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Semantic Modelling of 3D Multi-Utility Networks for Urban Analyses and Simulations:
The CityGML Utility Network ADE

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ABSTRACT

Current data models for representing, exchanging, and storing utility networks often meet the needs of specific domains only, i.e. they do not consider the integration of different network systems, mutual relations between networks and the embedding into 3D urban space. These important prerequisites for urban analyses and simulations are met by the CityGML extension Utility Network ADE. Originally developed for disaster management, this article presents the further development of the ADE by new and revised concepts that result from an extensive analysis of relevant use cases. A catalogue of requirements is presented, current data models are evaluated against these requirements, and the recent developments and refinements of the ADE are explained in detail. This includes the concepts of inter-feature links and network links, the linking of network components with city objects, the modelling of functional characteristics, a refined network components module, and a new electricity network package. In addition, an overview of projects that successfully have applied the ADE is provided.

KEYWORDS

3D City Models, 3D Data Models, 3D Utility Networks, CityGML, Multi-Utility Networks

1. INTRODUCTION

Semantic 3D city models represent city objects, such as buildings, bridges, tunnels, roads, and vegetation, that mainly constitute the visible parts of a city. Cities, however, also exhibit a large number of city objects that are not apparent at first sight, but that are crucial to the functioning of the city as a system. These city objects, which are (often) hidden below ground, contribute to the infrastructure of a city in the form of networks for water, electricity, sewage, gas, telecommunication, and other public utilities. Modern society depends on a stable and complex array of these networks to deliver the various commodities. Utility network infrastructures require a sophisticated model for managing the networks and their relations to other network systems and for providing an integrated view to understand the interaction between city entities and utility networks.

One well-known standard for representing 3D city models is the international OGC standard CityGML (Gröger et al., 2012). However, Utility Networks are not included in the standard. CityGML allows for systematically extending the core model with application-specific attributes and object

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types by means of so-called Application Domain Extensions (ADE), to enable representing city objects within 3D city models which are not part of the CityGML core model. A comprehensive list of ADEs that have been created over the past years for diverse applications is given in (Biljecki et al., 2018). Specifically, for applications dealing with supply and disposal networks, the CityGML Utility Network ADE (Becker et al., 2011; Becker et al., 2012b; Kutzner & Kolbe, 2016) provides concepts that allow for modelling different types of networks.

The CityGML Utility Network ADE was originally developed based on the use case of disaster management. The development started in 2009 as part of a project called SIMKAS 3D that aimed at identifying and analyzing the mutual interdependencies of critical infrastructures and simulating cascading effects in the failure of supply infrastructures (Becker et al., 2012a). The development was further continued in 2015 as part of the project Risk Analysis Supply Infrastructure that studied the possibilities of utilizing supply infrastructures in training simulators for crisis scenarios and for simulating the impact of failures on the population.

In 2016, an international and interdisciplinary working group formed that systematically analyzed a broad variety of use cases beyond disaster management, collected requirements to make the Utility Network ADE usable for a wider range of use cases and evaluated the ADE against these requirements to be able to provide a well-grounded rationale for the concepts defined in the ADE. As a result of this work, the ADE was revised and shortcomings were fixed. Concepts that are required by specific use cases, but are not yet supported by the ADE or are not yet elaborated in detail, have been added. Already existing concepts that proved to be modelled not semantically precise enough have been refined. In addition, test data sets have been developed and used in evaluating the concepts defined in the ADE based on selected use cases.

This paper presents the results of the use case analysis and the new developments of the Utility Network ADE. Several use cases in the context of utility networks are introduced, a catalogue of requirements specific to utility networks is presented, and it is shown that each use case has differing requirements to be fulfilled. In addition, several data models prevalent in the geospatial domain for representing utility networks are evaluated against these extensive requirements to analyze to which extent they cover the needs; the evaluation shows that the CityGML Utility Network ADE provides the best coverage. Afterwards, the paper explains the new and revised concepts of the ADE; this includes network links, a refined network components module, the modelling of functional characteristics, and a new electricity network package. In addition, existing concepts which turned out to be easily misunderstood when applying the Utility Network ADE in practice are explained more precisely; this includes inter-feature links and the linking of network components with city objects such as buildings, hydrants, or street lights. In addition, the paper gives an overview of projects that successfully have applied the Utility Network ADE and which also offer publicly accessible test data.

The paper is subdivided into six sections. Section 2 discusses use cases for utility networks and their requirements. Section 3 reviews different utility network data models and evaluates them against the requirements identified. Section 4 describes the new and revised concepts of the CityGML Utility Network ADE, section 5 presents projects that have successfully applied the ADE, and section 6 concludes this paper.

2. USE CASES AND THEIR REQUIREMENTS

2.1. Utility Network Use Cases

The exploration of the information requirements for utility network applications was completed with a group of 20 persons from different firms and organizations. The persons are dealing with a wide range of utility network tasks from different domains such as storm drainage, water, electricity, energy planning, and facility management. During the workshops a list of use case areas which include electricity grid planning and simulation, waste water network planning and operation, navigation