Creating digital twins of existing bridges through AI-based methods

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Abstract

Bridges require regular inspection and maintenance during their service life, which is costly and time-consuming. Digital twins (DT), which incorporate a geometric-semantic model of an existing bridge, can support the operation and maintenance process. The process of creating such DT models can be based on Point cloud data (PCD), created via photogrammetry or laser scanning. However, the semantic segmentation of PCD and parametric modeling is a challenging process, which is nonetheless necessary to support DT modeling. This paper aims to propose a segmentation method that is the basis for a parametric modeling approach to enable the semi-automatic geometric modeling of bridges from PCD. To this end, metaheuristic algorithms, fuzzy C-mean clustering, and signal processing algorithms are used. The results of this paper show that the scan to BIM process of bridges can be automated to a large extent and provide a model that meets the industry's demand.

Keywords: bridge; digital twin; building information modeling; semantic segmentation; parametric modeling; artificial intelligence; metaheuristic algorithms; fuzzy C-mean clustering

1 Introduction

In building information modeling (BIM), a digital twin (DT) can be defined as the high-level digital replica of an existing asset. This model coherently contains the geometric and semantic information of buildings, infrastructures, and built environments and is updated regularly [1, 2]. It also visualizes all the gathered information from the construction site and provides an appropriate basis for inspection, condition assessment, and rehabilitation.

Bridges, as critical structures, require regular inspection during their service life. In current practice, these inspections are conducted through direct observation at the location of existing bridges. However, this process has disadvantages: 1) some elements of bridges are not easily accessible or even observable, 2) the results of inspection might be subjective, 3) data management after detecting the possible defects is not simple, and 4) localizing any defects or potential problem areas is not possible. To support direct inspection, capturing methods such as laser scanning and photogrammetry can be employed. Compared with a visual inspection, these methods are faster and have higher measurement accuracy [3]. The resulting point cloud data (PCD) of these scanning methods can be used for creating the digital twin models of bridges [4-8]. The DT of a bridge visualizes the existing structure's current status and provides a basis for monitoring and further analyzing elements based on their current conditions. Despite the advantages of digital twins and recent scanning methods, digital twinning based on PCD is not easy. To create the DT of a bridge, the PCD of the corresponding bridge needs to be semantically segmented, and the instance model is instantiated based on a parametric model. Both of these steps are costly, labor-intensive, and error-prone.