construction robotics

international M.Sc.programme

Master Thesis

Advancing Steel Structure Assembly Automation: A Standardized Assembly Description for Enhanced Efficiency and Integration

Efficient Data Matching for Robotic Steel Assembly

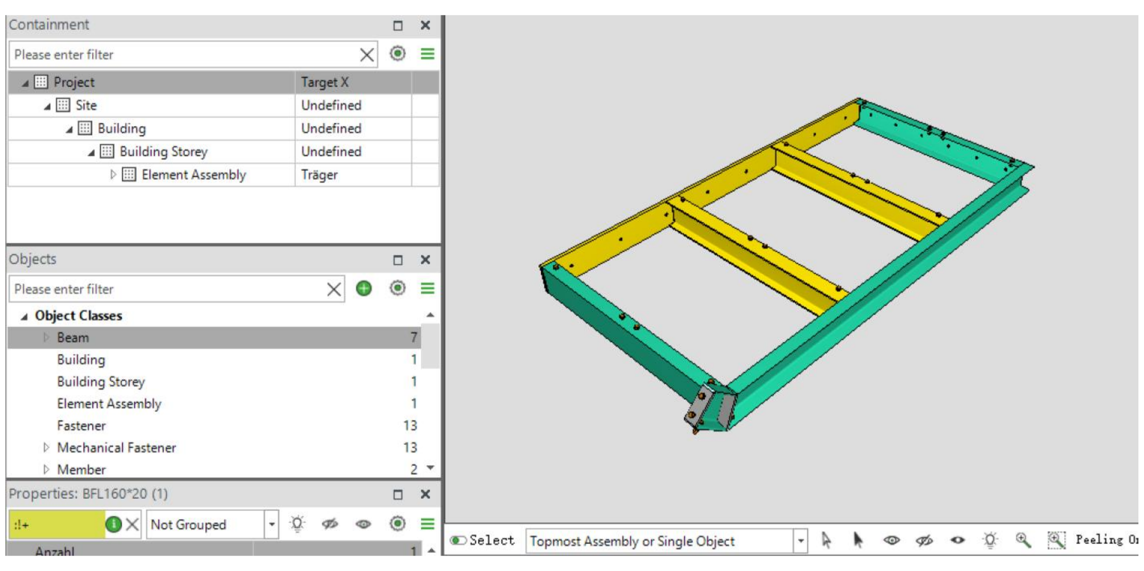

Figure 1 IFC Model Visualization: Nine-component Ring Beam Assembly [1].

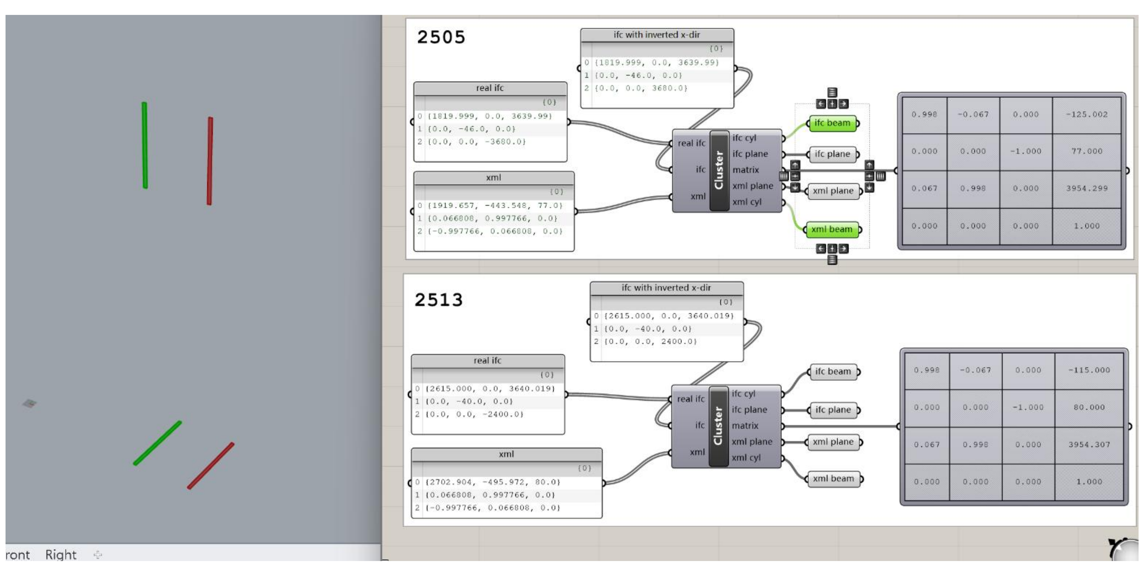

Figure 2 Visual validation (Grasshopper left / Rhino right) for two component pairs with negligible rotational error (ε_rot=0)—2505.nc and 2513.nc—from Case Study_2 [2], illustrating corrected alignment after manual verification in Case 2; similar correction was applied in Case 1 and 3.

Introduction

This research targets automated steel assembly workflows, critically relying on interoperability between IFC models and NC fabrication data. Currently, inconsistent data standards and manual interventions limit efficiency and scalability [3]. To address these challenges, we develop an automated matching framework between IFC and DSTV-XML data, exemplified through visual model verification (see Figure 1 and Figure 2).

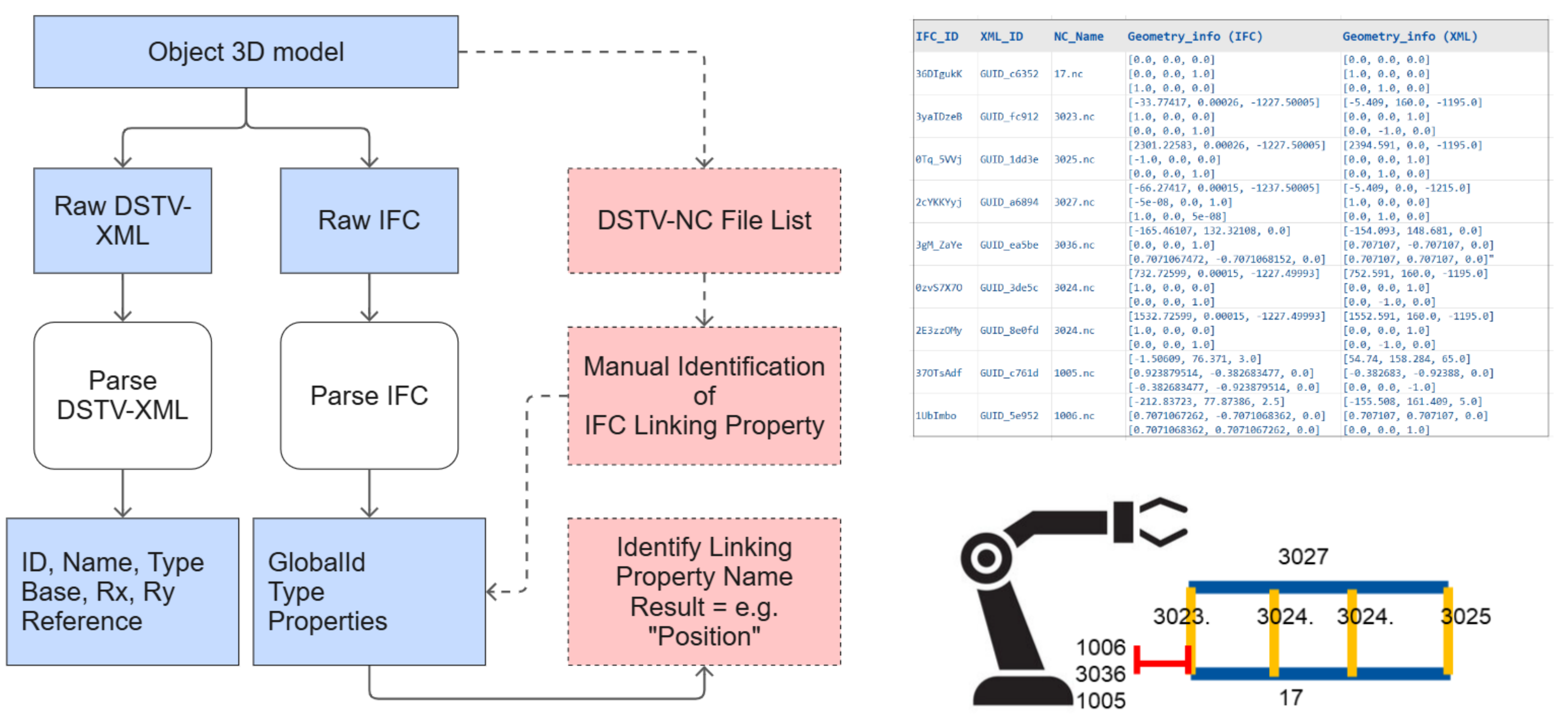

Figure 3 Comprehensive Parsing, Preprocessing, and Standardization Workflow for IFC and DSTV-XML Data. This is the pre-step of the entire workflow.

Strategy

This research began with a comprehensive literature review and an industry survey to identify key challenges and requirements. Subsequently, structured data preprocessing was performed, standardizing the data into JSON format for consistent handling, as depicted in Figure 3. The processed data was then matched using a robust **IFC–DSTV-XML matching and ambiguity resolution framework**, incorporating geometric and identifier-based methods (Figure 4). Finally, computational verification complemented by targeted manual validation ensured the accuracy and reliability of the matching results, as illustrated in Figure 2.

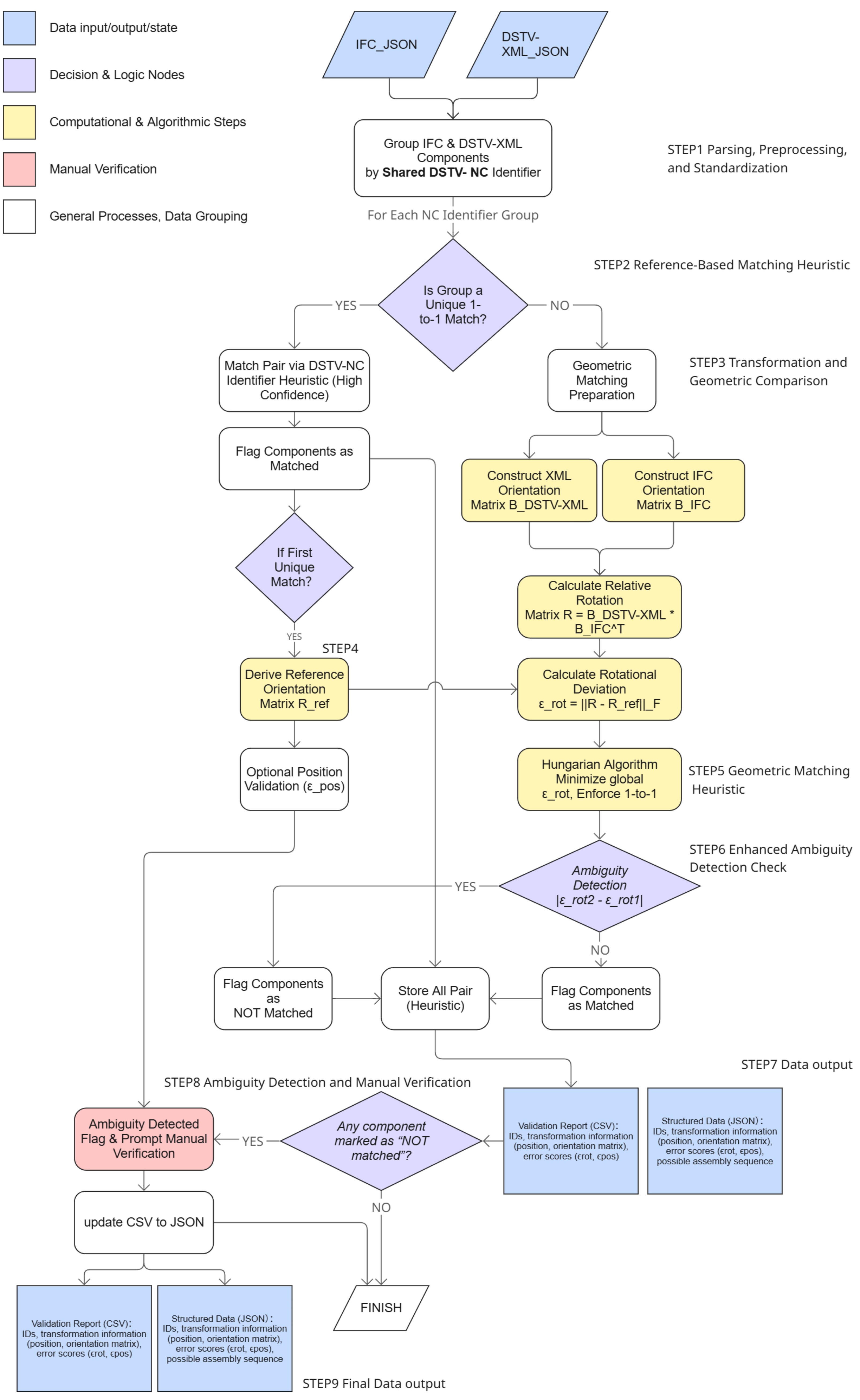

Figure 4 Robust IFC–DSTV-XML Component Matching and Ambiguity Resolution Framework.

Results

The initial case showed full automatic matching at first, but visual verification revealed two symmetry-related mismatches that were corrected to achieve true alignment. A more complex second case involving a realistic industrial steel structure demonstrated robustness, successfully matching 43 components despite duplicate identifiers and incomplete orientation data; 29 matched via unique identifiers, and 14 via geometric validation with Grasshopper and Rhino software. A third case compared IFC2x3 and IFC4 versions. Due to symmetric geometry, the IFC2x3 export produced an incorrect match despite identical error scores. Visual validation confirmed the IFC4 result as correct, reinforcing the importance of version-consistent exports and ambiguity detection.

Conclusion

Efficient interoperability between IFC and DSTV-XML data significantly reduces the need for manual verification, restricting human involvement exclusively to ambiguous cases. Case studies have confirmed that the developed matching framework is robust and scalable, effectively performing across various realistic scenarios. Furthermore, standardizing IFC properties and NC file naming conventions is critical for enhancing automation reliability. Future research should focus on integrating automated ambiguity detection and interactive validation directly into computational workflows to advance full automation in steel structure assembly.

Sources:

[1] C. H. Wu, M. Zöcklein, S. Brell-Cokcan, “Unified framework for mixed-reality assisted robotic path planning enabled by 5G,” 41st Int. Symp. Autom. Robot. Constr., Lille, France, 2024.

[2] S. Brell-Cokcan et al., “Einleitung Internet of Construction,” in IoC - Internet of Construction, Wiesbaden: Springer, 2024, pp. 1–15.

[3] L. Rocha et al., “BIM for the Steel Fabrication Industry Robotic Systems,” 34th Int. Symp. Autom. Robot. Constr., Taipei, Taiwan, 2017.

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