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Linked geodata: CityGML represented as a virtual knowledge graph

CityGML is a widely used and important standard for presenting 3D geometry, topology, semantics and appearance in 3D city models. The use of these models have seen an increase in various applications such as emergency response, energy consumption analysis and occupancy measurement. With the increase in complexity of the applications, cities such as Stockholm, Gothenburg, Malmö, Helsinki, Singapore and Zurich have all expressed a need for better management of 3D geodata, especially with linking external data to 3D city models. Knowledge graphs (KG) is a semantic web technology and a method for allowing seamless linking and connecting of different data and formats. Current day popular solutions regarding linking of data and interoperability revolve around transformation and ad-hoc solutions where semantic information is lost in the process. Employing a knowledge graph approach to interoperability challenges serves to improve interoperability by creating one comprehensive, fully semantic model based on different data formats.

This study demonstrates how CityGML data can be represented as a knowledge graph using tools like 3DCityDB and Protégé with the Ontop plugin. The aim is to improve interoperability between different data formats and improve the management of 3D city models. A framework was developed to create a virtual knowledge graph (VKG) using R2RML mapping to retrieve Malmö building data from a 3DCityDB relational database. This data was exposed through RDF triples based on the CityGML 2.0 ontology from the University of Geneva in Ontop. The resulting KG consisted of 20 mappings, detailing both Level of Detail 2 and Level of Detail 3 (LoD) buildings in 224212 RDF triples. Seven SPARQL queries were preformed to validate and test the resulting KG which returned the expected results for all seven queries, confirming that the KG representation of the CityGML data is effective, robust and complete.

The key findings presented in the study is the developed framework that provides detailed descriptions and explanations of the mappings done to expose the data as a VKG, especially the mappings for LoD3 buildings provide a novel description of the process as previous studies have highlighted a data paucity regarding LoD3 objects used for the approach.

The developed framework was efficient and robust for representing CityGML data as a knowledge graph and the approach shows potential by further enabling interoperability between different data formats in the future. The study shows that while the 3DCityDB schema can be improved, the tools used are still sufficient in order to transform CityGML data into a knowledge graph. The implemented method successfully highlights the practical implications of the VKG approach for urban planning and data management.

Keywords: Physical Geography and Ecosystem analysis, CityGML, geospatial knowledge graph, interoperability, data integration

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