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Digital 3D City Models Towards Urban Data Platform using OGC 3D GeoVolumes API

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Abstract: Nowadays, the digital 3D city models are the basis of the urban data platform. It plays an essential role in various fields of industry and research, from urban resource planning, environmental simulation, disaster management, and many more. Especially, there is more and more use of 3D city models in 3D visualization applications. However, one common issue is the accessibility difficulty according to different data formats generated from different data providers. Accordingly, there is a need for an interoperable 3D geospatial data delivery method to serve data in a standardized way. In this research, we introduce the use of the 3D GeoVolumes API, the open specification from Open Geospatial Consortium (OGC) to maximize interoperability, replicability, reusability, and accessibility of 3D geospatial data. The use cases had been implemented in the OGC Container and Tiles Pilot (2020) and OGC Interoperable Simulation and Gaming Sprint (2020 - 2021) using the 3D GeoVolumes API to deliver various 3D geospatial data formats. As a proof of concept, the 3D data from GeoVolumes API are visualized and showcased in game engines and web application clients.

1 Introduction

A 3D city model is a digital representation of a built environment and forms a fundamental building block for digital twins of cities. In a recent study, digital twins are seen as the ultimate tool for urban planners and city governments to design and build their infrastructure in a cost-effective way as well as share their vision with the general public (ABI RESEARCH 2021). The digital twins of cities is an accurate scale digital representation of city objects enabled to be paired with dynamic predictive models using simulations, data analytics, and machine learning to help decision-making by understanding cities' behavior in different "what if" scenarios. In the backend of the cities' digital twin is the urban data platform where the 3D city model, along with other urban datasets, are stored. Applications using 3D city models have already shown huge potential with respect to the built environment and motivated many public and private organizations to make use of it. For example, it has been used in several domains such as noise mapping (CZERWINSKI et al. 2007), the Helsinki 3D+ Digital Twins applications (AIRAKSINEN 2019), neighborhood planning (AGUGIERO et al. 2020), integrating dynamic sensor data with 3D city models (SANTHANAVANICH & COORS 2021), public participation method (WUERSTLE et al. 2021), urban infrastructure simulations (PADSALA et al. 2021), and many others. As a result, the demand for using 3D city models has increased drastically. It has become vital to create, analyze, store, visualize and share the 3D data for better planning and decision making. With the gap between desktop and web geo-visualization slowly minimizing, 3D visualization of geodata on the web increasingly has gained importance.

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One particular challenge in accessing, distributing, and visualizing 3D geodata on the web is in the data distribution method. As the need for web 3D geospatial visualization has risen, several solutions have been developed by different data vendors based on technical and internet bandwidth situations resulting in different data distributed methods. As a result, it has increasingly become challenging to access and integrate a variety of 3D content from different providers.
Thus, in this paper, we present the use of OGC 3D GeoVolumes, which seeks to address the above challenge by providing a corresponding Application Programming Interface (API) to integrate various data distribution methods into a single, open standard solution. The 3D GeoVolumes API defines a Web API enabling servers and clients to access 3D models and promotes interoperability providing the capabilities for 3D clients to access multiple servers and 3D formats such as 3D Tiles and CityGML. As a result, end-users and applications are able to search and access 3D contents using a common API, irrespective of its underlying distribution mechanism. The recent introduction of plugins to well know game engines like Unity and Unreal Engine now allow importing massive 3D city models into game engines to develop graphically rich and immersive next-generation interactive digital twin applications. Accessing, importing, and integrating 3D city models in such game engines or web applications with different underlying data distribution formats without data conversion represents a significant step forward in geodata interoperability.

2 Background

2.1 History of the 3D GeoVolumes API

The 3D GeoVolumes API concept had been first named and developed in the OGC 3D Container and Tiles pilot (MILLER et al. 2020a) as a candidate 3D delivery specification to address this issue by allowing software clients to access 3D geospatial contents from a single *HTTP* endpoint. Later, the 3D GeoVolumes had been successfully used as a data delivery specification in the OGC Interoperable Simulation and Gaming Sprint Year 1 (DALY & SERICH 2021) and Year 2 (DALY & PHILLIPS 2021). As a result, it shows the interoperability with multiple 3D data formats, integrations, and visualization.

2.2 3D GeoVolumes API Concept

The 3D GeoVolumes API is developed with the aim to conform with the OGC API-Common foundation resources, including landing page, conformance declaration, and collections. Being part of the OGC API family of standards, the 3D GeoVolumes API makes it easy for anyone to share, consume, filter the 3D geospatial resources through the web using the defined resource-centric APIs (HEAZEL 2020). Instead of accessing 3D data from different vendors, users can use 3D GeoVolumes API to manage the data heterogeneity and access data from a single source. The overview of the 3D GeoVolumes API resource path is shown in Tab. 1. In the GeoVolumes API, the collection is a group of spatial aggregation contents in the same regional level, e.g., city, country, continent, etc. Each collection is able to contain single to multiple children 3D containers. Each 3D container contains 3D resources in single to multiple 3D formats (see Chapter 3.2).

Tab. 1: The path and result from the 3D GeoVolumes API resources.

Resource	Path	Result
Landing page	/	Landing page in JSON or HTML.
Conformance declaration	/conformance	Conformance in JSON.
API definition	/api	API definition in JSON
Collection	/collections	All 3D collections in JSON/HTML.
Collection (with bbox)	/collections?bbox=[bbox]	Filtered 3D collections in JSON/HTML matching the bounding box [bbox].
3D container	/collections/[container_id]	3D Collections of [container_id] in JSON.
3D container (with bbox)	/collections/[container_id]?bbox=[bbox]	Filtered 3D collections of [container_id] in JSON matching the bounding box [bbox].
3D resources	/collections/[container_id]/[resource_format]	3D resources of [container_id] in the requested formats.

3 Use Cases

As a proof of concept, the 3D GeoVolumes API server had been implemented to serve the 3D city models through the web during our participation as part of the OGC 3D Container and Tiles pilot (MILLER et al. 2020a) and the OGC Interoperable Simulation and Gaming Sprint Year 1 (DALY & SERICH 2021) and Year 2 (DALY & PHILLIPS 2021). The overall structure of the development workflow for the 3D data management (Fig. 1) includes three main sections. Firstly, the 3D data sources in several formats were collected, integrated, and processed in the 3D data conversion pipeline (see Chapter 3.1). Secondly, these converted 3D data were served on the 3D GeoVolumes API server (see Chapter 3.2). Then, these data were evaluated on the web-, mobile-, and game engine applications (see Chapter 3.3). Moreover, we have integrated sensor data into the 3D building models to show the interoperability of the 3D GeoVolumes API with other OGC standards. The sensor data were integrated using the OGC SensorThings API standard based on the CityThings concept (SANTHANAVANICH & COORS 2021).

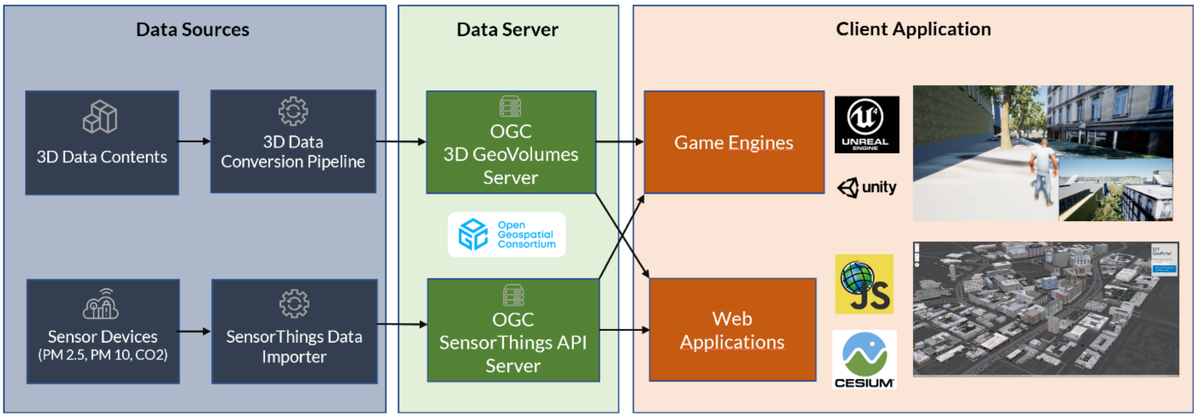

Fig. 1: Overall development workflow of the 3D data management.

3.1 3D Data Formats and Data Processing

Several 3D geospatial formats (Tab. 2) had been explored and processed to support 1) 3D visualizing in the web clients and game engines and 2) the tiling scheme to improve the rendering and streaming performance. The data conversion processes were done in the Feature Manipulation Engine (FME) software.

Tab. 2: The 3D data formats used to serve in the 3D GeoVolumes API.

3D Data Formats	Web Client and Game Engines Support	Tiling Support	Data Processing
OGC CityGML	No	No	Convert to glTF, I3S, and 3D Tiles format.
OGC CityJSON	No	No	Convert to glTF, I3S, and 3D Tiles format.
OGC Common Database (CDB)	No	No	Convert to glTF, I3S, and 3D Tiles format.
Esri 3D Shapefiles	No	No	Convert to glTF, I3S, and 3D Tiles format.
Esri Multipatch	No	No	Convert to glTF, I3S, and 3D Tiles format.
Wavefront Object file (Obj)	No	No	Convert to glTF, I3S, and 3D Tiles format.
Filmbox (FBX)	Yes	No	Convert to I3S and 3D Tiles format.
Graphics Language Transmission Format (glTF)	Yes	No	Convert to I3S and 3D Tiles format.
Esri Indexed 3D Scene Layer (I3S)	Yes	Yes	No need to convert.
Cesium 3D Tiles	Yes	Yes	No need to convert.

3.2 3D GeoVolumes API Development

The data server had been implemented using Node.js and Express.js web framework and shared publicly at our university's repository (SANTHANAVANICH 2020). This implementation was done following the development and design guide of the 3D GeoVolumes API architecture (MILLER et al. 2020b). The 3D GeoVolumes API was deployed and publicly accessible[2]. The converted 3D data in the area of Stuttgart city, Germany, and New York City, USA, had been served on this 3D GeoVolumes API service (Fig. 2).

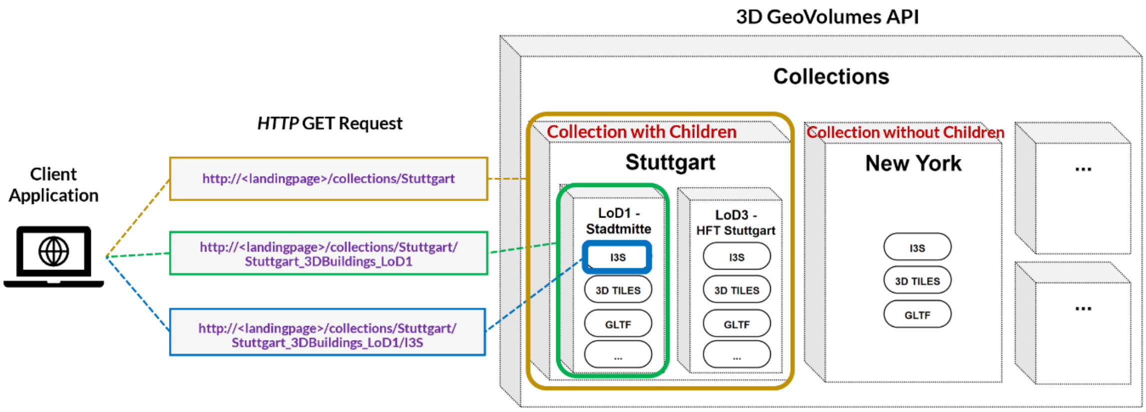

Fig. 2: The structure of developed 3D GeoVolumes API and example resource path URL to the 3D collections and 3D contents.

[2] Available online at https://steinbeis-3dps.eu/3dgeovolumes

3.3 Client Applications

The game engine and web client applications had been developed to evaluate different 3D data formats served through the 3D GeoVolumes API server. The CesiumJS and ArcGIS for JS web libraries were used as candidate web clients, while the Unreal Engine 4 and Unity 3D were used as our candidate game engine application. The convert 3D data were made ready in ESRI I3S, Cesium 3D Tiles, glTF, and FBX format and streamed from the 3D GeoVolumes server. As a result, Tab. 3 shows the evaluation result with the 3D visualization support.

Tab. 3: The 3D visualization support of web and game applications by 3D data formats streamed from the 3D GeoVolumes API.

Data format	Web Clients		Game Engines	
	CesiumJS	ArcGIS for JS	Unreal Engine 4	Unity3D
Esri I3S	Support with our custom plugin.	Support natively	Support with ArcGIS Maps SDK for game engines.	Support with ArcGIS Maps SDK for game engines.
Cesium 3D Tiles	Support natively	Not support	Support with Cesium plugin	Support with Unity3DTiles plugin
glTF	Support natively	Support natively	Support natively	Support natively
FBX	Not support	Not support	Support natively	Support natively

4 Conclusion

This paper explored the use of 3D GeoVolumes API in different client applications with varying degrees. It has shown an excellent solution as a standardized specification for delivering 3D resources to web and game engine applications. This gives the possibility of central data management for multiple web applications. Therefore, the 3D resources only have to be updated and managed at a single location. Additionally, it allows data owners to fully manage data accessibility. Additionally, it delivers 3D resources over the internet, which users can stream and visualize 3D resources in real-time without prior download. Even though the data streaming performance strongly depends on the internet connection, but it would have a significant impact on the application projects that require substantial 3D resources. The 3D GeoVolumes API has also shown interoperability with other OGC sets of standards such as OGC SensorThings API, OGC API Features, etc. In conclusion, the 3D GeoVolumes API can be used as an Urban Data Platform where 3D data sources with their metadata can be stored and provided in a standardized way. In future work, the 3D GeoVolumes API will be further explored and developed in the 3D data management project in cooperation with the Runder Tisch GIS, Technical University of Munich, the Stuttgart Technology University of Applied Sciences, and the State Office for Geoinformation and Land Development at Baden-Württemberg and Bayern. This project aims to use the 3D GeoVolumes API to serve the 3D data of different cities for the various use cases of applications.

5 Bibliography

ABI RESEARCH, 2021: Digital Twins the 'Ultimate Tool' for City Infrastructure Planning. https://gcn.com/articles/2021/08/12/digital-twin-city-planning.aspx, last accessed on 29.11.2021.

AIRAKSINEN, E., 2019: The Kalasatama Digital Twins Project. https://www.hel.fi/static/liitteet-2019/Kaupunginkanslia/Helsinki3D_Kalasatama_Digital_Twins.pdf, last accessed on 29.11.2021.

AGUGIARO, G., GONZALEZ, F. & CAVALLO, R., 2020: The City of Tomorrow from... the Data of Today. ISPRS International Journal of Geo-Information, **9**(9), 554, https://doi.org/10.3390/ijgi9090554.

CZERWINSKI, A., SANDMANN, S., STOCKER-MEIER, E. & PLUMER, L., 2007: Sustainable SDI for EU Noise Mapping in NRW - Best Practice For Inspire. International Journal of Spatial Data Infrastructures Research, **2**, 90-111.

DALY, L. & PHILLIPS, R., 2021: Interoperable Simulation and Gaming Sprint Year 2 Engineering Report. OGC Public Engineering Report. http://docs.ogc.org/per/20-058.html, last accessed on 26.11.2021.

DALY, L. & SERICH, S., 2021: Interoperable Simulation and Gaming Sprint Engineering Report. OGC Public Engineering Report. http://docs.ogc.org/per/20-057.html, last accessed on 26.11.2021.

HEAZEL, C., 2020: OGC API - Common - Part 2: Geospatial Data. OGC Implementation Standard. https://ogcapi.ogc.org/common/, last accessed on 26.11.2021.

MILLER, T., TRENUM, G. & SIMONIS, I., 2020a: 3D Data Container and Tiles API Pilot Summary Engineering Report. OGC Public Engineering Report. https://docs.ogc.org/per/20-031.html, last accessed on 26.11.2021.

MILLER, T., TRENUM, G. & LIEBERMAN, J., 2020b: 3D Data Container Engineering Report. OGC Public Engineering Report. https://docs.ogc.org/per/20-029.html, last accessed on 20.11.2021.

PADSALA, R., GEBETSROITHER-GERINGER, E., PETERS-ANDERS, J. & COORS, V., 2021: Inception of Harmonising Data Silos and Urban Simulation Tools Using 3D City Models for Sustainable Management of the Urban Food Water and Energy Resources. ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., **VIII**-4/W1-2021, 81-88. https://doi.org/10.5194/isprs-annals-VIII-4-W1-2021-81-2021.

SANTHANAVANICH, T. & COORS, V., 2021: CityThings: An Integration of the Dynamic Sensor Data to the 3D City Model. Environment and Planning B: Urban Analytics and City Science, **48**(3), 417-432, https://doi.org/10.1177/2399808320983000.

SANTHANAVANICH, T., 2021: OGC 3D GeoVolumes API. Zenodo. https://doi.org/10.5281/zenodo.5731579.

WUERSTLE, P., SANTHANAVICH, T., PADSALA, R. & COORS, V., 2021: Development of a Digital 3D Participation Platform – Case Study of Weilimdorf (Stuttgart, Germany). ISPRS - Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., **XLVI**-4/W1-2021, 123-129. https://doi.org/10.5194/isprs-archives-XLVI-4-W1-2021-123-2021.