Combing Consumer-grade Depth Camera with a Machine Learning Model for Bridge Deterioration Geometric Information Calculation

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Bridge inspection is critical for ensuring bridge safety, especially given the frequent occurrence of major bridge accidents in recent years. Despite most bridges undergoing rigorous inspection procedures and benefiting from advanced technical support, the limited information available about deterioration poses a challenge in accurately understanding the true geometric details. To overcome this challenge, this study specifically investigates non-contact detection methods that utilize photogram-metry and machine learning-based semantic segmentation techniques. The primary objective is to assess the condition of bridges quantitatively and objectively, complementing traditional visual inspection methods. This research further incorporates the use of consumer-grade depth cameras, such as the iPhone 13 Pro, to enhance the detection process by providing an additional data source. By using a depth camera to capture depth information from the visual image, it helps to accurately calculate the geometric information associated with deterioration areas of the bridge. By generating RGB-D (color and depth) images in real time, valuable data can be extracted for analysis, resulting in a more comprehensive of bridge conditions.

This research includes observing and correcting depth-value and RGB image misalignment problems, depth-value range errors, and pixel measurement errors, as well as accomplishing depth-value and RGB image resolution mismatch adjustments to generate RGB-D images. We utilize machine learning-based semantic segmentation techniques augmented by the Lawin transformer, which introduces a multi-scale representation to semantic segmentation. The model also incorporates large window focusing, which allows local windows to query a wider range of contextual window regions with minimal computational overhead. The semantic segmentation model can accurately delineate the deterioration area in an image. In terms of geometric information, we utilize the relationship between the image space and the object space with using the similar triangle formula to extract the correspondence between the actual size of the pixels in the image space and the real space, so as to compute the geometric information of the deterioration area, including the size, length, and width. In addition, the proposed method can seamlessly transfer images over the Internet to a server for deterioration detection and return the deterioration prediction results and various geometric information of deterioration. This capability facilitates remote inspecting and analysis for efficient and timely assessment of bridge conditions. By utilizing a remote computing approach, bridge inspections can be performed with greater flexibility and scalability.

The proposed approach offers quantifiable and objective inspection results, standardized assessments, remote inspecting capabilities, enhanced flexibility, and improved accessibility. These advantages contribute to more effective bridge inspection practices, ultimately enhancing bridge safety.

Keywords: Consumer-grade depth camera, Semantic segmentation, Bridge inspection, Deterioration detection, Photogrammetry