



DETERMINING THE RISK CONDITIONS OF STRUCTURES THROUGH 3D MODELING

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Abstract

By evaluating post-earthquake risks using Google Street View images for 3D data acquisition in Nurdagi, this study seeks to improve community safety and resilience. Using 180° and 360° scans, a total of 5548 images were gathered. The 'Structure from Motion' algorithm was then used to create surface meshes, depth maps, and a 3D point cloud. Texture mapping was used to successfully model structures in three dimensions. This method offers comprehensive data resources and makes important contributions to structural engineering, architectural conservation, and urban planning by using Google Street View photos as an alternative to conventional 3D modeling.

Introduction

With a wide range of uses, including advanced urban planning, the meticulous reconstruction of historic and ancient urban settlements, state-of-the-art educational and simulation programs, complex landscape architecture, the production of thorough environmental noise maps, and the development of strong disaster management plans, 3D city models have become more and more important in modern urban development and planning (Over et al., 2010). Building these complex 3D urban models frequently requires a multifaceted strategy that integrates a wide range of data sources. Advanced photogrammetry techniques, precise laser scanning, detailed data from Synthetic Aperture Radar (SAR), carefully planned architectural models, detailed 3D survey drawings, and a variety of other advanced measurement methodologies are usually used in this integration (Biljecki et al., 2016). The combination of highly detailed digital surface models and densely populated point clouds has caused a major paradigm shift in the field of urban modeling in recent years. A new era in 3D urban modeling has begun with these models, which are primarily produced using the cutting-edge methods of digital photogrammetry and the most recent LiDAR (Light Detection and Ranging) technology (Nex and Remondino, 2012).

Unquestionably, a crucial development for many stakeholders is the requirement for a standardized framework and the availability of these models on a single platform, even though the particular requirements and features of 3D city models differ greatly depending on their intended ap-

plication. The CityGML standards have been painstakingly created to meet this need. These guidelines are intended to facilitate the sharing and interoperability of three-dimensional urban models across various applications while also expediting the standardization process. CityGML, created by the International Open Geospatial Consortium (OGC), carefully outlines the geometric, topological, and semantic aspects of 3D city models (Kolbe et al., 2005). The spatial and semantic complexities of scalable modeling are systematically expressed across five different Levels of Detail (LoD) in accordance with these well-organized standards. The adoption of CityGML standards has revolutionized the way these intricate models can be shared and transferred across multiple platforms, guaranteeing their constant and extensive availability to a wide range of users. Furthermore, the introduction and ongoing development of numerous platforms and services, including the widely used Google Earth, intricate Photogrammetric Maps, and extensive LiDAR Data services, have transformed and enabled user interaction and engagement with 3D city models (Leberl et al., 2009). However, it is noteworthy that, in the current scenario, these sophisticated 3D city models are typically made available to users in relatively lower levels of detail, predominantly at the LoD1 or LoD2 stages, catering to a broad base of user requirements while balancing the complexity and resource intensity of higher-detail models (Yastıklı et al., 2017).

In this study, the formation of 3D models began with the systematic collection of Google Street View images, accessed through Google Maps. The data collection was carried out in the Nurdağı district of Gaziantep, resulting in a dataset of 5,548 images acquired over 629 sequential steps. A dual scanning approach was employed: a 360° image capture in narrow, single-lane streets (twelve images per scan), and a 180° scan in wider roads (seven images per scan). This method provided broad spatial coverage and multiple viewpoints for each building. The images were extracted per building and processed using the Structure from Motion (SfM) algorithm, generating 3D point clouds with texture mapping. These point clouds were then used to reconstruct the geometry of buildings. The full dataset contains images sufficient to generate 3D models for approximately 170 distinct buildings. In this paper, six representative buildings were selected to demonstrate the fea-

sibility and accuracy of the proposed workflow. Future work will extend the analysis to the entire dataset. The resulting models allow for the extraction of key geometric features such as floor count, façade irregularities, and the presence of short columns, which are relevant for seismic risk assessment and urban planning. The novelty of this study lies in its integration of freely accessible street-level imagery with automated 3D reconstruction techniques to rapidly generate structural models in post-disaster zones. This offers a scalable and cost-effective alternative to traditional site surveys, especially in urgent post-earthquake scenarios.

Dataset

This study focuses on generating 3D building models from 2D images. The steps of the study are illustrated in Figure 1. In this study, an extensive collection of Street View images was conducted along four primary roads that traverse the Nurdagi region, using OpenStreetMap (Contributors, 2004) as the base tool.

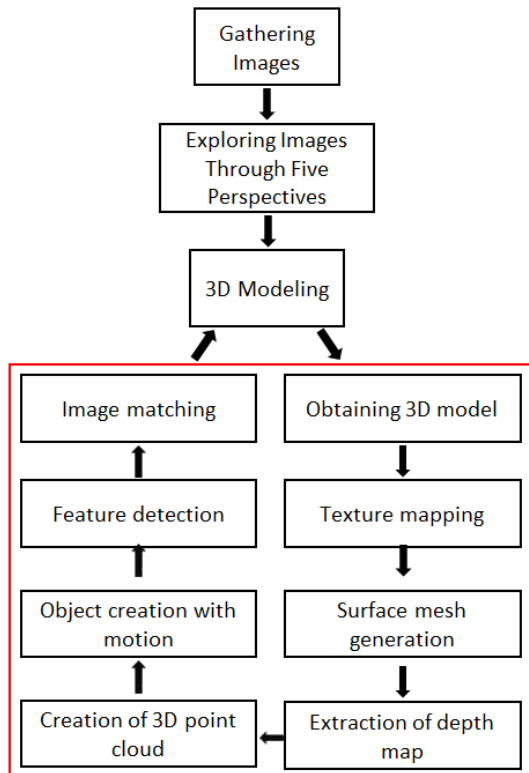


Figure 1: The flowchart illustrates the steps of the study

The process of gathering images was carried out using the Python programming language. Python was used extensively in this study to access Google Street View imagery through the API. The images were not screen captures or photographs of images; they were directly retrieved from the official API, ensuring consistency, resolution, and location accuracy. Python facilitated the process by automating repetitive tasks, handling data manipulation, and

integrating with other tools. It was chosen for its accessibility, library support, flexibility, and scalability. The aim was to enable efficient data collection and promote standardization and reproducibility in the study's methodology. What sets this data collection method apart is its approach of capturing images at intervals equivalent to human walking steps, enabling the acquisition of diverse perspectives of buildings. As a result, multiple images of the same structures from various angles were obtained, and these images played a central role in constructing a comprehensive 3D dataset. For the narrower and single-lane roads, a 360° scanning technique was employed, resulting in twelve images per scan. Conversely, in other areas, a 180° scanning methodology was adopted, leading to seven images per scan. Through this systematic approach, a total of 5,548 images were gathered over the course of 629 steps. Subsequently, the images underwent a sorting and extraction process, with each individual structure being identified. It is worth noting that images of the same structure were available at different steps throughout the process. For every distinct structure, these photos were sorted and grouped to create separate datasets. Figure 2 shows the four main roads' layouts as well as the geographic region from which this dataset was gathered.

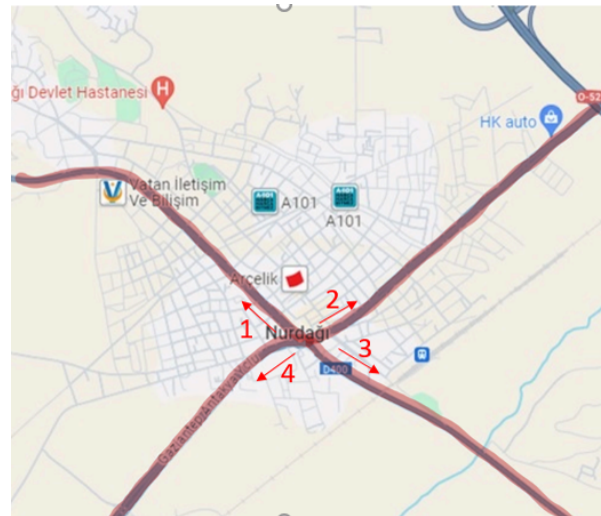


Figure 2: Four major roads and the region where the dataset was collected

3D Models

Exploring Images Through Five Perspectives

It is crucial to use images from at least five different perspectives when creating three-dimensional (3D) models from two-dimensional (2D) images. Compared to four perspectives, five perspectives offer superior accuracy, redundancy, coverage, and depth perception. Six viewpoints could increase accuracy even more, but they could also add needless repetition and computational complexity. As a result, five viewpoints balance 3D modeling efficiency and accuracy. This method is essential for faithfully conveying the complexity and subtleties of the subject. Through the

parallax effect, which occurs when an object's relative position appears differently when viewed from different lines of sight, multiple perspectives help people perceive depth. This effect is essential for comprehending a scene's depth and spatial relationships. Furthermore, more efficient feature extraction and matching are made possible by having photos taken from a variety of perspectives. It assists in recognizing important features of an object, such as edges and textures, which can be difficult to photograph from a single angle. By offering various perspectives of hidden or distorted features, multiple angles help to mitigate the ambiguity present in 2D images. This diversity is necessary to ensure the final model is cohesive by precisely aligning the images in a 3D space. A greater surface area of the object is also covered by photos taken from multiple angles, which is crucial for intricate structures or shapes where components could obstruct one another. A more thorough and intricate 3D representation is guaranteed by this extensive coverage. Additionally, it records changes in texture and lighting from various perspectives, which enhances the model's realism and depth. In order to render the model more accurately to the actual object, these variations are essential. Essentially, using at least five distinct viewpoints in 2D-to-3D modeling is a methodological approach that significantly improves the final 3D model's accuracy, detail, and realism in addition to being a technical necessity. By successfully overcoming the drawbacks of 2D imagery, this method improves the 3D reconstruction's overall quality and depth information. Five different views of a single building are shown in Figure 3, from which a 3D model has been created.



Figure 3: Five perspectives of one building

3D Modeling

The collected images underwent a meticulously executed processing phase, with the primary objective of generating comprehensive 3D models of the structures. Figure 4 serves as a visual representation of the meticulously crafted and texture-mapped model, showcased in a point cloud format. To achieve this model, several fundamental steps were undertaken.

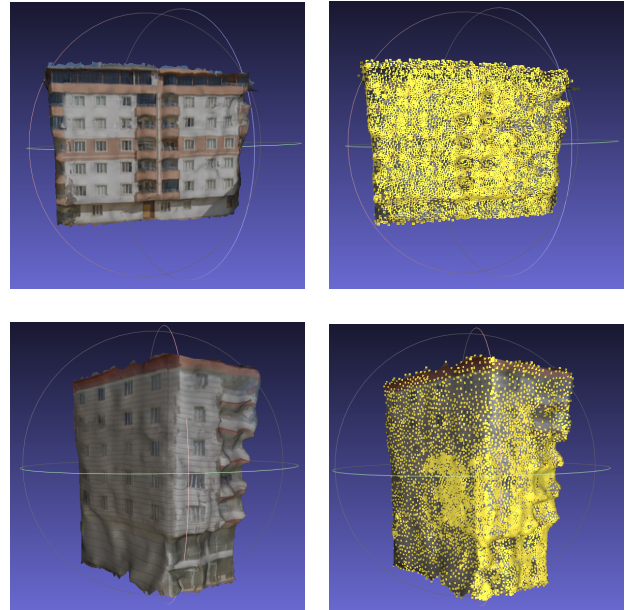


Figure 4: The representation of the point cloud for the cleaned texture-mapped model.

The initial stage involved the intricate extraction of camera characteristics from the amassed image dataset, a crucial foundation for subsequent steps. Following this crucial calibration step, the process seamlessly transitioned into feature detection and image matching processes, where intricate details and key points within the images were identified and aligned. These feature points, representing distinctive landmarks, served as the basis for establishing correspondences between images. Subsequently, the cutting-edge 'Structure from Motion' (SfM) algorithm was meticulously applied. This sophisticated algorithm analyzed the correspondences between feature points in different images to reconstruct the 3D positions of these points in space. In the end, it produced an extremely detailed 3D point cloud that accurately depicted the spatial arrangement of structures within the images by inferring the camera poses (positions and orientations) for each image. After that, depth maps that revealed the relative distances of the objects in the pictures were expertly extracted. In the reconstructed 3D space, these depth maps were essential for differentiating objects at different depths. A complex surface mesh was painstakingly built upon this geometric base. This mesh produced a visually cohesive 3D model by guaranteeing a smooth representation of the structures' geometries. The artistry of texture mapping was applied precisely in the last step of this complex process. The 3D modeling process was successfully completed by expertly applying the visual textures that were captured in the 2D images to the 3D model. This increased the 3D models' usefulness by making them both geometrically and aesthetically accurate. The Meshroom software (Moulon et al., 2019) was used to create these intricate models. By using sophisticated algorithms, this software made it possible to process and convert the gathered pho-

tos into 3D models in an efficient manner. Meshlab was used to post-process these models (Cignoni et al., 2008). A high-fidelity representation of the original structures was ensured by carefully removing extraneous elements from around the building models in Meshlab and refining the models for increased accuracy and detail. Automated detection algorithms can effectively identify important architectural features like wall planes, windows, and doors from this point cloud, as well as determine the number of floors and spot any obvious irregularities. However, it's essential to highlight that while the described 3D modeling process is highly advanced and precise, it has been executed for only six structures to date. The comprehensive coverage of the entire area remains an While the described 3D modeling process demonstrates significant advancement and precision, it is important to acknowledge the inherent design constraints and limitations of the study. Firstly, the process has only been applied to six structures to date, indicating a limited sample size. However, the most significant constraints encountered during implementation are related to the images. If there are cars, trees, or other objects in front of the buildings in the images, even with five perspectives, a 3D model cannot be created. Additionally, if the entire building is not visible in the images, either due to being too close or too far away, 3D models cannot be generated.ongoing endeavor, and Figure 5 provides a glimpse of the models created for these six structures.

Results

The completion of 3D models for all six buildings, as shown in Figure 4, represents a key milestone in this study. These models provide a foundation for seismic hazard assessments by enabling the identification of critical structural features. In particular, they allow for the evaluation of floor plan irregularities, number of stories, and the placement of windows and doors. To evaluate the accuracy of the generated 3D models, a comparison was made between the actual and modelled number of floors and detected irregularities for six selected buildings. The results are presented in Table 1. In all cases, the number of floors—reported as *Actual* and *Modelled*—was estimated with a maximum deviation of ± 1 floor, denoted as ΔF . Additionally, seven out of nine actual irregular floors (*Ir(A)*) were correctly identified by the model (*Ir(M)*), with their differences shown as ΔI . These findings demonstrate the effectiveness of the proposed method in capturing both the overall structure and structural irregularities relevant to seismic risk.

Table 1: Comparison of actual and modelled floors and irregularities

ID	Act	Mod	ΔF	Ir(A)	Ir(M)	ΔI
B1	7	7	0	1	1	0
B2	8	7	-1	2	1	-1
B3	6	5	-1	1	0	-1
B4	8	8	0	2	2	0
B5	4	4	0	1	1	0
B6	7	7	0	2	2	0

In addition, the findings of this study align with recent

literature highlighting the role of digital tools in post-earthquake evaluations. By transforming Google Street View imagery into 3D models, this study demonstrates the potential of image-based methods to enhance both the speed and accuracy of structural assessments. Overall, the resulting models offer a practical basis for seismic risk analysis and open new possibilities for the evaluation and mitigation of structural vulnerabilities in urban environments.

Conclusions

This study introduces a novel method for assessing post-earthquake structural risks by transforming Google Street View imagery into detailed 3D models. The proposed approach provides a practical alternative to traditional field surveys, significantly reducing the time and resources required for onsite data collection. Our findings demonstrate that this method can enhance the speed and depth of structural vulnerability assessments, offering timely insights following seismic events. Beyond earthquake engineering, the workflow can also be adapted for use in urban planning and infrastructure monitoring. While the study initially showcases results from six buildings, the underlying dataset covers 170 structures and is being progressively analyzed to broaden the scope of validation. Although the creation of a globally unified platform may remain challenging, the methodology presented here is transferable and adaptable across tools and regions. Its value lies in delivering actionable insights in a scalable and accessible way, especially for professionals operating in time-critical or resource-limited environments. In summary, this research highlights the potential of publicly available street-level imagery combined with automated 3D reconstruction to support rapid, scalable, and cost-effective risk assessments in post-disaster scenarios.

Acknowledgments

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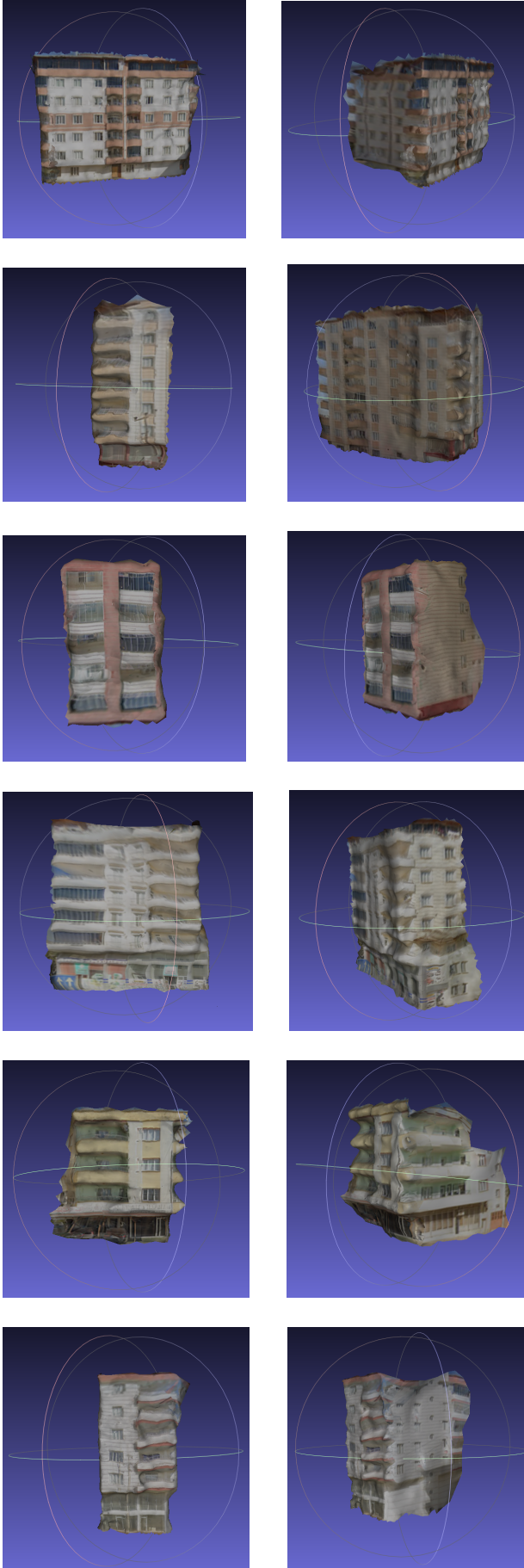


Figure 5: 3D Models

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