

Individual 3D Modeling Using Tilted Model Paradigm

Mingchen Bai *

School of Geomatics and Urban Spatial Information Beijing University of Civil Engineering and Architecture Beijing, China

* Corresponding author: Mingchen Bai (Email: mingchenbai@163.com)

Abstract: With the rapid development of 3D Geographic Information Systems (3D GIS) and smart city construction, oblique photogrammetry has been widely adopted for 3D reality modeling due to its efficiency and high precision. However, the triangular irregular network (TIN) models generated from oblique imagery typically form continuous surface models, making direct individualization and independent management challenging. This paper systematically examines the strengths and limitations of existing individualization methods and proposes a structured workflow for model individualization. By employing techniques such as model reconstruction and attribute association, the study achieves independent extraction and structured representation of targets (e.g., buildings, roads) within oblique models. Experimental results demonstrate that the derived models support subsequent spatial analysis and attribute management, providing enhanced data foundations for refined 3D geospatial applications.

Keywords: 3D Modeling; Individualization; Oblique Photogrammetric Model.

1. Introduction

"Individualization" refers to the process of creating independently selectable and manageable entity objects, where each element can be highlighted (e.g., through mouse-click interactions), assigned attributes, and queried or statistically analyzed. In manual 3D modeling, the production process inherently achieves individualization by default [1].

In recent years, 3D spatial models have gained increasing recognition and widespread adoption across various departments and industries, driven by the demands of smart city construction as well as urban and territorial planning management. Oblique photogrammetry, a cutting-edge technology promoted in the international surveying and mapping field, utilizes multiple sensors to capture image data from various angles, thereby obtaining a more realistic representation of ground features [2]. However, this technology has inherent limitations. Due to its automated modeling mechanism, oblique photogrammetry does not inherently support individualization. The resulting model resembles a continuous, undulating "skin" covering the entire area, where individual surface objects cannot be selectively manipulated or managed. Consequently, essential GIS operations—such as attribute queries, spatial queries, and thematic mapping—cannot be performed. This renders the 3D data visually impressive but functionally limited, significantly diminishing its practical value and utility [3]. Therefore, post-processing individualization of reality-based 3D models becomes imperative. Only by achieving "individualization" can the data transition from being merely visually accessible to being fully manageable [4].

2. Research Objectives

2.1. Software Foundation

This study utilizes oblique image-based models and employs a suite of specialized software for comprehensive processing, including DasViewer, Unity, Revit, and Blender, to conduct thorough and meticulous treatment of the target campus area. During processing, customized independent operations were performed on different feature objects

according to practical application requirements, decomposing the oblique model into individual units that can be independently processed, edited, and enriched with various attributes. Through these refined processing steps, we successfully completed the campus building mapping work. This achievement provides robust technical support and data assurance for precision campus management and efficient operations, significantly enhancing the campus's management capabilities and operational efficiency.

2.2. Data Overview

The target campus is located in Ningbo City, Zhejiang Province, covering a total area of 49,873.306 m², with 26,479.64 m² allocated for core functions and internal facilities within the campus boundaries, while the remaining 23,393.666 m² comprises peripheral areas dedicated to green spaces, roads, and auxiliary facilities. The built-up area spans 11,028.239 m², accommodating diverse functions including offices, research facilities, and production units, demonstrating the campus's scientific planning and practical design.

The building base areas suffer from significant visual obstruction due to surrounding vegetation, making it particularly challenging to clearly observe and extract geometric information of the lower structures. Compounding this difficulty, the original image models exhibit substantial distortion caused by severe camera tilt during acquisition, which not only deforms the overall building morphology but also severely compromises the accuracy of geometric feature extraction. Furthermore, the buildings demonstrate highly diverse surface characteristics, featuring extensive glass curtain walls combined with complex structural elements such as railings, protruding balconies, and various door openings - this architectural complexity substantially increases the challenges in automated feature extraction.

The road network presents significant challenges due to its complex composition and varying characteristics, while building base areas are particularly problematic as surrounding vegetation causes visual obstructions that obscure lower structural details, substantially complicating geometric information extraction. These difficulties are

compounded by pronounced model distortions resulting from severe camera tilt during image acquisition, which not only deform overall building morphology but also critically impair accurate feature identification. Furthermore, the diverse surface characteristics of buildings - including extensive glass curtain walls combined with architectural elements such as railings, protruding balconies, and varied door openings - introduce additional complexity that exacerbates automated extraction challenges, creating a multi-layered problem set that requires sophisticated processing solutions.

Furthermore, the ground surface exhibits remarkable diversity with numerous small-scale elements including various vegetation types, landscape features, and paving materials. These elements are characterized by their extensive quantity and wide spatial distribution, posing significant challenges during 3D modeling processes. Particular attention must be paid to avoid omission of these details, as any oversight could compromise both the completeness and accuracy of the final model representation.

3. Technical Methodology

3.1. Model Construction

The final deliverable of this research is in the Unitypackage format. However, during actual implementation, using Unity for modeling presents numerous inconveniences and limitations. To overcome these challenges, a common solution is to utilize specialized modeling software to generate models in .fbx format, which are then imported into Unity for further processing and application. In this study, we employed Revit and Blender to create the required .fbx models for the campus environment.

The specific workflow is as follows: First, we used DasViewer software to perform precise measurements of various elements within the inclined imagery of the campus, obtaining detailed geometric data. Subsequently, these measurement results were imported into Revit or Blender to construct accurate 3D models based on the acquired geometric information. During the modeling process, we observed that certain sections of the buildings exhibited geometric distortions due to occlusion by trees. To address this issue, we implemented a corrective approach: by referencing on-site photographs, we carefully analyzed and identified the detailed structural characteristics of the affected areas, then refined the modeling accordingly. This ensured the authenticity and accuracy of the final models [5].

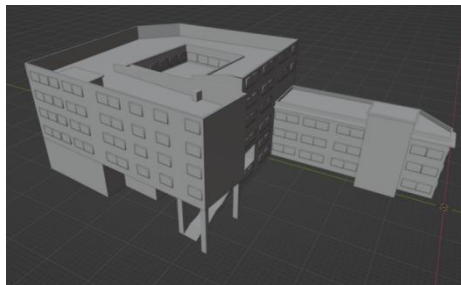


Figure 1. Construction of Building Massing Model

3.2. Texture Mapping

To ensure the authenticity and realism of the constructed models, this study requires meticulous texture mapping on the completed building massing models. In the underlying graphics processing mechanism, the system can only recognize and process images with dimensions that are

powers of two (e.g., 2, 4, 8, 16, etc.). For images that do not meet this standard, the system automatically converts them to the nearest power-of-two dimensions. However, this conversion process is not only technically complex but also time-consuming, significantly increasing overall processing time costs. Therefore, texture materials must strictly adhere to power-of-two dimensions, and to balance performance with visual quality, the maximum size should not exceed 2048×2048.

Furthermore, to achieve more realistic and nuanced light-shadow interactions, this study incorporates normal maps and ambient occlusion (AO) maps, which substantially enhance surface lighting details and depth perception [6]. In specific areas, achieving texture continuity and completeness requires tiling a single photo repeatedly until the region is fully covered. However, directly using unprocessed original photos for splicing often results in harsh and unnatural seams, severely compromising the final visual effect. To address this issue, the study performs necessary post-processing on the provided source images, employing professional techniques to convert them into seamless textures. This ensures natural transitions at splicing boundaries, thereby improving the overall visual realism of the models [7].



Figure 2. Texture Mapping Process on the 3D Model

3.3. Data Integration

A meticulous integration process was performed on all submitted deliverables, accompanied by rigorous inspection to detect any minor gaps at data junctions. When gaps were identified, immediate precision adjustments were implemented to rectify these imperfections. In cases where gap severity exceeded the capacity of minor adjustments, comprehensive reworking procedures were mandated to ensure the final deliverables maintained complete structural integrity and accuracy.

3.4. Model Quality Inspection and Modification

The model undergoes rigorous quality inspection to identify any light leakage at junctions, verify whether its precision meets predetermined standards, check if material naming complies with specified conventions, and confirm that texture dimensions satisfy project requirements. Any non-compliant models detected during this process must undergo comprehensive reworking and modification until full compliance is achieved. The final deliverables must be free from light leakage, insufficient precision, non-standard material naming, or substandard texture dimensions, and must pass strict quality verification by the client's model inspectors to ensure full compliance with all quality specifications.

4. Experimental Results and Analysis

4.1. Experimental Outcomes

(1) Building A 3D Entity Model (Figure 3): The "Building A. fbx" file contains 10 feature categories, with a footprint area of 2,209.317 square meters across five floors.

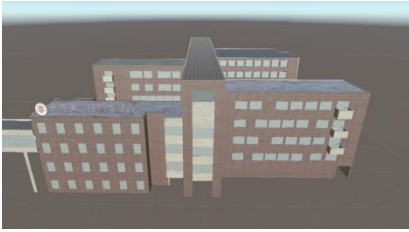


Figure 3. Modeling results of the Building A

(2) Building B 3D Entity Model (Figure 4): The "Building B. fbx" file contains 16 feature categories, with a footprint area of 3154.714 square meters across six floors.



Figure 4. Modeling results of the Building B

(3) Building C 3D Entity Model (Figure 5): The "Building C. fbx" file contains 9 feature categories, with a footprint area of 1527.843 square meters across six floors.



Figure 5. Modeling results of the Building C

(4) Building D 3D Entity Model (Figure 6): The "Building D. fbx" file contains 7 feature categories, with a footprint area of 2372.061 square meters across two floors.

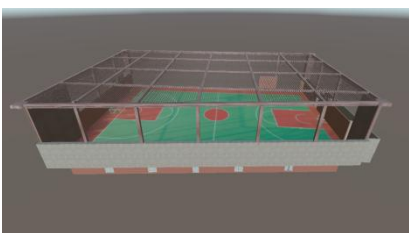


Figure 6. Modeling results of the Building D

(5) Building E 3D Entity Model (Figure 7): The "Building E. fbx" file contains 5 feature categories, with a footprint area of 1141.885 square meters across two floors.



Figure 7. Modeling results of the Building E

(6) Annex Building C 3D Entity Model (Figure 8): The "Annex_C_Building. fbx" file comprises 6 feature categories, covering a footprint area of 449.987 square meters with two floors.

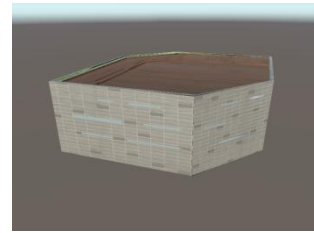


Figure 8. Modeling results of the Annex_C_Building

(7) Monomerized 3D Entity Model of the guard building (Figure 9): Guard Building. fbx, containing 6 types of elements, with a floor area of 172.432 square meters and a total of one floor.



Figure 9. Modeling results of the target park

(8) Monomerized 3D Entity Model of geomorphic features (Figure 10): Landform. fbx, containing 41 types of elements, with a floor area of 49,873.306 square meters.

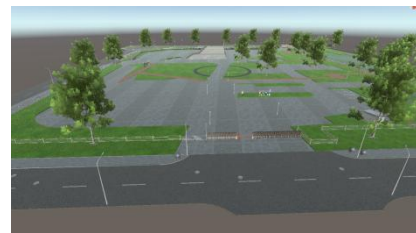


Figure 10. Modeling results of the Landform

(9) Monomerized 3D Entity Model (Figure 11): Park. fbx model, containing 8 groups of element groups, and exported as Park. unitypackage file, with a floor area of 49,873.306 square meters.



Figure 11. Modeling results of the target park

4.2. Summary and Analysis

In recent years, the rapidly developing oblique aerial photogrammetry technology has enabled the rapid and efficient acquisition of large - scale urban real - scene 3D model data. However, the automatically constructed 3D models are merely continuous 3D surface models of the overall scene without semantic topological relations. They are only suitable for simple applications such as macro - level visual browsing of the overall scene and cannot meet the needs of applications like refined urban management. Therefore, conducting research on the monomerization

method of buildings in real - scene 3D models is of great significance for promoting the construction of refined management in smart cities. Through monomerization modeling technology, oblique models can be transformed into individual entities that can be processed, edited independently and have attributes attached, which contributes to the refined and efficient operation and management of the park.

In this study, oblique image models were used as the initial data. The geometric parameters of the park were obtained by measuring the image models. Based on these parameters, drawing was completed using Revit and Blender software, and texturing was done in combination with on - site photos of the park. Finally, the models were spliced and imported into Unity to generate a. unitypackage file. Eventually, 8 groups and 100 types of monomerized models were obtained, with a total area of 49873.306 square meters.

5. Conclusion

In this study, through the monomerization modeling technology based on oblique image models, the 3D model monomerization processing of the target park was successfully realized, transforming the oblique model into independent objects that can be operated, edited and attached with attributes individually. The research completed key steps such as model construction, texture drawing, data splicing and quality inspection using software including DasViewer, Revit and Blender. Finally, a monomerized model containing 8 element groups and 100 types of elements was generated, with a total area of 49,873.306 square meters.

The research results show that the monomerization technology has effectively solved the problem that oblique photogrammetry models cannot be managed and queried independently, significantly improved the practicality and management efficiency of the models, and provided strong

support for smart cities and refined operation management of parks. Although there were challenges such as tree occlusion and model distortion during the research process, through manual intervention and technical optimization, the final results met the needs of practical applications, verifying the feasibility and effectiveness of this technical process.

References

- [1] Gao Xiaolong, Chai Shuchun, Li Xiaojun. 3D Modeling of Yardangs Based on Multi-source Data Fusion [J]. Beijing Surveying and Mapping, 2024, 38(8): 1141-1145.
- [2] Dong Zhaoxuan, Liu Ronghua. Discussion on Model Repair Technology for 3D Refined Modeling Based on UAV Oblique Imagery [J]. China New Technologies and Products, 2024(1): 104-107.
- [3] Feng Siwei, Yan Jun, Liu Luming, et al. Construction and Application of Refined 3D Models from UAV Oblique Photogrammetry [J]. Geomatics & Spatial Information Technology, 2024, 47(6): 48-50, 54.
- [4] Xu Bangsui, Shen Xiangyu. Method for Monomerization of Building Models Based on Oblique Photogrammetry [J]. Beijing Surveying and Mapping, 2024, 38(9): 1317-1322.
- [5] Fan Fangchao, Wang Qiang, Wu Di. Application of Multi-source Data Fusion Technology in 3D Reconstruction of Ancient Buildings [J]. Geomatics & Spatial Information Technology, 2025, 48(S1): 157-159.
- [6] Zhang Min, Sun Lue. Research and Implementation of Pseudo-indoor Texturing Based on Parallax Mapping [J]. Advanced Motion Picture Technology, 2023(3): 23-29.
- [7] Li You, Yao Mengmeng, Wei Zhiwei, et al. Adaptive Generation Method for Lightweight Indoor Perspective Textures [J]. Bulletin of Surveying and Mapping, 2025(2): 83-88. DOI: 10.13474/j.cnki.11-2246.2025.0215.