and used to calculate depths. The camera used in this study was a Matterport Pro2 3D Camera (Figure 2d) that has three infrared sensors for capturing depth data together with visual data (RGB) at 360° (left – right) and 300° (vertical). When completed, the scans are uploaded to Matterport's cloud service for 3D data registration and the point cloud is obtained.

Figure 2 – Data acquisition equipment: (a) Terrestrial laser scanning; (b) Canon EOS 5D; (c) Unmanned aerial vehicle – 3DR SiteScan; and (d) Infrared scanning – Matterport Pro2 3D.

4. RESULTS AND ANALYSIS

The analysis was carried out both quantitatively and qualitatively. The first step was to create a 3D model of each of the scanned bridges and compare the visual capabilities of each method. A qualitative process was also carried out to highlight the potential of each method investigated. Quantitatively, geometric deviations were calculated when comparing the span length and width of each bridge deck. Only selected results are given in the following sections; the complete details of the study can be found in Popescu, Täljsten [3], [4]. Selected 3D models, as created by TLS, CRP and IS, are shown in Figs. 3 and 4.

Figure 3 – 3D models of Kedkejokk Bridge: differences in level of detail

Figure 4 – 3D models of Juovajokk Bridge: differences in level of detail

5. CONCLUSIONS AND FUTURE WORK

This study investigated the use of three optical methods for creation of digital models of bridges. It has been shown that the 3D models could serve as a tool for bridge inspectors from which measurements could be extracted. A complete off-site inspection is currently not feasible as some areas of the bridges were difficult to capture mainly due to restricted access and narrow spaces. The main conclusions of the study were as follows:

- All methods tested provided a digital model with different level of completeness, from which general measurements (span length, deck widths, pier diameters etc.) could be extracted with good accuracy.
- No special training is needed to create good quality 3D models using CRP or IS imaging. The high level of automation of the IS method, although a positive aspect, gives limited control and flexibility for improving the end-model by the bridge inspector.
- The point clouds generated were denser for TLS and CRP while for IS, the density was several times lower. Denser point clouds enable better visualization, however, at the cost of increased computational time, storage space and difficulty in handling the models.

Efforts are being devoted on automated damage detection by employing artificial intelligence and enriching the 3D model by additional information such as material properties and inner geometry. In order to study the existing structures over time and provide objective information of visible changes, additional scans would be necessary.

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