A 3D data modelling approach for integrated management of below and above ground utility network features

By means of the CityGML Utility Network ADE

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Problem statement and motivation

Substantial work has already been done in the modelling and representation of above ground features in the context of 3D city modelling

BUT the below ground part of the real world, of which utility networks form a big part, is often neglected in 3D city models

At the same time…

Several existing utility network data models exist.

BUT these are commonly tailored to a specific domain

Thus,

How to efficiently model below ground utility networks and related above ground 3D city objects in order to facilitate integrated asset management?

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Why the CityGML Utility Network ADE?

Data model	2D/3D	Scale	Topological relationships		Utility type
			network features	network features and city objects	
INSPIRE Utility Networks	2D	Urban	Yes	No	Any
IFC Utility model	2D+3D	Building	Yes	Yes*	Any
ESRI Utility Network	2D**	Urban	Yes	No	Any
PipelineML	2D	Urban	Yes	No	Oil and gas
CIM	-	Urban	Yes	No	Electricity
IMKL	2D+3D	Urban	Yes	No	Any
CityGML Utility Network ADE	2D+3D	Urban	Yes	Yes	Any***

Table 3.1: A comparison between the different utility network data models

The capability of:

- Relating utility network features as well as utility network features and above ground city objects
- Modeling relationships and dependencies between network features of **different** types of networks
- Embedding into 3D urban space (since it is part of the matured CityGML standard)

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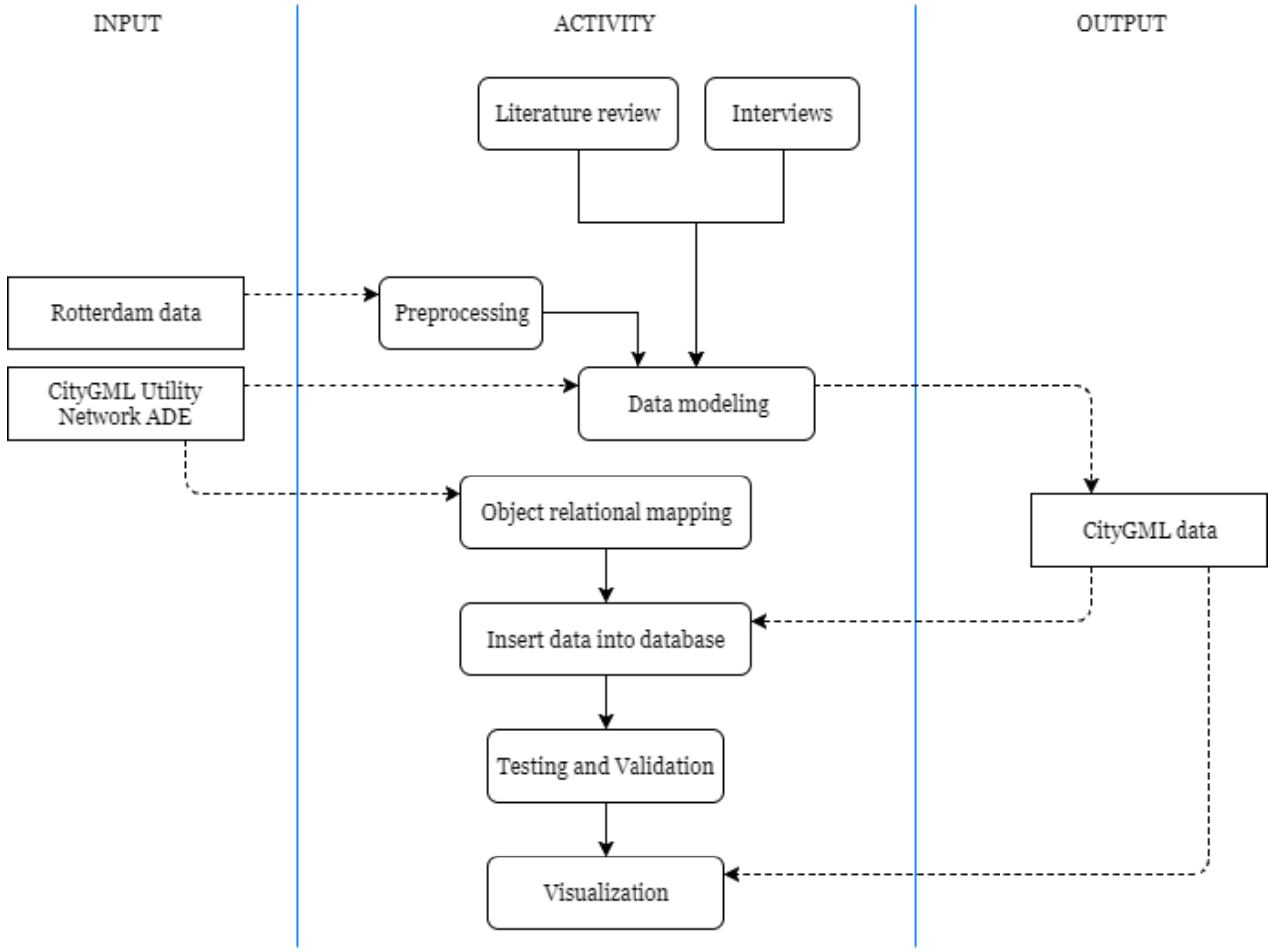
Conceptual design



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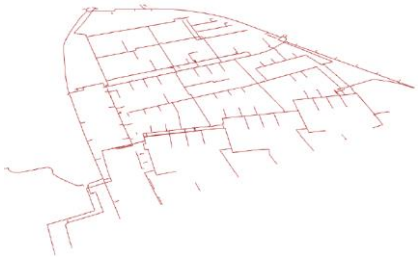
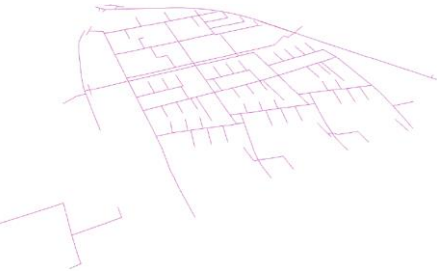
What are we working with?





Electricity network data

- Electricity lines:
  - An ESRI Shapefile containing 3D line objects representing the electricity lines (LV and OV)
- Streetlights:
  - An ESRI Shapefile containing point objects representing the location of a streetlight (with the type of connection and physical properties, e.g. the height, put in the attribute fields)

Sewer network data

- Sewer network lines
  - An ESRI Shapefile containing 3D line objects representing the standard sewer pipes
- Manholes
  - An ESRI Shapefile containing point objects representing the location of the manhole (cover)

Rotterdam 3D

- A 3D city model of Rotterdam in CityGML format including buildings, trees, ground level, design and building information. Pipes and cables are also part of the 3D city model but are modeled as generic city objects.

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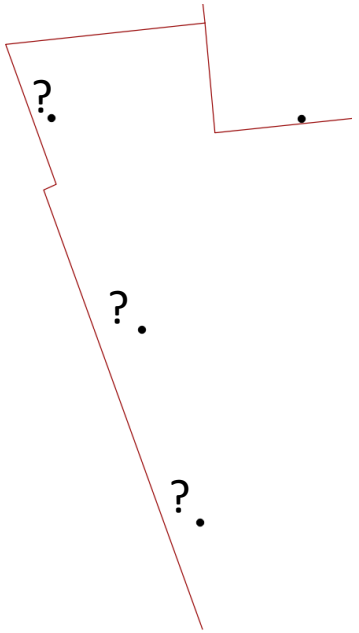
Preprocessing

Problem

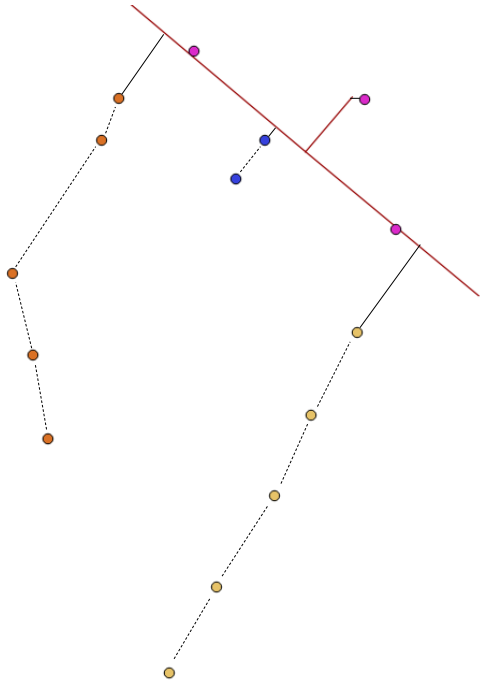
The connection line between the above ground feature and main electricity line is not registered

→ it is unknown how the streetlights are connected to the below ground electricity lines.



Solution

An algorithm that computes a best estimate of what streetlights are connected to what streetlights and what streetlights are connected to what electricity line



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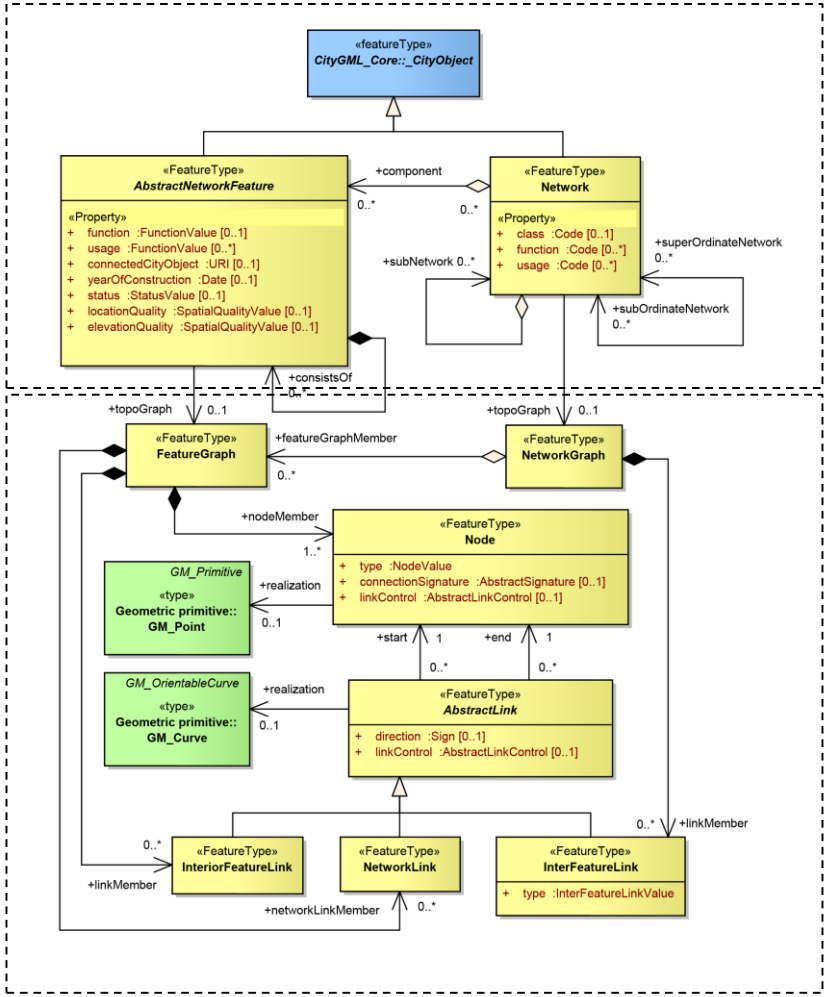
The Utility Network Core module

Topograph →

Graph →



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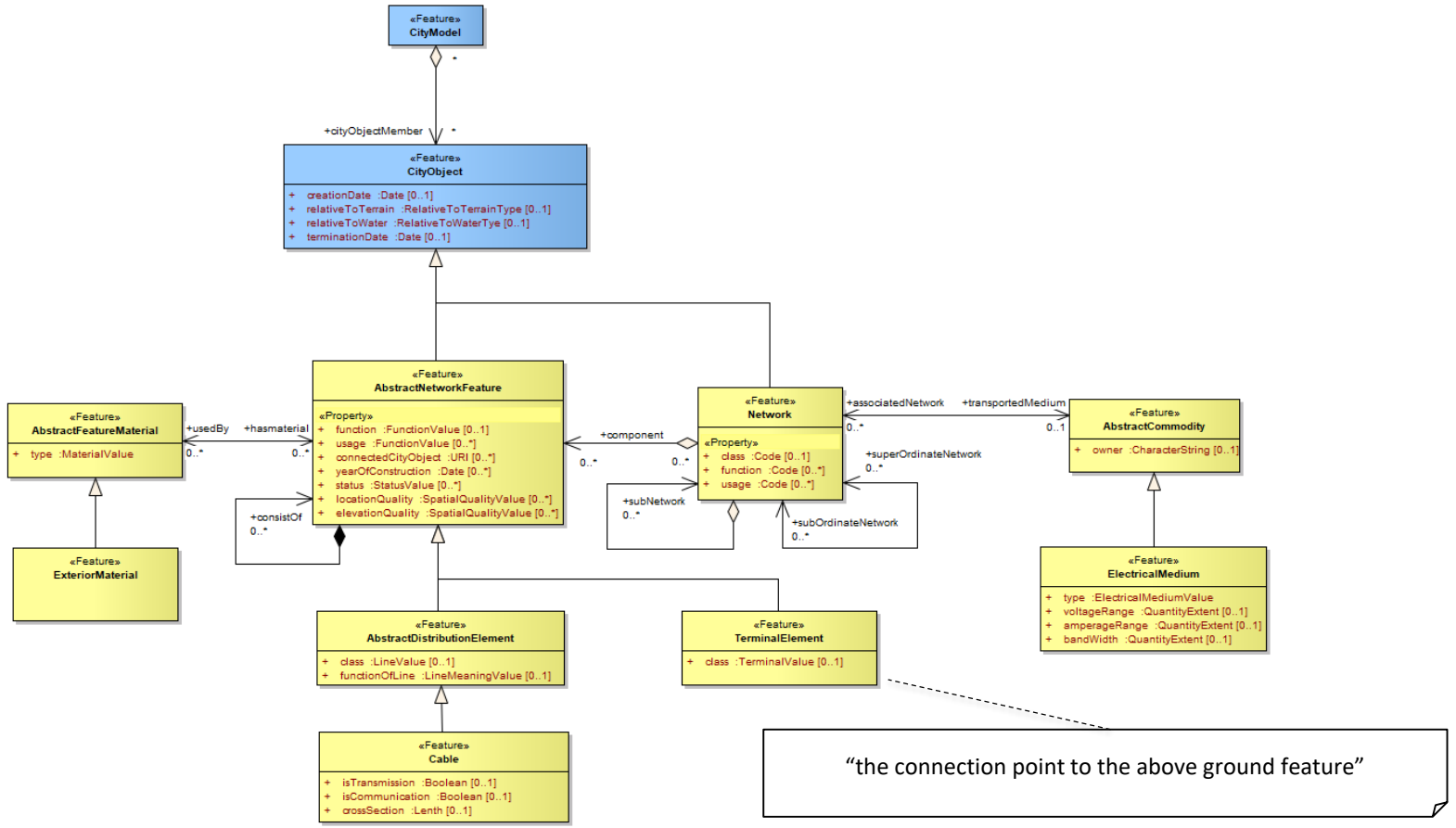
Electricity network data modelling approach



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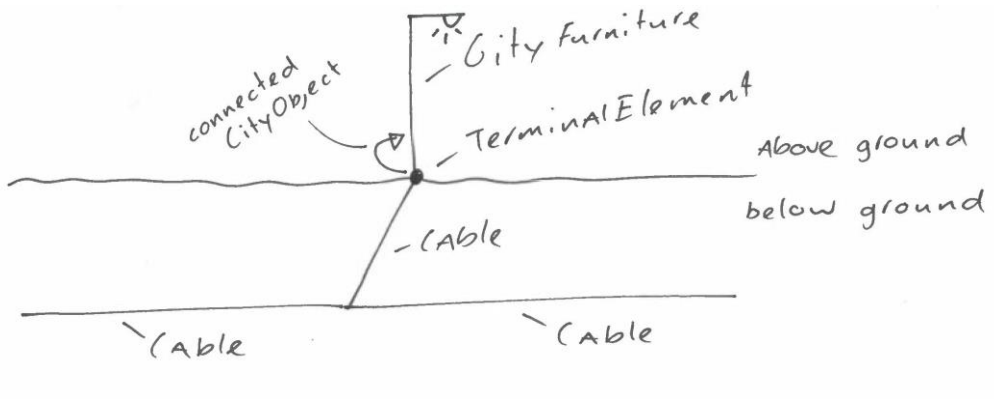
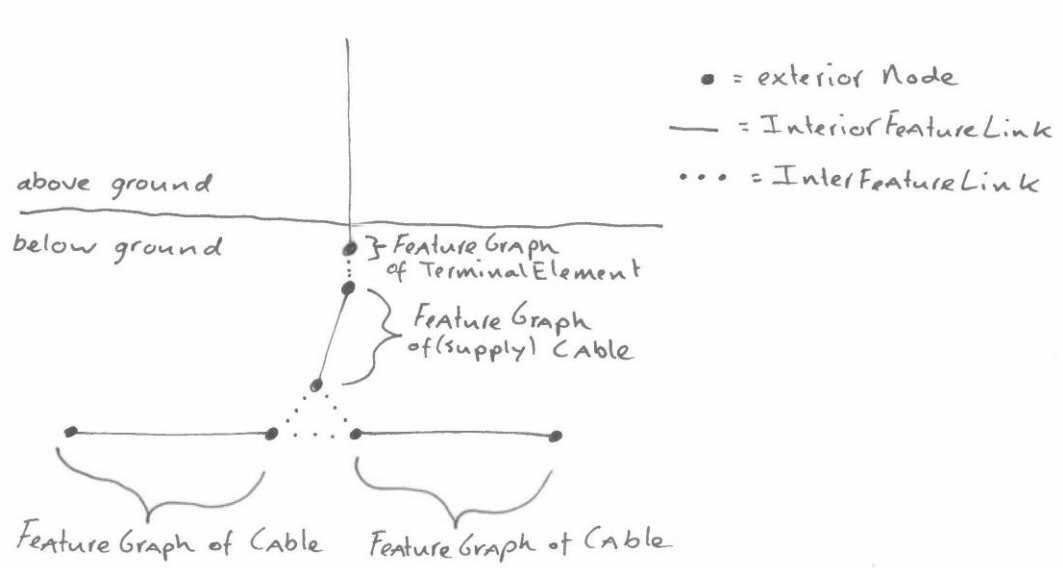
This is the idea

Electricity network

Topography



Topology



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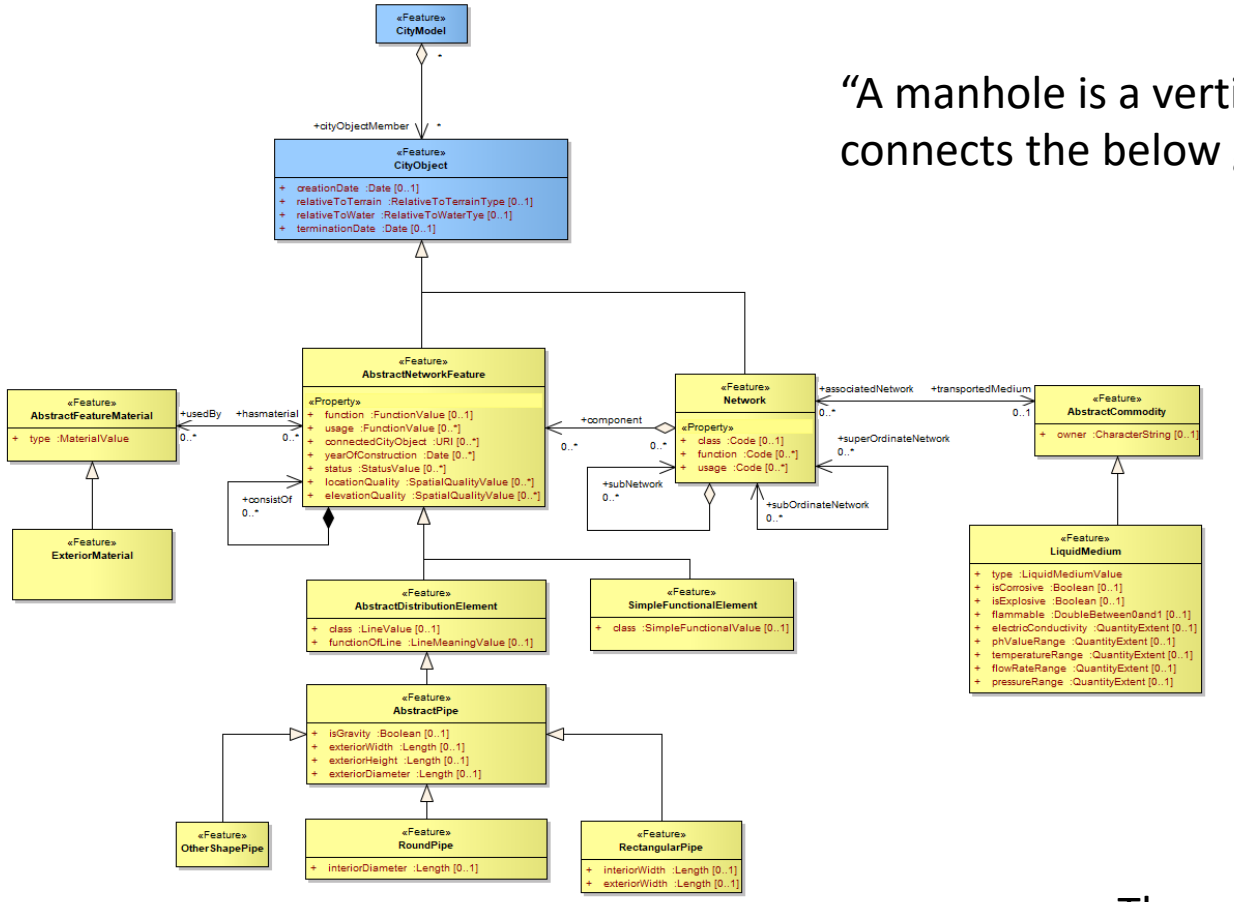
Sewer network data modelling approach



"A manhole is a vertical pipe, usually made of concrete, that connects the below ground sewer network to the surface"

These are manholes! →

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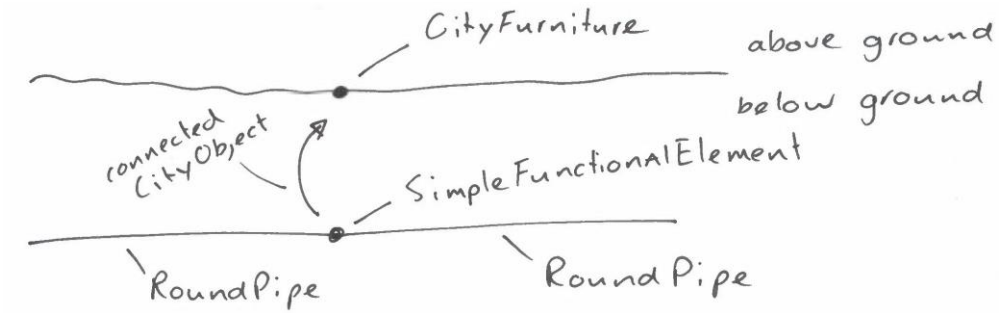
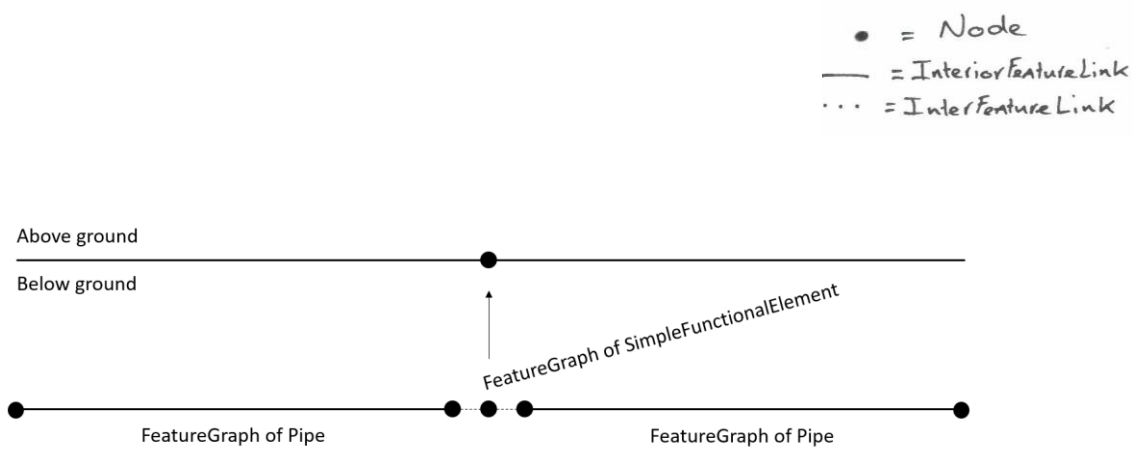
This is the idea

Sewer network

Topography



Topology



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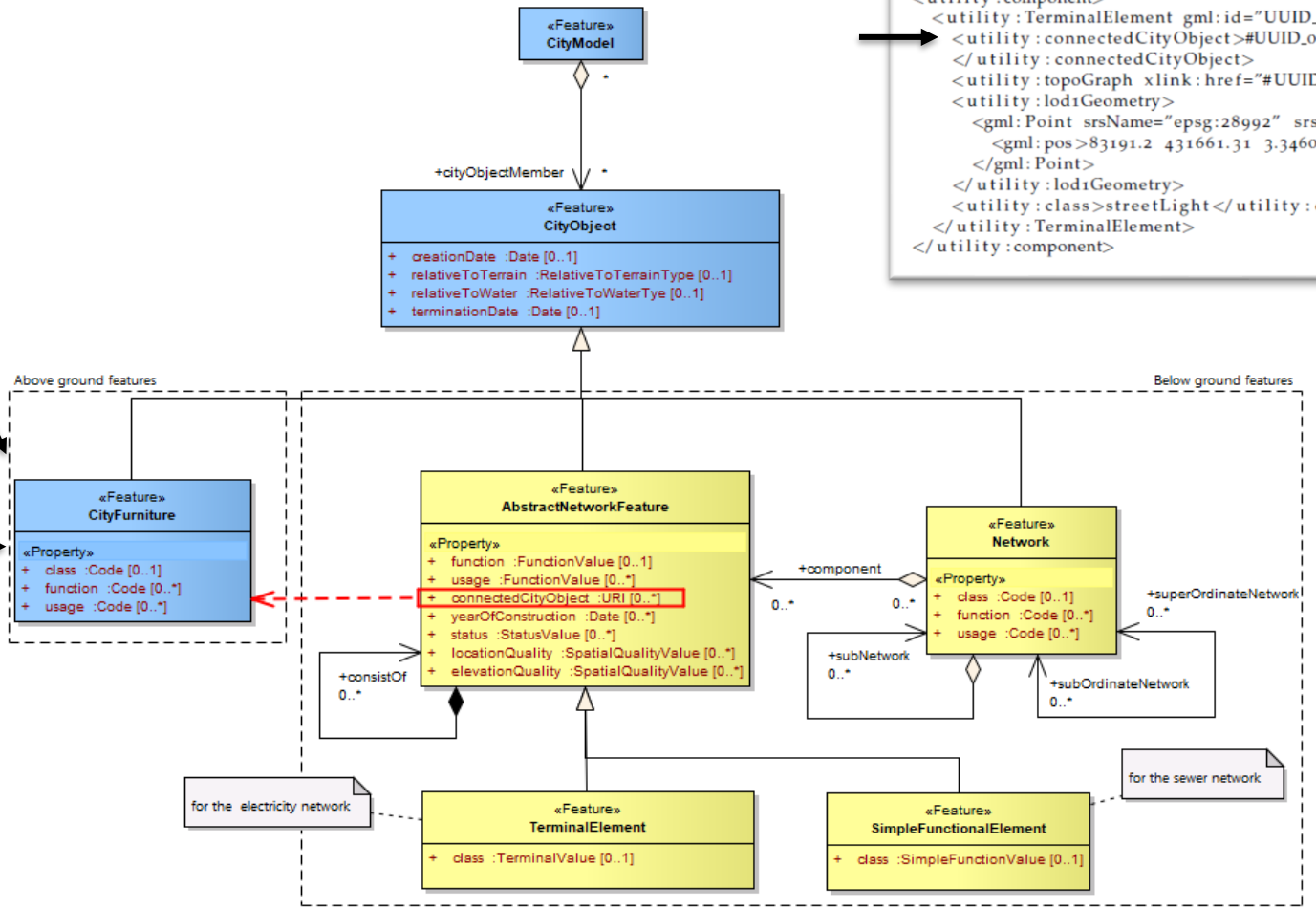
Linking below and above ground utility network features




```
<utility:component>
  <utility:TerminalElement gml:id="UUID_44c9797e-4259-42be-99bb-4fddf85e11b3">
    <utility:connectedCityObject>#UUID_011b78d3-7fef-408a-9a7b-8ffd378ab42a
    </utility:connectedCityObject>
    <utility:topoGraph xlink:href="#UUID_40c9b3fd-f66d-4023-8a37-6c014de015b9"/>
    <utility:lod1Geometry>
      <gml:Point srsName="epsg:28992" srsDimension="3">
        <gml:pos>83191.2 431661.31 3.346012028694 16</gml:pos>
      </gml:Point>
    </utility:lod1Geometry>
    <utility:class>streetLight</utility:class>
  </utility:TerminalElement>
</utility:component>
```

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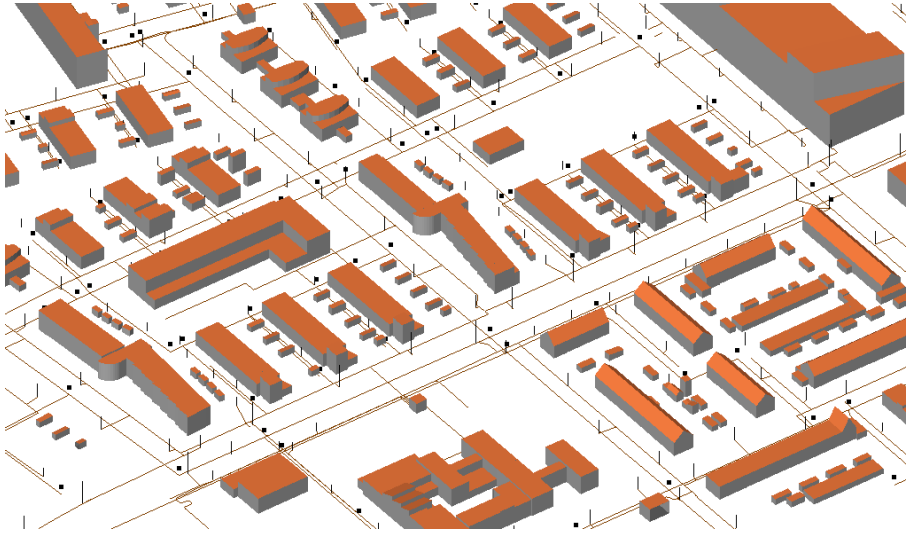
This is completely done in FME!

- This is a complex translation (over a 100 transformers are used and lots of relationships)
- The workspace is particularly designed for the Rotterdam data in vector file format

- Building the topology is an important step. Its success relies on the type and quality of the input data

→ a .gml file is output

And can be visualized in the FZKViewer or the FME Data Inspector



BUT the support and possibilities are limited

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Derivation of the relational database

Why?

- CityGML datasets may become very large and objects may be arbitrarily nested leading to complex data structures
- Efficient storage and management of CityGML data requires carefully optimized database schemas
- To ensure interoperable data access and detailed (network) operations

How?

- Mapping the CityGML Core
- Mapping the CityGML Utility Network ADE

All by means of 3DCityDB!

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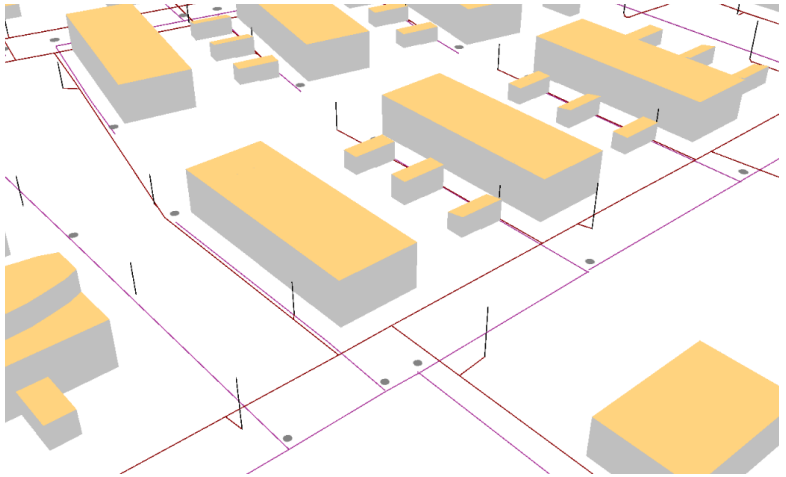
Importing the CityGML data

- The inserting of the CityGML Utility Network ADE data is done in FME (again)
- The order of importing is a task that must be handled with care. Parallel importing of all feature types into the tables in a single workspace might cause an error due to referencing to not existing id’s.
- A command line batch file is created that runs the different workspaces, used to populate the different tables with the CityGML data, after each other

And connecting to ArcGIS



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Testing and Validation; querying the database

- SQL scripts are written in order to conduct (network) analyses on the spatial data in the relational database

Scenario: A utility strike, what streetlights are affected?

- Knowing the location, what geometries are affected?
- What FeatureGraphs and corresponding nodes are affected?
- What nodes can (not) be reached? (PgRouting)
- What city furniture objects (streetlights) are affected?

id	classname	cityobject_id	lod1_other_geom
142	TerminalElement	1560	01020000A040...
151	TerminalElement	1569	01020000A040...
159	TerminalElement	1577	01020000A040...
1037	Cable	null	null
1038	Cable	null	null
1039	Cable	null	null
1235	Cable	null	null
1291	Cable	null	null
1326	Cable	null	null

```
SELECT ntw_feature_id, classname, cityobject_id, lod1_other_geom
FROM(
    SELECT ntw_features.id as ntw_feature_id, classname, cityobject_id
    FROM(
        SELECT id, objectclass_id, cityobject_id
        FROM(
            SELECT utn9_feature_graph.ntw_feature_id
            FROM(
                SELECT feat_graph_id
                FROM(
                    SELECT sum(cost) AS sum_cost, end_vid as node_id
                    FROM pgr_dijkstra(
                        'SELECT id, start_node_id::int4 AS source,
                        end_node_id::int4 AS target, cost::double precision
                        FROM utn9_link
                        WHERE id != 2440',
                        1647, array[1,2,3...], false)
                    GROUP BY node_id
                    ORDER BY sum_cost ASC) as nodes_in_reach
                JOIN utn9_node ON nodes_in_reach.node_id = utn9_node.id
                GROUP BY feat_graph_id) as feat_graph_ids
            JOIN utn9_feature_graph ON feat_graph_ids.feat_graph_id =
            utn9_feature_graph.ntw_feature_id) as ntw_feature_ids
        JOIN utn9_network_feature ON ntw_feature_ids.ntw_feature_id =
        utn9_network_feature.id) as ntw_features
    JOIN objectclass ON ntw_features.objectclass_id = objectclass.id)
    as terminalelement_ids
LEFT OUTER JOIN city_furniture ON terminalelement_ids.cityobject_id =
city_furniture.id
```

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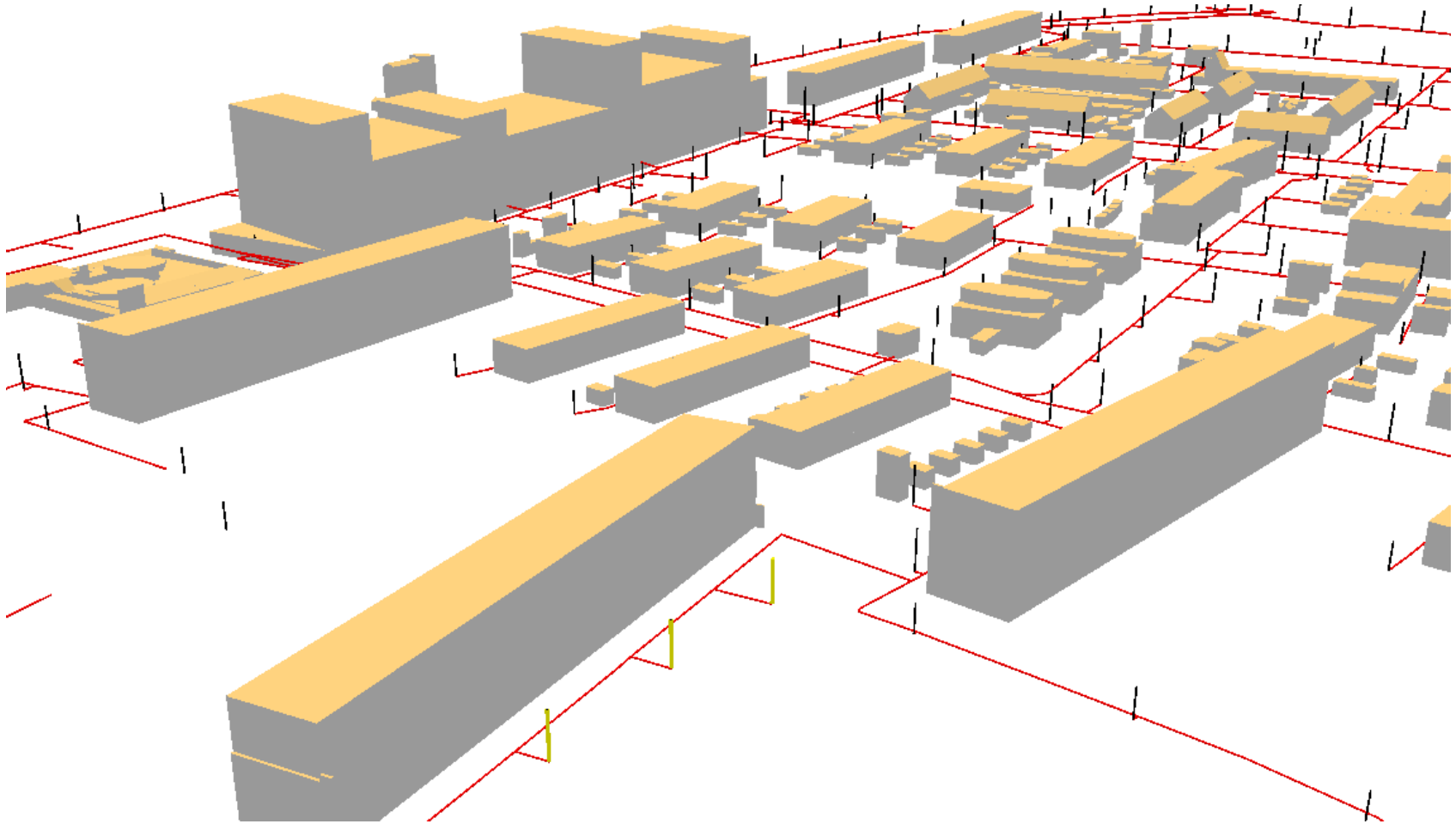
Affected streetlights in ArcGIS



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Conclusion

This research has shown the suitability of the CityGML Utility Network ADE by the implementation of two types of below ground utility networks (viz. electricity and sewer)

And is successfully examined by implementing relationships between:

1) the below ground electricity network and above ground streetlights and
2) between the sewer network and the above ground manhole covers

The object-oriented CityGML model is successfully mapped to a relational database which has proven to be efficient for storing, management and analyses by means of the performed (network) operations.

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Future work

- Implementation of more different utility networks and city objects
- Modeling in a higher Level of Detail (LoD)
- Detailing the CityGML Utility Network classes and use
- Better investigating on more types of analyses
- Implementing larger datasets
- Implementing datasets with a different accuracy
- Exporting a CityGML file from the relational database
- Better investigating on visualization of the data
- Investigation on how to model different types of relationships

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References

1. https://github.com/TatjanaKutzner/CityGML-UtilityNetwork-ADE
2. https://github.com/3dcitydb/3dcitydb
3. https://github.com/gioagu/3dcitydb_ade

4. http://www.citygmlwiki.org/index.php/CityGML_UtilityNetworkADE
5. https://www.citygml.org/

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Thank you!

https://github.com/XanderdenDuijn/CityGML-Utility-Network-ADE

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