A novel hybrid approach for alignment modelling of virtual trial assembly of steel box girder bridge

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This paper

perform denoising on the point cloud data. The normal-based bilateral filtering algorithm is a well-established method for reducing noise as it considers both the distance from neighbouring points to the point and the distance along the normal direction. This approach preserves sharp edges better and performs well in filtering noise while retaining important features. Therefore, this paper uses normal-based bilateral filtering to reduce the noise of the steel box girder point cloud.

2.1.2 Segmentation

Point cloud segmentation aims to identify the point clouds belonging to the real sides and the base flange of the steel box girders

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The diffraction phenomenon model of the point cloud is then analysed, and the angle between the diffraction plane of the point cloud and the plane of the steel box girder can be obtained.

The point cloud data of a steel box girder segment are then segmented properly through the proposed algorithm with proper thresholds (Figure 2(b)). The effects of threshold

Figure 5: (a) First fitting (b) Detail of first fitting (c) Second fitting (d) Detail of second fitting

2.2.4 Reconstruction of the BIM model

The high-accuracy steel box girder model is finally constructed using Revit Dynamo, which allows the model to be parameterised and the position parameters of each node or line to be easily adjusted. The key inputs for this process are the box girder end nodes obtained from Section 2.2.2 and the bottom and top alignments from Section 2.2.3. These parameters include the 8 corner points of each steel box girder, the alignment, and the design thickness of the steel plane on each side, as shown in Figure 6.

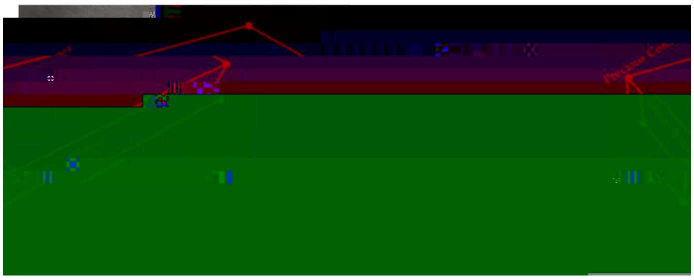

Figure 6: (a) End nodes of a box girder (b) BIM model of reverse generated steel box girder

2.3 Virtual assembly

After constructing a high-accuracy virtual model of the steel box girder, the Generalized Procrustes Algorithm (GPA), a widely used method in VTA, is used for alignment of multiple models. While previous studies have successfully applied this method to assemble multi-section prefabricated rods sequentially, cumulative errors may lead to failure in the final assembly of multi-segment members. To address this challenge, this study proposes a trial assembly method that combines design drawings, involving three key steps. Firstly, the nodes of the reverse model are projected onto the graph, as depicted in the figure. Secondly, the ICP algorithm is used to roughly register the reverse model and the design drawings. Finally, the GPA algorithm is used for the final registration of the steel box girder plane, followed by fitting the z value of one side of steel box girder to calculate the z-axis displacement value of each steel box girder, as shown in Figure 7. This method provides an excellent initial position for the trial assembly for the steel box girder, effectively avoiding the accumulation of assembly errors, and enabling a more accurate and efficient construction process.

Figure 7: (a) Node projection of the model (b) Model's node projection outcome

3. Case study

3.1 Experimental Process

To examine the effectiveness and accuracy of the proposed quality assessment technique, 3-segment steel box girders were fabricated and experiments were conducted on the specimen, as shown in Table 2. The end of the specimens was a rectangle surrounded by multiple straight lines, with dimensions of 300×600mm.The purpose of the experiments was to evaluate the

3.2 Result and Discussion

The results show that the deviations between VTA model line and design line can be identified and visualised (shown in Figure 9), which provides an important indicator for quality monitoring of the VTA process of steel box girder bridge. It can further help the construction workers to assess the weld size or cut size, as shown in Figure 10.

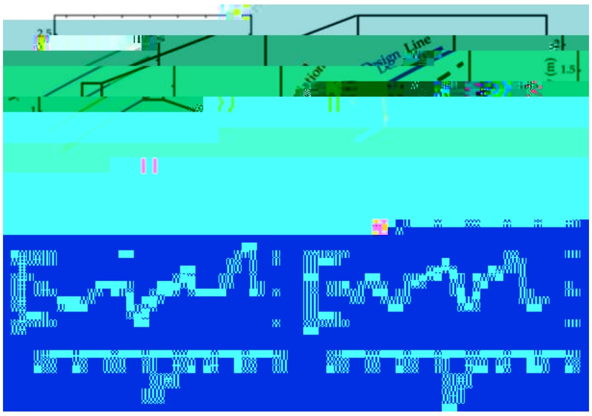

Figure 9: (a) Designed line shape of Top and Bottom planes (b) Line shape deviation between VTA and design models (c) Line shape deviation of the top plane (d) Line shape deviation of the bottom plane

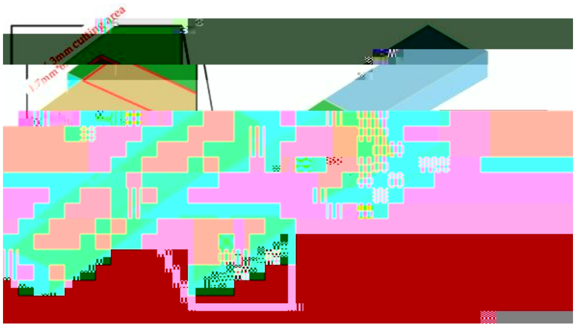

Figure 10: Weld and cut prediction in model

3.2.1 Accuracy analysis

Through comparing the pointwise deviations, the developed approach can provide an accurate modelling of steel box girders (Figure 11), where more than 90% of the deviations of three steel box girders are within 1.6 mm, and 76.3% of deviations of girder #3 are within 0.4 mm.

The deviation analysis of corner points in the VTA model is also conducted on the x, y, and z-axis, including the corner points connecting #1 and #2 girders, and those connecting #2 and #3 girders. These x-axis deviations are the smallest ones, with maximum value of 0.2 mm, as shown in Figure 12. However, the deviations on the Y and Z axes are relatively large, especially for the left and right nodes of the bottom plane, which are around 1mm.

can also quickly evaluate the quality of the steel box girder and promptly identify and resolve issues to improve the quality and safety of the structure.

4. Conclusions

The proposed hybrid modelling method offers significant improvements in both efficiency and accuracy in the quality inspection and trial assembly of steel box girders. In terms of efficiency, the method's fast, accurate, and automated features lead to reduced costs, improved work efficiency, and increased potential for broader applications. In terms of accuracy, statistical analysis reveals a high level of precision, with more than 90% of the girders exhibiting a maximum deviation of 1.6mm. These findings demonstrate the potential for the proposed method to significantly improve the quality and safety of steel box girder structures. However, it is important to note that this study has some limitations that require further exploration in future work. Firstly, the proposed quality assessment technique was only validated on laboratory samples, which may result in differences between the obtained results and actual engineering outcomes due to the small size of the laboratory sample. Secondly, this study only pre-assembled the three-segment steel box girder, and future research should focus on verifying the trial assembly of the full-bridge steel box girder, which may present greater challenges due to the complexity of boundary conditions.

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