Cross-border Delivery and Web-based Visualization of 3D Buildings

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***Abstract*—Need for 3D geodata is increasing in various environmental and energy-related applications. This concerns in particular the content theme buildings. Cross-border provision of 3D buildings is thus an important research and development objective, as the challenges related to human settlements tend to traverse physical boundaries and need to be tackled in the international context. The GeoE3 project has been developing a content integration platform for facilitating cross-border access to 3D buildings datasets from five European countries. The approach is based on the utilization of modern standards, like OGC API Features and CityJSON, and applies on-the-fly processing of datasets for improved coverage and harmonization.**

Keywords-3D buildings; cross-border; harmonization; CityJSON, OGC API Features.

I. INTRODUCTION

Cross-border provision of 3D geodata is a new and challenging task for the Pan-European Spatial Data Infrastructure development [1]. The provision of nation-wide 3D data is in early stages and related standards are currently in rapid development phase [2]. First examples of genuine cross-border 3D geodata services are just being developed.

GeoE3 project has been working on cross-border interoperable provision of 3D buildings [3]. The project consortium includes National Mapping and Cadastral Agencies (NMCAs) from five European countries: Estonia, Finland, Norway, Spain and The Netherlands. The project has continued for one year and a half and has achieved significant results [4][5]. Although the approach selected by the NMCAs vary drastically from country to country, the GeoE3 project has managed to set up consistent access to 3D buildings from all the participating countries.

The service architecture adopted in the GeoE3 project relies on three-tier model. On the bottom tier, the varying national legacy content provision mechanisms are utilized to get access to the geodata content. On the second tier the GeoE3 data integration platform is responsible for adapting the content encodings and service interfaces to the needs of the modern technologies used on the client side. On the third tier are the client applications making use of the GeoE3 datasets in various identified renewable energy and smart city related use cases.

The Open Geospatial Consortium's new family of service interface standards, called OGC API [6] is the basis of the GeoE3 data integration platform. All the content provision from the platform is based on this set of standard interfaces and the related data encoding specifications. So far, GeoE3 has successfully implemented content access services based on OGC API Features [7] and OGC API Coverages [8] service specifications. In addition, the platform applies OGC API Processes [9] for supplementary on-the-fly processing and OGC API Records [10] for metadata provision. The core software solution used for the integration platforms Python-based computing environment is the OGC API Features reference implementation called pygeoapi [11]. In addition to OGC API Features, the software package supports at least preliminarily all the other needed OGC API standards. Django [12] is used as the Web application framework on the GeoE3 content integration platform and pygeoapi is adapted by the project to run in this framework.

In addition to 3D buildings, the GeoE3 project delivers also 2D buildings, together with rich attribute content. Schema for the building attributes is modelled on the basis of INSPIRE alternative encoding and model simplification rules [13]. GeoE3 is also working with coverage type content themes like Digital Terrain Model (DTM) and Digital Surface Model (DSM). Based on the needs of the selected use cases, some climate-related datasets, like temperature, windspeed and sunshine hours, are also included. These are accessed from the bottom tier as point observations, converted to coverage type data on the platform and provided through OGC API Coverages compliant service points to the client applications.

3D buildings are accesses from various different legacy sources from the bottom level and provided from the integration platform via OGC API Features service end point. According to the general approach adopted in the GeoE3 project, all the available country-specific datasets are configured as individual data collections inside a single OGC API instance. This way a simple but powerful solution for content integration can be achieved. Individual country's dataset can be accessed by querying the appropriate collection. Cross-border data requests are supported naturally with the so called cross-collection query, supported in the OGC API Features standard (Part 3: Filtering and the Common Query Language) [14]. The new CityJSON encoding standard for 3D geodata representation is adopted for the transfer of 3D buildings [15].

The rest of the paper is organised as follows. Section II discusses the solutions used for the provision of 3D building data. Section III describes the approach for delivering 3D buildings via the OGC API Features service interface. In Section IV Web browser-based 3D visualization is discussed. The paper ends with the conclusion in Section V.

II. Delivery Solutions

As the 3D provision of buildings data is in its early stages by the NMCAs, the solutions and selected standards vary significantly from country to country. However, the GeoE3 project has been able to provide full country coverage of 3D buildings in a consistent manner from all the participating five countries. This also involves dynamic, on-the-fly creation of LOD1 building geometries in some cases. 3D buildings are provided via the OGC API Features, Web Feature Service (WFS) or OGC API Processes interface, and are encoded in CityJSON format.

In the case of Estonia and Finland, the approach is quite the same. 3D buildings data are available on the country level as CityGML [16] file downloads. The Estonian dataset covers the whole country. The Finnish 3D buildings dataset at the moment only covers 10 distinct production areas, situated all over the country. The datasets are downloaded to the GeoE3 integration platform and then uploaded to the 3D City DB database [17]. The WFS-compliant service implementation provided by the 3D City DB developers is used to access the contents of the database. Along the adopted principles of the GeoE3 integration platform, the WFS interface is hidden behind an OGC API Features instance, through which the clients will access the 3D buildings using feature ID and BBOX queries.

The Norwegian NMCA, Kartverket, is just about to start the 3D buildings production. An OGC API Processes -compliant on-the-fly process has been developed on the GeoE3 integration platform to provide a temporary solution for the provision of Norwegian 3D buildings. The solution currently only supports feature ID -based queries. When a feature ID comes in to the OGC API Processes instance, the corresponding building is queried from the 2D buildings OGC API Features interface of the GeoE3 platform. From the received feature geometry the Minimum Enclosing Rectangle (MER) of the building is retrieved and the corresponding piece of DTM and DSM are queried. Then DTM and DSM height values inside the area of the building are used to calculate elevation for the building's roof and floor. Finally, the footprint geometry of the building and the derived elevations are used to generate a CityJSON-encoded LOD1 3D model of the building. The process is integrated to the GeoE3 platform so that it can be used as a source for 3D buildings in a similar fashion than other countries' buildings. Input parameters of the OGC API Processes interface include the code of the country from which the building is queried, and the identifier of the building, see Figure 1.

In the case of the Netherlands, the 3D buildings are available for file download readily in the CityJSON format. However, the buildings are packaged into a tiled file structure. Thus, a lot of preprocessing is required to download and integrate the buildings with the GeoE3 platform in a way that facilitates an individual building to be efficiently retrieved. A custom-built database is used on the GeoE3 platform to store the ID of the building, together with the corresponding CityJSON representation of its 3D model. The access interface is currently modelled after the WFS interface's feature ID query.

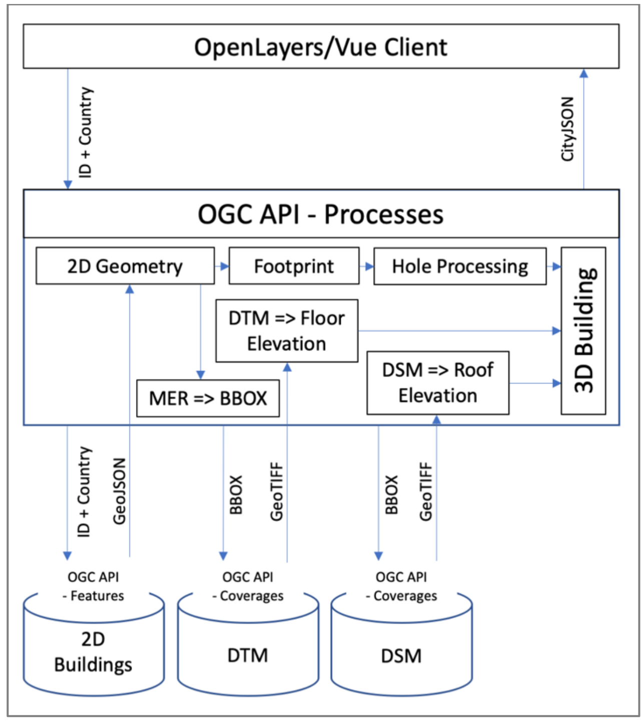

Figure 1. Processing pipeline for the OGC API Processes-based on-the-fly generation of LOD1 category 3D building models on the GeoE3 integration platform.

Spain is a special case among the GeoE3 countries, as it already has a functioning service interface for the 3D buildings available. The service provides access to KML-based representation of the building's 3D model via a feature ID query. So, the interface only supports retrieval of individual buildings. The KML encoding is generated dynamically by the service from a database of floorplans. The resulting 3D model is thus detailed in the internal subdivision of the building, but still represents only LOD1 category 3D modelling. To integrate the Spanish service to the GeoE3 platform, a proxy service was developed for transforming the KML encoding into the CityJSON format. The proxy service publishes to the calling application an interface supporting WFS's feature ID query. Examples of 3D buildings from all the GeoE3 participating countries are presented in Figure 2 (from top to bottom: Finland, Estonia, Norway, The Netherlands, Spain).

III. OGC API Features-based Access

There are several actions going on to define a service interface for accessing wide scale 3D geodata. Many of them

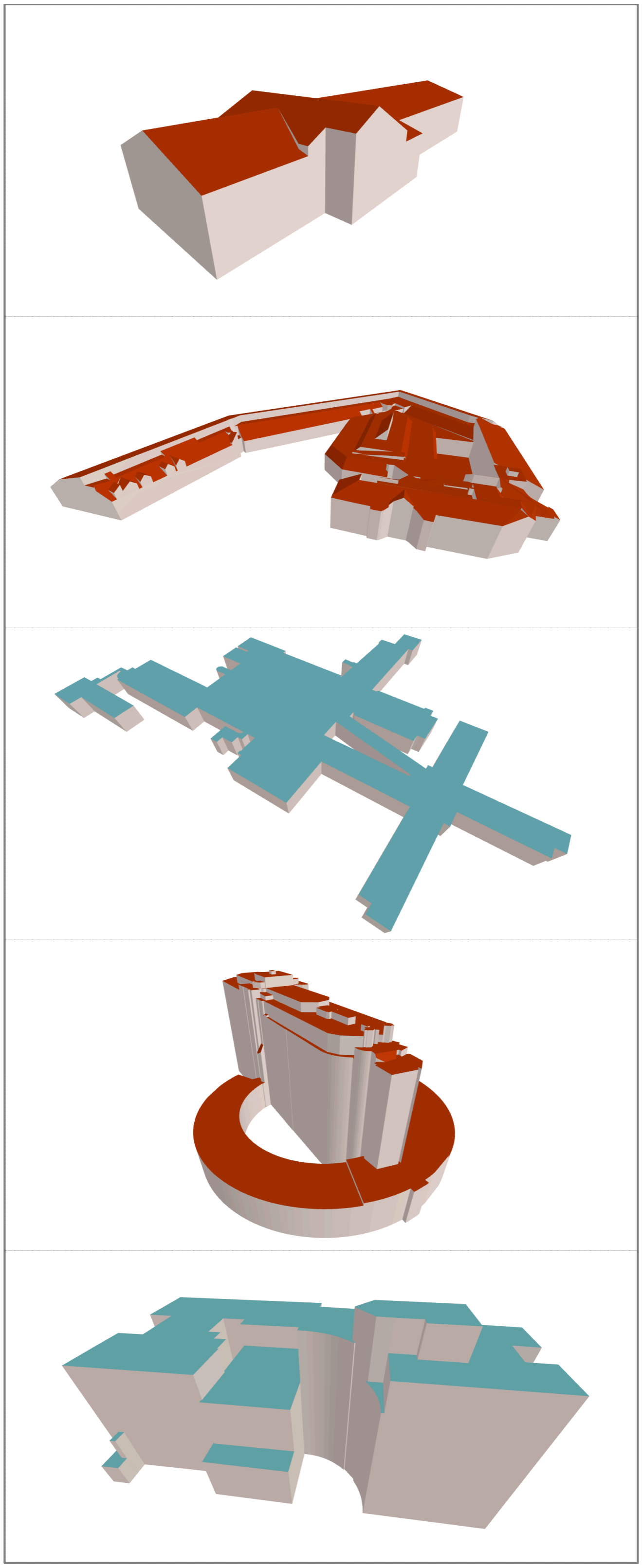

Figure 2. Examples of 3D buildings from all the GeoE3 countries.

focus on efficient streamed delivery of continuous 3D scenes [18]. In GeoE3 the approach to 3D geodata delivery has been kept simple. The idea is to select the area desired for 3D inspection on a 2D basemap, and then request the 3D representation of the whole area in one single query. At the moment the access interface is simply based on the OGC API Features standard, with the format query parameter having value 'cityjson' and the BBOX parameter indicating the area to be requested. The approach is appropriate for conveniently viewing city block level environments. This facilitates general inspection of the whole area with natural 3D controls, and the selection of individual buildings for detailed attribute analysis. At the moment the OGC API Features-based access to 3D buildings is only available for the Finnish and Estonian datasets.

A rich set of attribute information has been added to the 3D building to support the envisaged renewable energy-related use cases. In the case of the Finnish dataset, all attributes available in the corresponding 2D building are first integrated. Then an external service is queried using the building attribute 'externalReference_reference' as the key. Several technical attributes can be added to the building as a result of this query. The climate-related OGC API Coverage services available on the GeoE3 platform are queried next, with the position of the building as the parameter. Three additional parameters, indicating long-period average temperature, windspeed and yearly sunshine hours on the location of the building, can then be added. Finally, the energy certificate register is queried to find out the energy efficiency category of the building. This attribute is added to the building, if available. As a result, the 3D building has a wide set of attributes present, supporting various energy-related analysis scenarios with 3D visualization capabilities (see Figure 3). Similar functionalities will be added to the buildings of other countries once necessary data sources become available.

IV. WEB-BASED 3D VISUALIZATION

The 2D mapping functionalities of the GeoE3 platform's user interface rely on use of the OpenLayers library [19]. However, CityJSON and the related software packages have been selected as the solution for 3D visualization needs in the GeoE3 project [20]. All the 3D geodata delivered from the GeoE3 integration platform are currently encoded in CityJSON format. Buildings have varying support on semantic surfaces, depending on the availability of this information in the national datasets. The omission of semantics is partially accounted for by on-the-fly computations in the visualization module (i.e. walls are distinguished from the roof and the floor by their vertical nature). The 3D visualization in the GeoE3 user interface is based on the Vue component 'ThreeJsViewer', part of Ninja [21], developed by the University of Delft [22]. Various helping functionalities have been developed to guide the camera position by mouse movements on the 2D map, potentially considering the elevation information derived from DSM via the GeoE3 platform's OGC API Coverage service. In some cases, the GeoE3 platform also supports 3D viewing of DTM together with the building's 3D model.

Figure 3. City block-level view of the 3D buildings, requested by a BBOX query from the OGC API Features service of the GeoE3 platform (top). Attribute display of the selected building with technical, climate and energy related attributes shown (bottom).

V. Conclusion

The GeoE3 project has been able to develop an advanced content integration platform supporting cross-border access and visualization of 3D buildings. The technical integration across participating countries' 3D data is facilitated by treating individual datasets as collections inside a single OGC API Features service instance. Seamless cross-border queries are supported by applying so-called cross-collection queries of the OGC API Features specification, Part 3. CityJSON is used as the efficient means for transferring and consuming 3D geodata in Web-based user interfaces. Despite the challenges related to varying production mechanisms, 3D building data has been made consistently available from all five participating countries. Various on-the-fly mechanisms have been developed to facilitate the 3D provision of buildings. In particular, an OGC API Processes-compliant process computes LOD1 category building models in real-time from building's 2D footprint and DTM/DSM-derived elevation values.

The work continues to improve the consistency among the countries' datasets and the service interfaces through which they are delivered. For instance, buildings from the Netherlands are to be made available via the OGC API Features interface with support for BBOX queries. All WFS feature ID queries will be replaced by the OGC API Feature interface's Item query. New datasets will be added as they become available – in particular this involves new production areas in Finland. Client application solutions will also be developed for demonstrating the utilization of 3D buildings in further use case scenarios.

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