

Cross-border and Cross-domain Integration of Content in a European Geospatially Enabled Ecosystem

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Abstract—The Geospatially Enabled Ecosystem for Europe (GeoE3) project has commenced with the main goal to develop use case-oriented, cross-border and cross-domain geospatial services conforming to the second-generation interface standards. The five-nation project focusses on cross-domain integration of content by applying dynamic, service level methods for joining meteorological and statistical data with geospatial features. Various technologies will be tested for providing seamless, cross-border access to geospatial resources in context of the new Open Geospatial Consortium’s family of service interface standards. 3D aspects of geospatial data will also be considered, both from content encoding and service interface point of view. The project aims at supporting renewable energy- and smart city-related applications.

Keywords—geospatial ecosystem; cross-border; cross-domain; OGC API; solar energy; smart city.

I. INTRODUCTION

In an interoperable computing environment, every participating actor should gain benefits. This is the main guiding principle in the spatial data ecosystems currently being developed. A major action, Geospatially Enabled Ecosystem for Europe (GeoE3), has commenced to establish an ecosystem of use case-oriented geospatial services in five European countries [1]. The action is part of the Connecting Europe Facility (CEF) programme advancing European transport, energy and digital infrastructure development [2]. The project runs for three years and involves five national mapping and cadastral agencies, together with a few other governmental organizations and private companies. The main goals of the project include adaptation of modern geospatial APIs (Application Programming Interfaces) to establish cross-border services for renewable energy and urbanization related use cases, use of dynamic service-level mechanisms for cross-domain content integration, and promotion of the developed approaches through extensive online innovation and education programme.

GeoE3 consortium membership includes the national mapping or cadastral agency from Finland, Norway, Estonia, The Netherlands and Spain. Furthermore, the consortium includes the national meteorological and statistical agency of Finland: Finnish Meteorological Institute and Statistics Finland, respectively. Private companies include Spatineo

from Finland and Aventi Intelligent Communication from Norway. Open Geospatial Consortium (OGC) Europe participates in the project as a representative of the standardization community. National Land Survey of Finland coordinates the project that will be finalized by Sep 2023 [3].

The main use cases identified by GeoE3 include renewable energy applications, specifically in the context of buildings construction and use. In particular, this involves solar energy potential, based on solar panels on rooftops. Wind energy and heating/cooling facilities of the buildings are considered too. The other use cases deal with traffic applications, in particular efficient use of electric cars, and with various urbanization challenges. The last one is considering urban expansion efficiency employing the United Nation’s Sustainable Development Goal (SDG) indicator 11.3.1 ‘Ratio of land consumption rate to population growth rate’ [4].

The paper is organized as follows. In Section II, the envisioned service architecture of the GeoE3 platform is described. Section III discusses various mechanisms for content integration. In Section IV, some novel ideas concerning OAPIF functionality are discussed. Section V presents the initial considerations of the project on dealing with 3D geodata. The paper ends with conclusions in Section VI.

II. SERVICE ARCHITECTURE

The GeoE3 project aims at establishing a set of use case - oriented services that enable content integration both across national borders and domain boundaries. The idea is to set up an integration layer on top of national services. The integration layer would provide modern service interfaces to the client side and accommodate various categories of source services on country level. The GeoE3 services are to be based on the OGC API family of second-generation, internationally standardized service interfaces [5]. These include services like OGC API Features [6], OGC API Coverages and OGC API Records. Internally the GeoE3 platform will apply at least OGC API Processes [7] for introducing analysis-based content layers to the clients and Table Joining Service (TJS) [8] for content integration across domain boundaries. OGC API Environment Data Retrieval (EDR) [9] interface will be used for requesting meteorological data, particularly for supporting transport-related applications.

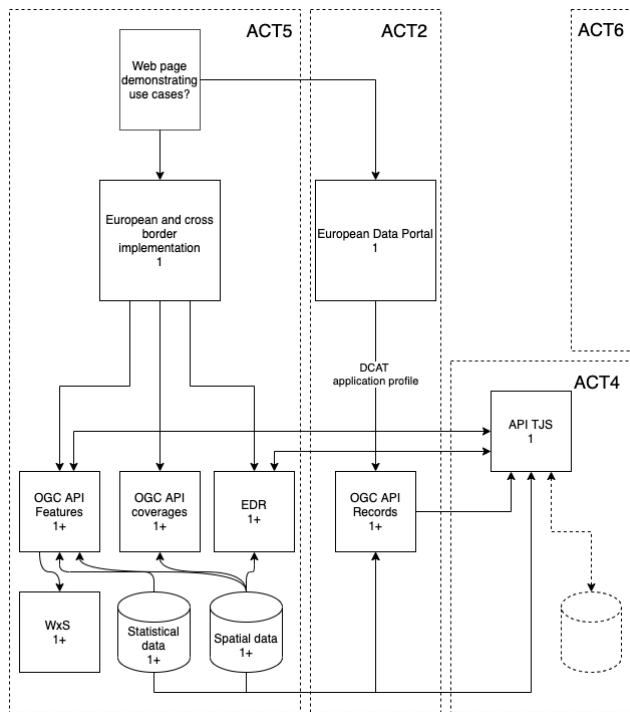


Figure 1. The preliminary GeoE3 service architecture. Dashed boxes indicate division of responsibility among GeoE3 subgroups (Activities).

The illustration in Figure 1 shows the envisaged GeoE3 service architecture. The WxS box in the left bottom corner represents all the country level data resources that will mostly be accessed through service access points conforming to the OGC standard interfaces, like WFS, WCS and the OGC API family of services. The databases at the bottom emphasize the GeoE3 goal of integrating spatial data with statistical and other tabular data sets. All the data resources will be made available via modern interface standards and be integrated in a cross-border manner by the GeoE3 integration platform. Metadata records of all GeoE3 services will be stored into the European Data Portal (EDP) and also be available from the OGC API Records service interface maintained on the GeoE3 platform. An implementation of the TJS standard is an essential component of the GeoE3 service architecture. It will be responsible for joining tabular data sets with geospatial features. The resulting combined resource is then made accessible to client applications via OGC API Features services.

III. CONTENT INTEGRATION

A. Content Integration with OAPIF

An essential component on the GeoE3 integration layer is OGC API Features (OAPIF) service interface. The successor for the OGC’s Web Feature Service (WFS) interface specification, OAPIF follows the principles of the so-called REST (Representational State Transfer) service architecture.

The output of the service consists of individual geospatial features, organized as a GeoJSON -encoded feature collection [10], geometries expressed in WGS84 Coordinate Reference System (CRS). The OAPIF service instance offers a set of data collections, accessible from the given service address paths. This provides a natural setting for organizing individual countries’ data sets as collections inside a single OAPIF instance. For instance, the buildings data sets of Finland, Norway and Spain could be organized as follows.

- /geo3/buildings/collections/buildings_FI/items
- /geo3/buildings/collections/buildings_NO/items
- /geo3/buildings/collections/buildings_ES/items

The OAPIF implementation adopted in the GeoE3 platform is the OAPIF reference implementation, called pygeoapi [11], a Python library supporting OAPIF and partially supporting OGC API Coverages [12], OGC API Tiles and OGC API Processes. pygeoapi provides a flexible plugin architecture for content provision and formatting. The off-the-shelf library supports, via OpenGIS Simple Features Reference Implementation (OGR) [13] and rasterio [14] provider plugins, a vast array of vector and raster source formats and services. For example, WFS is supported as source service. OGR provider also supports OAPIF service access, thus enabling cascading OAPIF service approaches. Specific project-related needs can be accommodated by developing a tailored plugin. As the plugin architecture is based on Python language, all the Python-based geospatial libraries can be easily utilized. The set of already available preliminary GeoE3 components include plugins for WFS versions 1.1.0 and 2.0.0 with basic schema transformation capabilities, and a plugin for WCS version 1.0.0.

B. Content Integration with OGC API Processes

OGC API Processes is a new resource-based process definition standard. The standard defines how the client program can start the process and how the process inputs are provided, and where the results of the process are stored.

Computational tasks are wrapped inside the process and the results are provided to the client application. Processes can be for example geometry buffering or routing from point A to point B. The process can be either synchronous, giving the result immediately, or asynchronous, in which case the service informs the client, when the results are ready and where they can be found.

The GeoE3 project develops a process, in which the footprint of a building is taken as a starting point and the 3D geometry of the building is analysed using the Digital Surface Model (DSM). In addition, a process is being developed to calculate the average amount of solar energy in a building area. This dynamically created information can then be integrated back to the original features.

The OGC API Processes interface standard follows the same principles as the other OGC API standards (e.g., OAPIF). The path structure of the GeoE3 OGC API Processes services might be as follows.

- The service landing page (/geoe3)
- Conformance classes (/geoe3/conformance) describing what service can do
- The list of processes in the service (/geoe3/processes)
- Process to create 3D buildings from the building footprint (/geoe3/processes/3d-building-creator)
- Solar energy potential calculator (/geoe3/processes/solarenergy-potential)

C. Content Integration with Table Joining Service

OGC Table Joining Service (TJS) provides a method for joining spatial and tabular data. The standard is currently being revised by the OGC and the new draft standard is going to be used in GeoE3 [15]. It allows integration of statistical (tabular) data to the platform.

To carry out the join, the service needs the spatial and tabular data and a common identifier between them. Several columns of the tabular data can be joined at once. Both the spatial and tabular data can either be configured to be available from the server or they can be uploaded on demand. Spatial data can thus be delivered via OGC Features APIs and tabular data, e.g., via PX Web API.

The goal of the project is to evaluate the fitness for purpose of TJS in the use cases identified in the project. A TJS instance will be set up and configured, along with a browser-based end user interface. While TJS can be demonstrated and used with a user interface, it can be more valuable when used in the background as a part of an automated process. The obvious benefit of joining data is that spatial data need not be stored in several places.

The output of a TJS has several options. The combined data can be downloaded for further use in several spatial formats, such as GeoJSON. Furthermore, results from the joining operation can be calculated from the data. This includes information about successful joins, unsuccessful joins and extra data rows. In the project this derived data will be visualized in the user interface as a report for the user.

IV. OAPIF RETHOUGHT

Some of the OAPIF concepts have been rethought in the development of the preliminary GeoE3 platform. For instance, the HTML-formatted feature browsing in the OAPIF development is understood as a tabular presentation of feature properties, browsed through the feature collection page by page. When there are potentially millions of features in the national databases, and when the order of features presented is arbitrary, the browsing process becomes unfeasible. The feature browsing in the GeoE3 OAPIF is returned back to the traditional spatially organized, map-based browsing. A plain background map is first shown to the user. The individual vector features are requested and presented only when the user zooms in deep enough.

Another new concept introduced in the GeoE3 project is the idea of treating the HTML-formatted visualization of an individual spatial feature as an application-specific dashboard

of the feature [16]. Into this dashboard, a wide set of feature properties and visualizations can be collected by the GeoE3 integration platform. For example, a sun energy-related building dashboard could contain all the relevant building attributes - like the area, volume and heating information, and the DSM from the building's area - useful for solar energy analyses. Furthermore, climate-related information could be integrated to the same dashboard on the GeoE3 platform by accessing appropriate values from a meteorological service. The dashboard could be seen as a shop window for the available content, and could later be downloaded into a digital analysis process as the corresponding JSON-formatted data set. An example of a prototypical building dashboard for renewable energy related applications is shown in Figure 2. OAPIF browsing by map view is shown on the left. On the right, a detail window of the selected feature (The Finnish Parliament) is shown, together with the DSM rendered inside the building footprint, and average speed of wind in the area shown below.

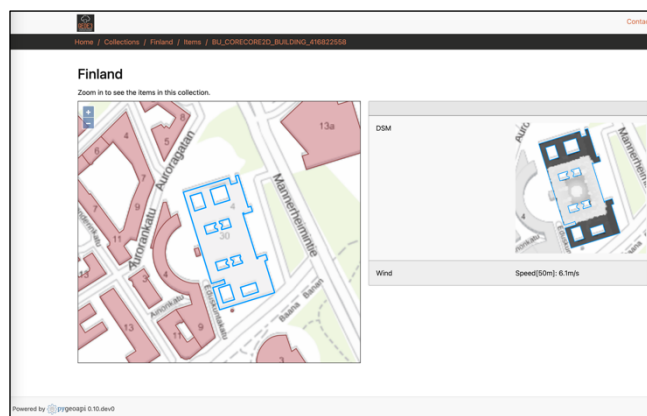


Figure 2. Preliminary OAPIF html output as a building's renewable energy dashboard from the GeoE3 platform.

V. 3D CONSIDERATIONS

The GeoE3 project introduces the idea of HTML-formatted application-specific dashboard, especially in the context of building construction and use with renewable energy applications, such as solar energy potential. While computing the energy potential, many data sources and service interfaces can be utilized, depending on the computing tasks in hand. Using gridded Digital Elevation Models (DEMs), DSMs and building footprints, one can automatically compute a 2D raster layer that indicates rooftops suitable for solar energy production. This raster layer can then be portrayed together with the DSM and the orthophoto for 3D visual exploration.

In the exemplary visualization shown in Figure 3, locations suitable for solar panels are presented with yellow colour. The visualization is a result of a parameterized on-the-fly process, in which the DMS slope and aspect values are used, together with the building footprints and the height difference between the DSM and the DEM, to compute the areas well exposed to sun energy. Figure 3 shows a three.js-based [17] Web application that requests the analysis result

layer and the DSM from OGC-compatible service interfaces and drapes the raster on top of the DSM. Corresponding visualization could also be integrated as part of the GeoE3's HTML-based feature dashboard.

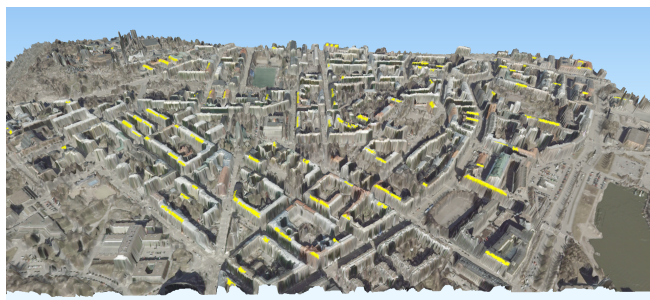


Figure 3. Visual exploration of potential solar panel locations on rooftops. Analysis is based on the use of DSM slope and aspect values, height differences between the DSM and the DEM, and building footprints.

One of the goals of the GeoE3 project is to make use of 3D vector data, provided that project partners are able to produce 3D data during the project's lifetime. For instance, the project coordinator, NLS Finland, aims at making 3D building models available by the end of 2021. The production process is based on the use of the building footprints and DSM, and aims at constructing LoD2 category building geometries. A widely accepted, production-level service interface specification for 3D models does not exist yet. A possible workaround for this situation is to store the 3D geometries into a 3DCityDB database and export them as a CityGML, CityJSON or gltf -formatted file on demand.

At this moment, CityJSON format is the most interesting proposal for the 3D vector representation. CityJSON is a JSON-based subset of the OGC's CityGML [18] data model and is designed for storage and transfer of 3D city models. CityJSON is not yet standardized by the OGC, but is currently being considered as an official OGC Community Standard. Current version of the CityJSON standard is available at the CityJSON development site [19].

Freely available browser-based applications for visualization of CityGML does not yet exist. However, JSON processing is widely supported in browsers, and CityJSON can naturally benefit from this too [20]. There are development initiatives for providing an easy-to-use CityJSON-supporting software component for Web applications. On the left side in Figure 4, an example is presented of browser-based visualization displaying NLS Finland buildings in CityJSON format utilizing a software component called Ninja [21]. On the right side in Figure 4, the same features are presented using the 3D map view of the QGIS application [22]. GeoE3 is also interested in utilizing 3D Tiles, an OGC Community Standard for visualizing 3D geospatial content in desktop, Web and mobile applications [23].

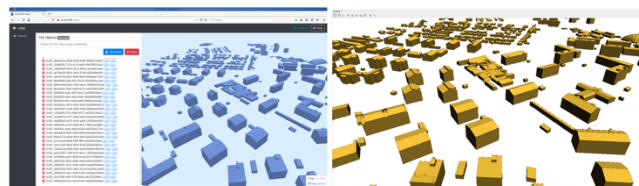


Figure 4. Visualization of 3D vector buildings in browser using Ninja (on the left) and in the 3D map view of the QGIS application (on the right).

VI. CONCLUSIONS AND FUTURE WORK

GeoE3 project has commenced with the main goal of developing a geospatially enabled ecosystem of use case-oriented services conforming to modern, second-generation interface standards. The project will tackle the challenge of cross-border and cross-domain integration of content employing a flexible, state-of-the-art development platform, based on OGC API Python library called pygeoapi. The plugin architecture of pygeoapi facilitates development of tailored components for connecting the platform to various different country level source services.

The overall service architecture of the GeoE3 project can be seen as a three-tier architecture with country level services forming the bottom data layer. The GeoE3 integration platform with advanced capabilities for dynamic content integration and use case-specific adaptation of the resulting data sets works as the middle processing layer. Finally, end user applications form the third architecture layer.

An application-specific output from an OAPIF service can be provided in the form of an html-formatted dashboard of the feature in focus. Based on the user needs, an appropriate set of information items can be collected and put together by the GeoE3 platform, and the resulting data set be formatted in html as a shop window for potential users. Finally, the same data set could be requested as a JSON-encoded package, to be fed into an external analysis process.

The project will continue developing the described functionalities over the coming two and half years and aims at wide adoption of the services by actors working in the identified use case domains.

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