Archeologia e Calcolatori
35.2, 2024, 255-262
doi 10.19282/ac.35.2.2024.27

SIMPLIFYING CONTEXTUALIZATION OF 3D MODEL ARCHIVES IN WEBGIS: 3DMODELCOMMONS

1. Introduction

The surge in availability and diversity of 3D models of humanities reconstructions in a plethora of 3D model formats has provided GIS with a wealth of data potentially transformative for spatial analysis and decision-making. However, the effective use of these models in webGIS applications is often hampered by inconsistent data formats, lack of contextual metadata, and the absence of standardized integration practices. 3DModelCommons addresses these issues by focusing on the systematic collection and utilization of metadata to enhance the reusability of pre-existing 3D model archives within webGIS environments. By creating a framework that supports the consistent integration of these diverse models, 3DModelCommons aims to unlock the potential of 3D data for a broad range of GIS applications, from urban planning to cultural heritage preservation.

2. Background

The integration of 3D models into Geographic Information Systems (GIS) represents a significant evolution from traditional two-dimensional (2D) data handling (Zlatanova 2002; Billen 2009). This shift not only provides a richer, more intuitive understanding of spatial environments but also introduces complexities related to data management, interoperability, and visualization (Fairbairn 2006). 3D modeling technologies have become more sophisticated and widely used across various sectors including urban planning, architecture, and environmental studies, but they also have become available to the general public because of practical applications in 3D printing and independent game development and are shared via public archives. For these reasons, the need for effective tools to manage and utilize these models in GIS platforms has become evident.

3D models offer detailed visual and structural information that can enhance decision-making processes in urban planning, disaster management, and environmental monitoring. However, the integration of these models into GIS platforms is not straightforward due to several inherent challenges:

– Data volume and complexity: 3D models, especially those representing complex urban environments or intricate architectural details, can be large in file size and geometric complexity. This poses significant challenges for storage, retrieval, and real-time rendering in web-based GIS applications.

– Diversity of formats: there is a wide array of 3D file formats such as STL, OBJ, FBX, and Collada, each with its own specific use cases and supported features. This diversity necessitates robust conversion and standardization tools to ensure that these models can be uniformly processed and integrated into GIS platforms.
– Lack of metadata: many 3D models are created without comprehensive metadata, which is crucial for their effective use in GIS. Metadata not only aids in the identification and retrieval of relevant models but also provides critical information about the accuracy, scale, provenance, and appropriate usage of the data.
– Spatial accuracy and georeferencing: ensuring that 3D models are accurately positioned in a spatial context is essential, especially when they are used in conjunction with other spatial data layers. Models must be properly georeferenced to real-world coordinates, a process that can be complex depending on the origin and quality of the 3D data.

Several tools and platforms have attempted to address these challenges, yet each presents its own limitations. Traditional GIS platforms have predominantly focused on 2D spatial data, with 3D capabilities often added as an afterthought. While newer platforms have begun to integrate 3D functionalities more seamlessly, they frequently require extensive customization or suffer from performance issues when handling large datasets. Open source libraries like Three.js have enabled more dynamic and visually appealing 3D renderings in web browsers, thus providing a foundational technology for 3D GIS applications. However, without a comprehensive approach to the underlying challenges of data management and integration, the full potential of these technologies remains untapped (Haklay *et al.* 2008).

The absence of standardized and targeted metadata for 3D models is a critical gap that impedes their effective integration into GIS workflows. IIIF offers a set of metadata descriptors, but it is an adaptation of metadata descriptors thought of and created aiming at placing 2D items on visualizers. Metadata plays several roles in this specific context:

– Enhancing discoverability: by providing key descriptive information, metadata allows users to quickly find models relevant to their specific needs.
– Facilitating interoperability: standardized metadata helps ensure that 3D models can be effectively shared and utilized across different systems and platforms, enhancing collaborative efforts and reducing redundancy in model creation.
– Improving data quality and relevance: metadata can include information about the accuracy, resolution, and time relevance of the data, which is crucial for ensuring that the models are suitable for specific analytical tasks.

Addressing these challenges through a unified approach that encompasses robust metadata management, data standardization, and efficient rendering technologies is the key to advancing the use of 3D models in GIS. The development of 3DModelCommons represents a strategic response to these needs, aiming to simplify and enhance the integration of 3D models in webGIS environments by leveraging advanced tools and methodologies.

3. Methodology

A robust metadata schema is critical for the contextualization and integration of 3D models into GIS applications. 3DModelCommons develops a metadata framework tailored to the needs of GIS users, which includes fields for geolocation, model creator, creation date, data source, spatial resolution, and intended application area. This framework ensures that each model can be easily located, understood, and utilized in various GIS projects. To address the issue of diverse 3D model formats, 3DModelCommons incorporates a conversion tool that standardizes models to a web-optimized format such as glTF, which is supported by Three.js. This process is vital for ensuring that models are not only uniformly accessible but also ready for integration into the MapLibre-powered GIS interface.

Using the standardized models (Baca 2016) and enriched metadata, 3DModelCommons leverages map to integrate these models into a dynamic, interactive GIS environment. This integration allows users to overlay 3D models on 2D base maps, interact with the models, and perform complex spatial analyses. The metadata managed by 3DModelCommons has the following structure:

- Core data
  - Original URL
  - Origin (name of the web archive)
  - GLTF local version (for caching)
  - Ownership (name of the user who detains ownership
  - Rights (dictionary explicitly stating what can be done with the model)
- Coordinates (space and time)
  - Lat, lon (array of floats locating the point of origin of the model)
  - Elevation (for DEM based renders)
  - From, to (dates representing when the model is valid)
- Rotation
  - X, Y,Z rotation (array of floats representing the expected rotation for the model
- Scale
  - Default: 1 (float representing the scale at which the model has been created)
- Tags (list of strings)

The ownership and rights are crucial for a primary filtering of the feasible models to be visualized on a map. This enables private collections or copyrighted materials to be only metadated and made usable by the owners alone, without having to lose the metadata about the existence of those models.

Furthermore, the metadata schema also supports additional fields for model quality assessment, such as accuracy indicators, source reliability, and documentation of any modifications made during the conversion process. These fields provide users with a deeper understanding of the model's provenance and quality, aiding in the selection of appropriate models for specific applications. The comprehensive metadata framework of 3DModelCommons ensures that all aspects of the 3D models are well-documented, enhancing their usability and integration into GIS workflows.

4. Implementation

The implementation of 3DModelCommons involves several critical components designed to handle the integration, management, and visualization of 3D models within a webGIS environment effectively. Each component is structured to optimize performance, ensure user-friendly interactions, and facilitate the robust management of 3D model archives. To manage the extensive data requirements of the converted 3D models, 3DModelCommons utilizes a cloud-based object-storage to collect the 3D model files and a document database for their associated metadata. This cloud infrastructure provides scalable storage solutions and high availability, which are essential for handling large datasets and supporting concurrent user access from various geographic locations. The repository supports various file formats and converts them into a standardized format (glTF) to ensure compatibility and performance optimization across different platforms.

Given the diversity of 3D model formats, a key feature of 3DModel Commons is its ability to convert various formats into a more uniform, web-optimized format such as glTF. This process not only reduces the file size, making it more suitable for web delivery but also simplifies the rendering process on client devices. The platform employs automated tools that also correct any errors in the models during the conversion process, such as misplaced vertices or incorrect normals, which can affect the visual accuracy and rendering performance.

MapLibre GL JS plays a crucial role in the platform, providing the GIS functionalities needed to overlay 3D models onto interactive maps. It allows users to manipulate map views (zoom, pan, rotate) and interact with the 3D models directly within their spatial context (Ware 2012). This integration is made seamless through the use of a custom-developed plugin (Fig. 1) that syncs the 3D model's geolocation metadata with the MapLibre map canvas, ensuring that models are accurately placed according to real-world coordinates.

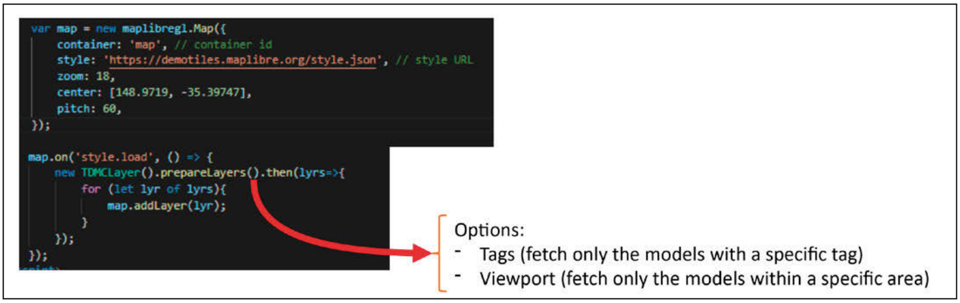

Fig. 1 – Example usage of the MapLibre GL JS plugin.

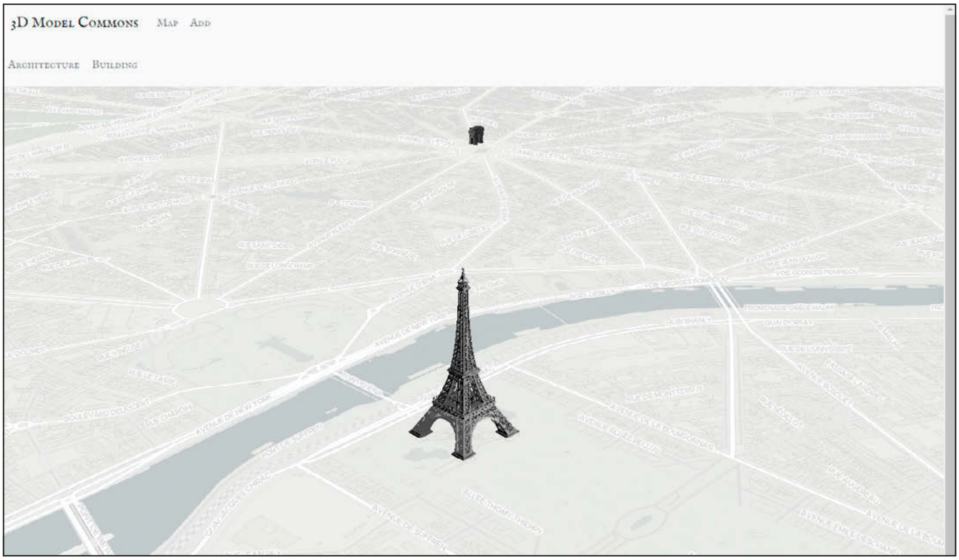

Fig. 2 – Visualization of the models on the map.

The interaction capabilities are further enhanced by incorporating various GIS tools within the MapLibre environment, such as measuring distances and areas, querying model details, and creating spatial annotations. These tools are essential for users who need to perform detailed spatial analysis and need precise interaction with the 3D models (Fig. 2). Rendering 3D models efficiently in a web browser is a significant challenge due to the computational and graphical demands. 3DModelCommons uses Three.js, a robust JavaScript library that leverages WebGL for hardware-accelerated graphics. Three.js is utilized for its efficient rendering capabilities, which include handling lighting, shadows, and textures, which are crucial for producing realistic visualizations of 3D models.

Rendering 3D models efficiently in a web browser is a significant challenge due to the computational and graphical demands. 3DModelCommons uses Three.js, a robust JavaScript library that leverages WebGL for hardware-accelerated graphics. Three.js is utilized for its efficient rendering capabilities, which include handling lighting, shadows, and textures, which are crucial for producing realistic visualizations of 3D models. The library's extensive feature set and active development community ensure that it remains at the cutting edge of web-based 3D rendering technologies.

Three.js also supports various rendering optimizations such as level-of-detail (LOD) techniques, which reduce the model complexity as the camera moves away from the object, and frustum culling, which skips the rendering of objects outside the camera's view. These optimizations are critical for maintaining high performance and smooth user experiences, especially when dealing with complex or multiple 3D models (Kim, Lee, Han 2013). By implementing these techniques, 3DModelCommons ensures that even large and intricate models can be rendered efficiently on a wide range of devices, from high-end desktops to mobile phones.

The implementation strategy of 3DModelCommons also includes a comprehensive user interface designed to facilitate easy access and manipulation of 3D models. The interface provides intuitive controls for navigating the 3D environment, selecting models, and adjusting their properties. Users can easily switch between different views, such as top-down or perspective, and apply various filters to highlight specific features or attributes of the models. This user-centric design ensures that both novice and experienced users can effectively utilize the platform for their GIS tasks.

Overall, the implementation of 3DModelCommons is characterized by a focus on resilient architecture, seamless integration of 3D models with GIS capabilities, and efficient rendering technologies, aimed at maximizing the accessibility and usefulness of 3D model archives in webGIS applications. By addressing the key challenges associated with 3D model integration and visualization, 3DModelCommons provides a powerful tool for enhancing spatial analysis and decision-making across a wide range of disciplines.

5. Conclusion and future work

3DModelCommons demonstrates how a focused approach to metadata can transform the use of existing 3D models in webGIS environments. By facilitating better management, searchability, and integration of 3D data, the platform ensures that these resources are more accessible and useful for a wide range of applications. As the field of GIS continues to evolve, such innovations will be crucial for leveraging the full potential of spatial data in various areas. Future work will focus on expanding the capabilities of 3DModelCommons to support more advanced features and integrations. This includes enhancing the conversion pipelines to generate models with various Levels of Detail (LOD) so that they can be used in different types of applications, from detailed architectural visualizations to broad landscape analyses. Additionally, efforts will be made to simplify integrations with major tools like Unity, which is widely used in the Digital Humanities community and beyond. By providing seamless workflows between 3DModelCommons and these popular platforms, users can more easily incorporate 3D models into their projects, regardless of the specific software they are using.

Another area of future development is the enhancement of metadata standards and practices. As new types of 3D data and applications emerge, the metadata framework will need to be updated to capture relevant information accurately. This includes the development of more detailed quality metrics and provenance tracking to ensure the reliability and trustworthiness of 3D models. Additionally, collaborative efforts with other metadata standardization initiatives will help align 3DModelCommons with broader industry practices, facilitating interoperability and data sharing.

The integration of machine learning and artificial intelligence (AI) technologies also holds significant potential for 3DModelCommons. By incorporating AI-driven tools for automatic metadata extraction, quality assessment, and anomaly detection, the platform can further streamline the management of 3D model archives. These technologies can also enhance the user experience by providing intelligent recommendations and insights based on the analysis of large datasets. Finally, expanding the community and user base of 3DModelCommons will be a key priority. By engaging with a diverse range of users, from academic researchers to industry professionals, the platform can continuously evolve to meet the needs of its users. Workshops, training sessions, and collaborative projects will help build a vibrant community around 3DModelCommons, fostering innovation and knowledge sharing.

In conclusion, 3DModelCommons tries to represent a useful advancement in the integration of 3D models into webGIS environments. Through its comprehensive approach to metadata management, data standardization, and efficient rendering technologies, the platform addresses the critical challenges associated with 3D model integration. As the platform continues to develop and expand, it can play a central role in unlocking the potential of 3D data for data visualization across various disciplines.

Marco Montanari, Lucia Marsicano
Open History Map
marco.montanari@openhistorymap.org, lucia.marsicano@openhistorymap.org

REFERENCES

Baca D., Blazek P., Vojtek M. 2016, *Metadata management in GIS: Approach for efficient implementation*, «ISPRS International Journal of Geo-Information», 5, 5, 77.

Billen R., Zlatanova S. 2009, *3D Geo-Information Sciences*, Berlin, Springer.

Fairbairn D., Parsley S. 2006, *The use of the Internet in teaching cartography to support distance learning*, «Journal of Geography in Higher Education», 30, 1, 77-90.

Haklay M., Singleton A., Parker C. 2008, *Web mapping 2.0: The neogeography of the GeoWeb*, «Geography Compass», 2, 6, 2011-2039.

Hill L.L. 2004, *Georeferencing: The Geographic Associations of Information*, Cambridge, The MIT Press.

Kim K., Lee S., Han J. 2013, *An efficient LOD management framework for large-scale 3D urban models in web-based GIS*, «Computers, Environment and Urban Systems», 39, 152-164.

Ware C. 2012, *Information Visualization: Perception for Design*, San Francisco, Elsevier.

Zlatanova S., Rahman A.A., Pilouk M. 2002, *Trends in 3D GIS development*, «Journal of Geospatial Engineering», 4, 2, 71-80.

ABSTRACT

This paper presents a transformative approach that allows for the utilization of existing 3D models from diverse sources within a geographic context. It introduces the concept of external metadata, which describes these models, making them searchable, accessible, and seamlessly intergrated in webGIS environments using Three.js and MapLibre GL. This paper addresses the demand for the reuse of three-dimensional data representation in the geospatial domain and acknowledges the wealth of 3D models available from various sources. By introducing a standardized metadata schema, it establishes a structured framework for the incorporation of these models into webGIS systems. A central theme of this work is the development of a metadata standard that acts as a bridge between 3D models and webGIS environments granting it all information that can be used to correctly locate, scale and orient the models. It enables efficient searching, rendering, and utilization of these models within geographic contexts. Leveraging MapLibre GL JS and Three.js, the paper showcases how external metadata can significantly enhance the integration of 3D models into webGIS, thereby fostering a more versatile and comprehensive geospatial data exploration experience.