RFI on Underground Infrastructure Mapping and Modeling Response

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1 Responding Organisation

The Chair of Geoinformatics (http://www.gis.bgu.tum.de/en/) at the Technical University of Munich (TUM) is well-known for its research focusing on the development of methods for spatial, temporal and semantic modeling, storage, analysis and visualisation of the environment. Key areas are virtual 3D city and landscape models, city system modeling, smart cities, 3D geodatabases, 3D geoinformation systems, GIS and simulations, and indoor navigation. The concepts and methods developed in these areas are validated in interdisciplinary research projects based on scenarios from different disciplines.

2 Use cases for underground mapping and modeling

In the following, use cases which require information on supply and disposal networks are listed. A distinction is made between use cases focusing on a single utility and use cases involving multi-utilities.

A more detailed description on these use cases is provided in the publication:

- Hijazi, Ihab; Kutzner, Tatjana; Kolbe, Thomas H. (2017) Use Cases and their Requirements on the Semantic Modeling of 3D Supply and Disposal Networks. Publikationen der Deutschen Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V., Volume 26, Kersten, T. P. (ed.), 37. Wissenschaftlich-Technische Jahrestagung der DGPF, March 8-10 in Würzburg, 382-394: http://mediatum.ub.tum.de/doc/1352269/192884.pdf

Single-utility scenarios

- **Storm drainage network**
  - Reducing the overflow
  - Collecting storm drainage network fees
- **Clean water act**
  - Inspecting waste water discharged by chemical labs / factories
  - Detecting the location of elements not working properly
- **Vulnerability assessment and disaster management emergency response**
  - Assessing the impact of a natural or man-made disaster on networks and analysing how their failure affects buildings and inhabitants
- **Urban facility management**
  - Coupling of supply/disposal networks with indoor installations
  - Management of planned/unplanned maintenance operations at the level of the individual consumer
  - Failure detection based on the suppliedness of individual consumers
  - Location of easy access points for maintenance
- **Smart energy planning, simulation and operation**
  - Analysing how a change in land use can affect energy consumption and production
  - Simulating and forecasting feed-in power and consumption over small periods which allows network operators to optimise operation in small-scale distribution networks

Multi-utility scenarios

- **Multi-utility planning, simulation and operation**
  - Planning of combined district heating and electrical power generation and distribution
  - Analysing how a change in consumption of one commodity (e.g. gas) impacts consumptions of other commodities (e.g. district heating)
- **Smart Cities**
  - Integrated urban planning, i.e. analysing the impact of planned urban transformations on multiple aspects (energy, traffic, environment)
- **Cascading effects in the failure of infrastructures**
  - Failure propagation of an electric grid on the water and gas supply

3 Architectures, standards and technologies

The international OGC standard CityGML is an open data model and XML-based format for the storage and exchange of semantic 3D city models. By means of so-called Application Domain Extensions (ADEs) the core model of CityGML can be extended systematically by application-specific attributes and object types. The **CityGML UtilityNetwork ADE** represents such an extension. The CityGML UtilityNetwork ADE defines a common data model for representing different types of infrastructure networks, such as electricity, freshwater, wastewater, gas, oil, district heating and telecommunication networks.

Characteristics of the CityGML UtilityNetwork ADE are:

- Simultaneous representation of heterogeneous utility networks, i.e. the ADE is not restricted to specific network types
- Topographic 3D and topological representation of infrastructure networks (dual representation)
- Hierarchical modeling on the feature and network level
- Representation of functional aspects in the form of supply areas, the characterisation of city objects and network features according to functional roles and the representation of the potential and current supply of commodities to city objects
- Linking utility networks with 3D city models; this is not supported by other existing standards
- Modeling multi-utility scenarios; this is not covered by other existing utility modeling standards
- The ADE provides a common data model which can serve as information hub for various stakeholders and various use cases. Data conforming to the ADE can be shared and integrated seamlessly with other utilities, without loss of information or functionality.
- The ADE can not only be applied in urban areas, but also in rural and suburban areas to represent the transmission of resources from generation plants, wells and reservoirs located outside urban areas.

In-depth information on the design decisions of the CityGML UtilityNetwork ADE is provided in these publications:

- Becker, Thomas; Nagel, Claus; Kolbe, Thomas H. (2011) Integrated 3D Modeling of Multi-utility Networks and Their Interdependencies for Critical Infrastructure Analysis. Advances in 3D Geo-Information Sciences, Lecture Notes in Geoinformation and Cartography, Kolbe, T. H., König, G. & Nagel, C. (eds.), Springer, Berlin Heidelberg, 1-20: http://mediatum.ub.tum.de/doc/1145740/358854.pdf
- Becker, Thomas; Nagel, Claus; Kolbe, Thomas H. (2012) Semantic 3D modeling of multi-utility networks in cities for analysis and 3D visualization. Progress and New Trends in 3D Geoinformation Sciences, Lecture Notes in Geoinformation and Cartography, Pouliot, J., Daniel, S., Hubert, F. & Zamyadi, A. (eds.), Springer, Berlin Heidelberg, 41-62: http://mediatum.ub.tum.de/doc/1145724/287720.pdf

- Kutzner, Tatjana; Kolbe, Thomas H. (2016) Extending Semantic 3D City Models by Supply and Disposal Networks for Analysing the Urban Supply Situation. Publikationen der Deutschen Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V., Volume 25, Kersten, T. P. (ed.), 36. Wissenschaftlich-Technische Jahrestagung der DGPF, June 7-9 in Bern, 382-394: http://mediatum.ub.tum.de/doc/1304227/264880.pdf

Originally, the UtilityNetwork ADE was developed as part of a project called SIMKAS 3D which aimed at identifying and analysing the mutual interdependencies of critical infrastructures and simulating cascading effects in the failure of supply infrastructures. In October 2016, a joint SIG 3D and OGC series of workshops started which aims at collecting further requirements to be included in the UtilityNetwork ADE in order to make it usable / useful for a wide range of use cases.

- Further information on the UtilityNetwork ADE workshops is available at http://en.wiki.utilitynetworks.sig3d.org/
  Resources resulting from these workshops are provided on a github repository. This includes the UML model and the XML schema as well as information on how to derive the XML schema from the UML model using ShapeChange and on how to use the ADE with FME:
  https://github.com/TatjanaKutzner/CityGML-UtilityNetwork-ADE
- The CityGML wiki provides information on the UtilityNetwork ADE as well:
  http://www.citygmlwiki.org/index.php?title=CityGML_UtilityNetworkADE
  The resources available at the CityGML wiki refer to version 0.9.0 of the UtilityNetwork ADE. This version serves as basis for the further development of the ADE by the joint SIG 3D and OGC Utility Network ADE workshops.

4 Implementation examples

The CityGML UtilityNetwork ADE was applied in the SIMKAS 3D project which aimed at identifying and analysing the mutual interdependencies of critical infrastructures and simulating cascading effects in the failure of supply infrastructures.

Further information on the project is available in the publications listed above as well as in:

- Becker, T., Bartels, M., Hahne, M., Hempel, L. & Lieb, R. 2012: Cascading Effects and Interorganisational Crisis Management of Critical Infrastructure Operators. Proceedings of the 8th International Conference on Geo-Information for Disaster Management, Enschede, 105–116.

Above that, the ADE was successfully applied in a study conducted on behalf of the German Armed Forces on the possibilities of utilising supply infrastructures in training simulators for crisis scenarios (e.g. evacuation), for simulating the impact of a failure on the population and for simulating the impact on tactical operations.