Automatic semantic and thematic classification of 3D models to create CityGML

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P5 Presentation

Master of Science in Geomatics for the Built Environment

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TU Delft

Presentation overview

- Introduction
- Problem statement and research scope
- Methodology
  - Indexing
  - Region growing
  - Thematic classification
  - Semantic classification
  - LoD detection
- Results
- Conclusions
- Future work

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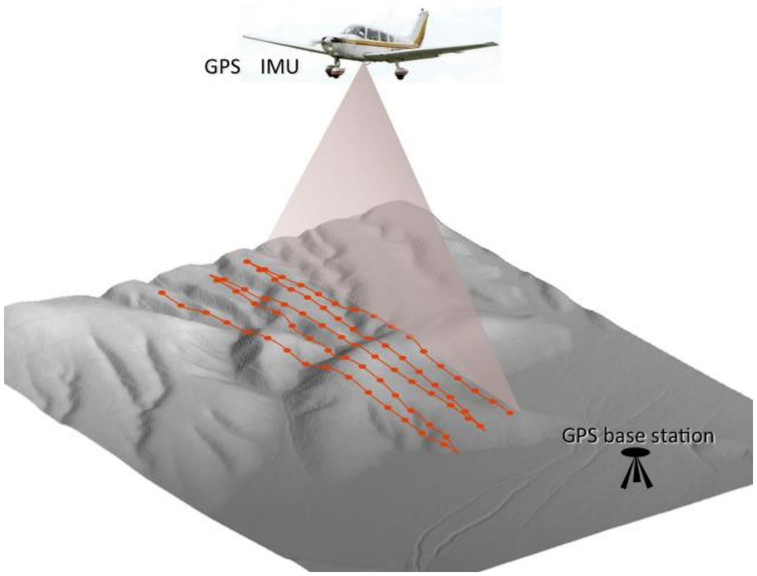
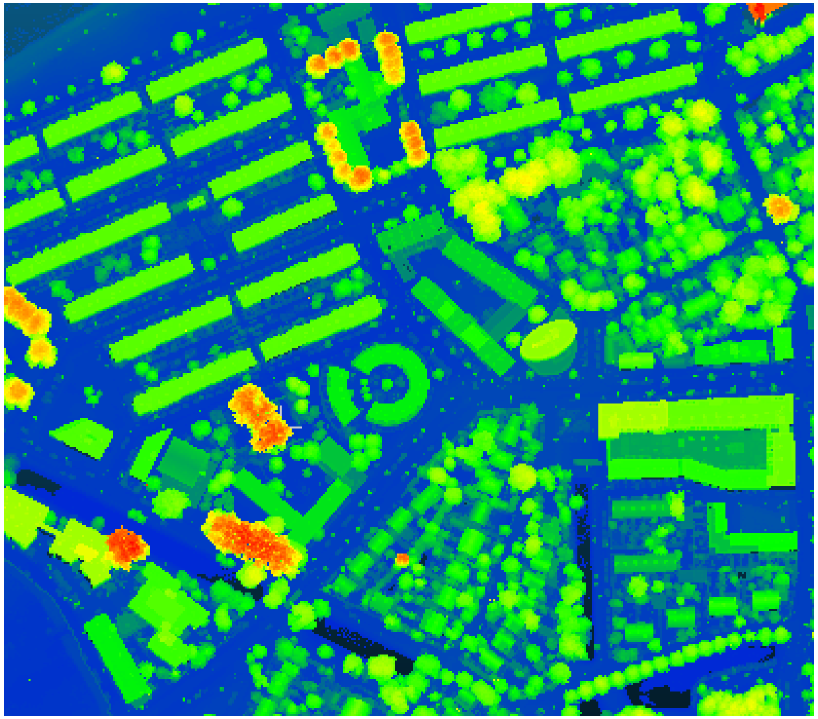
Advancing developments in remote sensing



Source: serc.carleton.edu



Source: AHN3

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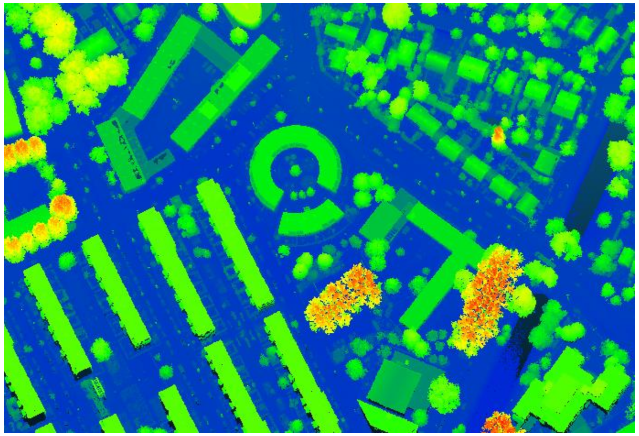
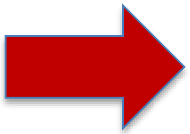
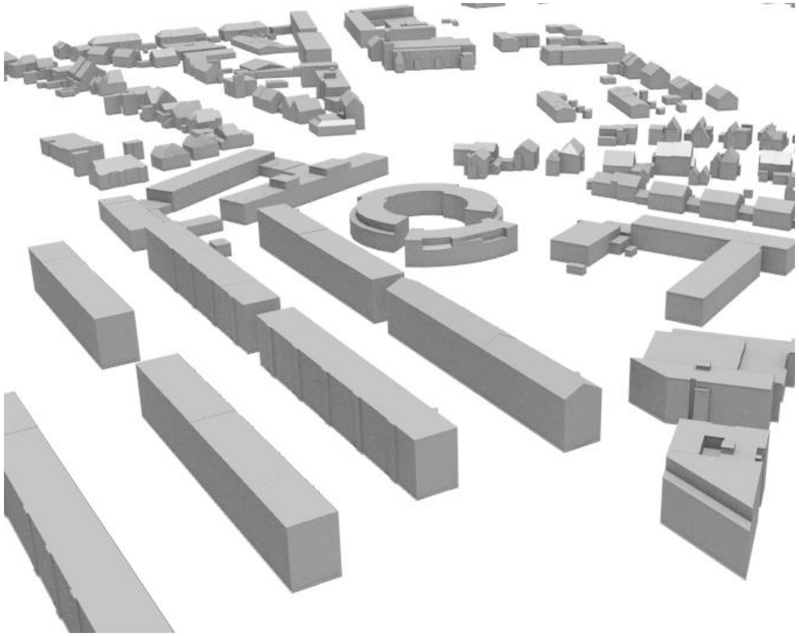
3D GIS: the creation of 3D city models

Top10NL



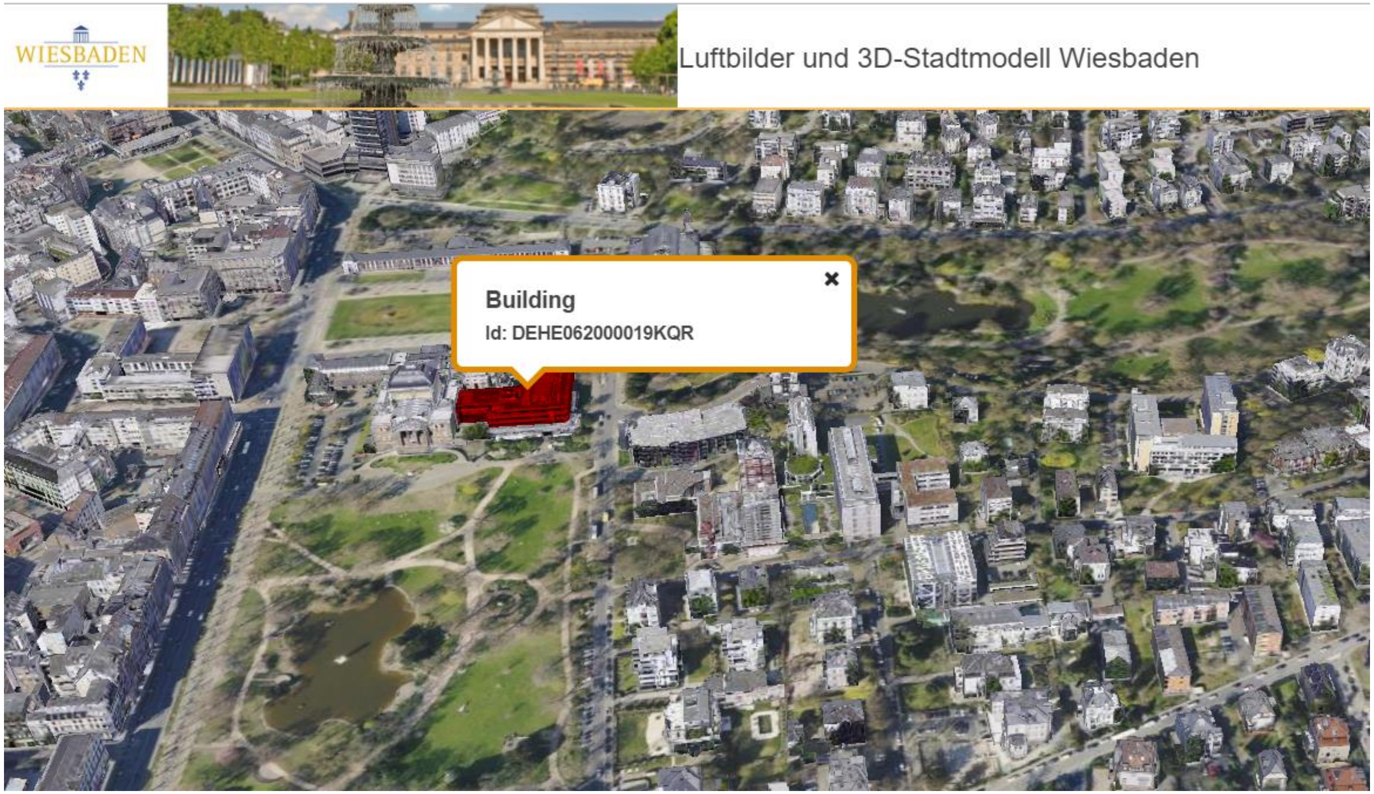
AHN3





Rotterdam 3D

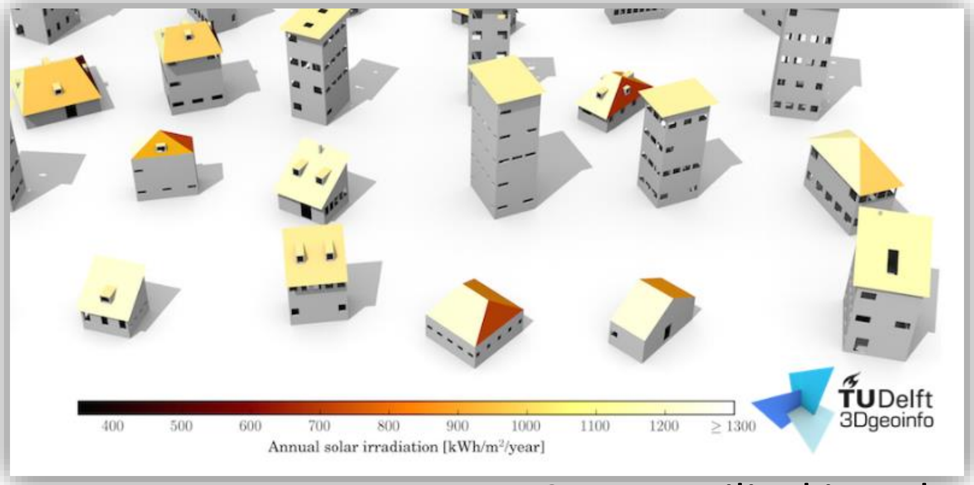
Applications 3D GIS



Applications of 3D GIS

Flood modelling

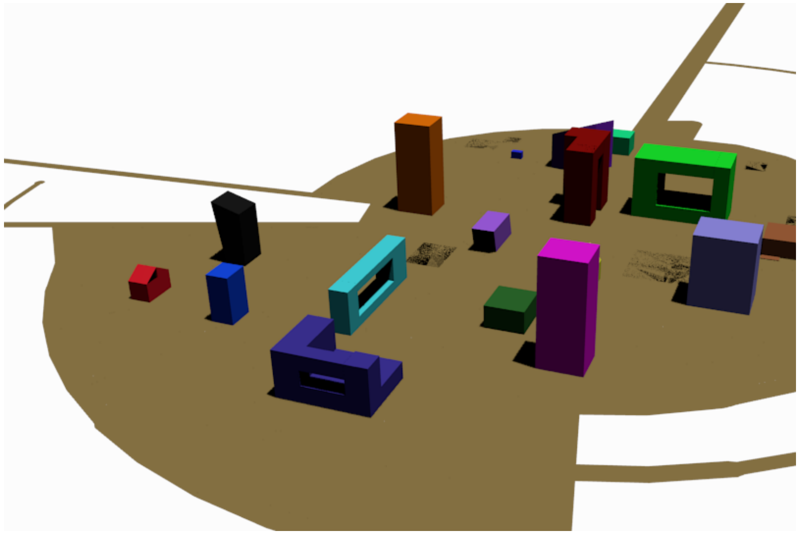
Solar irradiation analysis



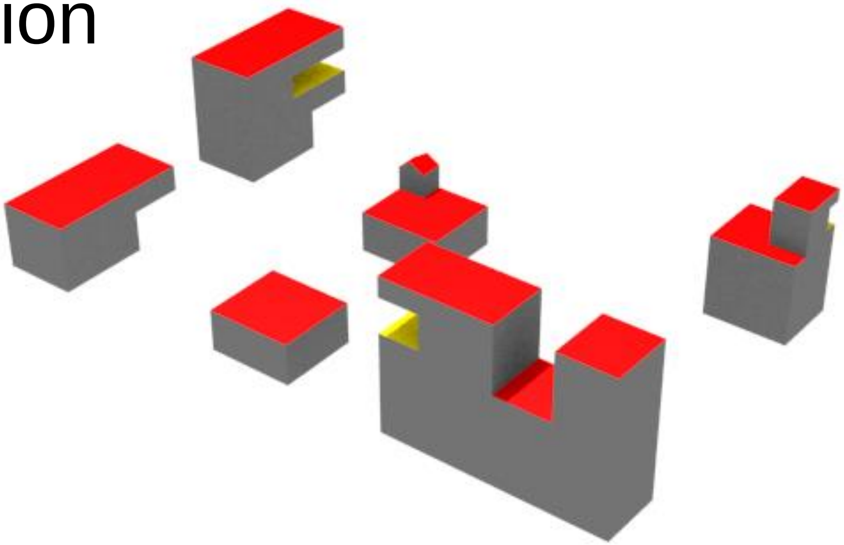
Source: Biljecki et al. (2016)

Semantic and thematic information

- Thematic information



- Semantic information



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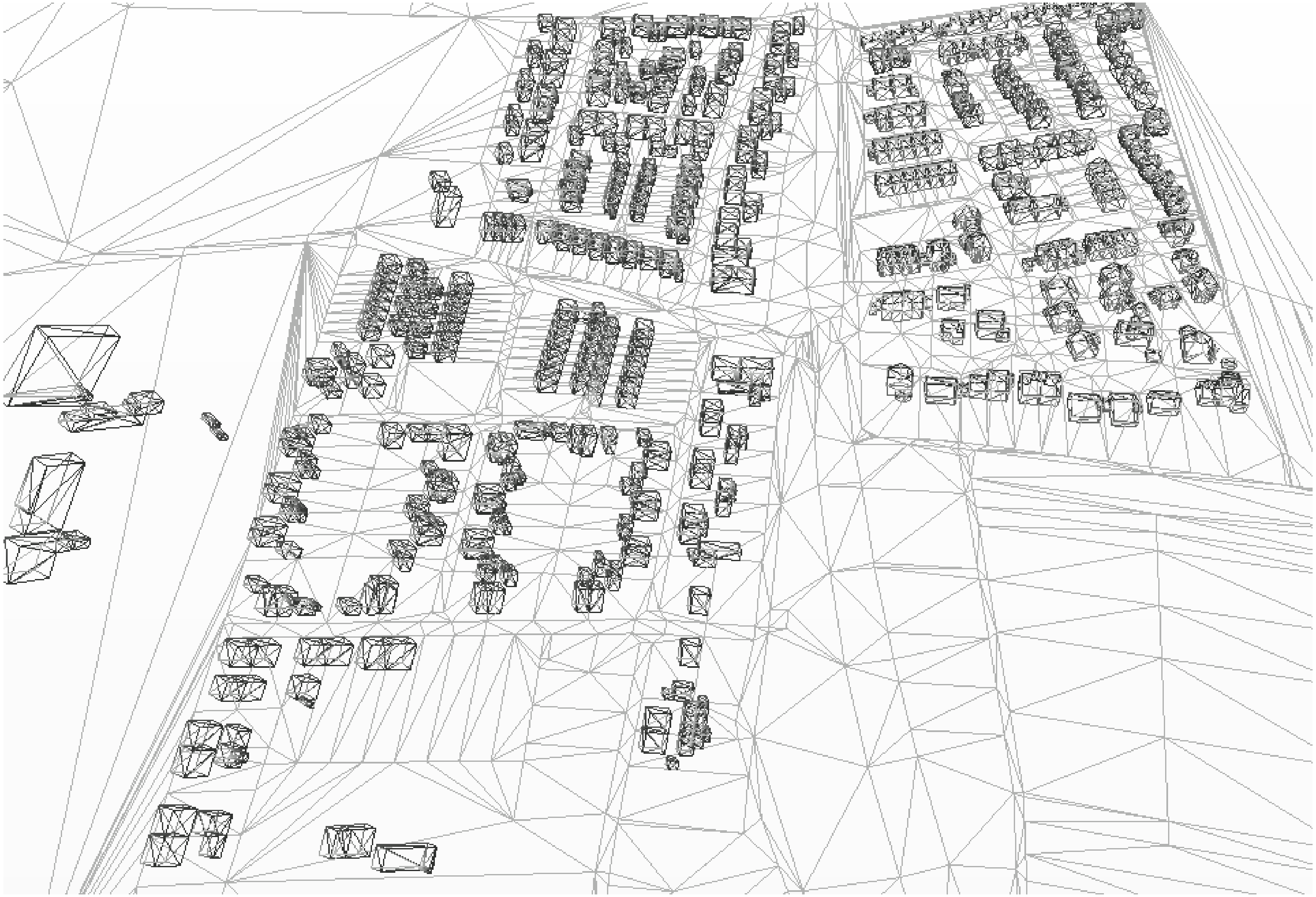
Semantic and thematic information

- Use of semantic and thematic information:
  - Query: select surfaces or objects of interest
  - Spatial analysis & real world simulations
  - Interoperability

Problem statement



Data source: Waldbrucke model

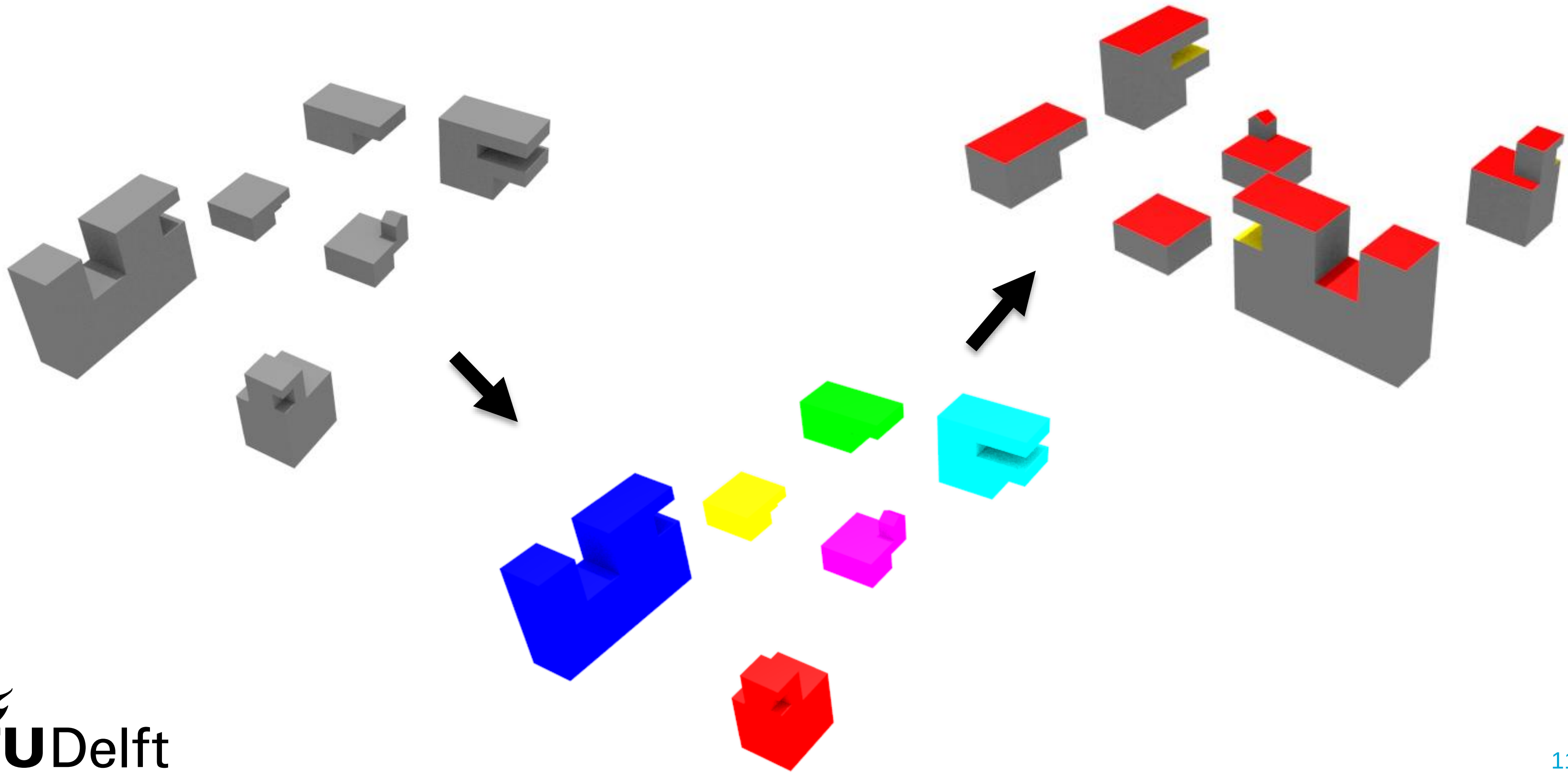
Semantic and thematic classification

- Mostly a manual process: time and cost expensive

- Limitations of current research:
  - Thematic aspect is ignored
  - Not all semantic classes that are required to create CityGML are covered

Research question

How to automatically enrich a 3D city model with thematic and semantic information as defined in CityGML, by only utilising the models geometry?



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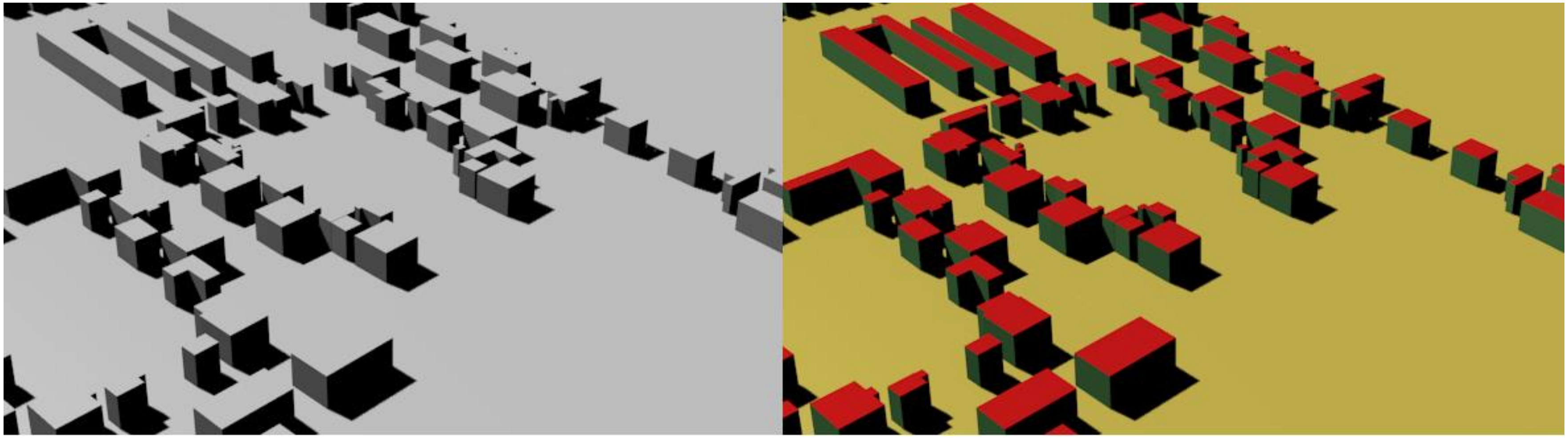
Research goal



Automate the process of thematic and semantic classification, in accordance with the CityGML standard

CityGML

- OGC standard
- 3D city model with attached its thematic and semantic information.

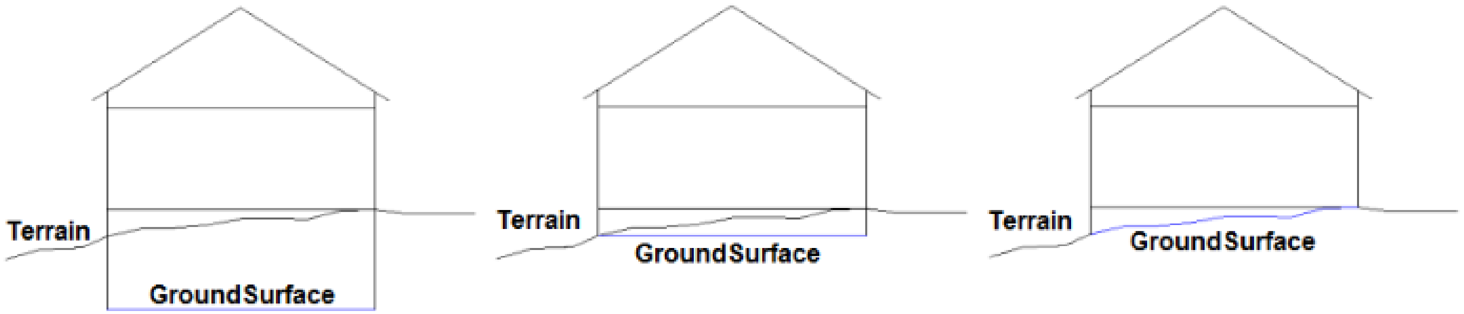
- Most important: defines the thematic and semantic structure used in this research

Research challenges

- 5 Challenges are identified

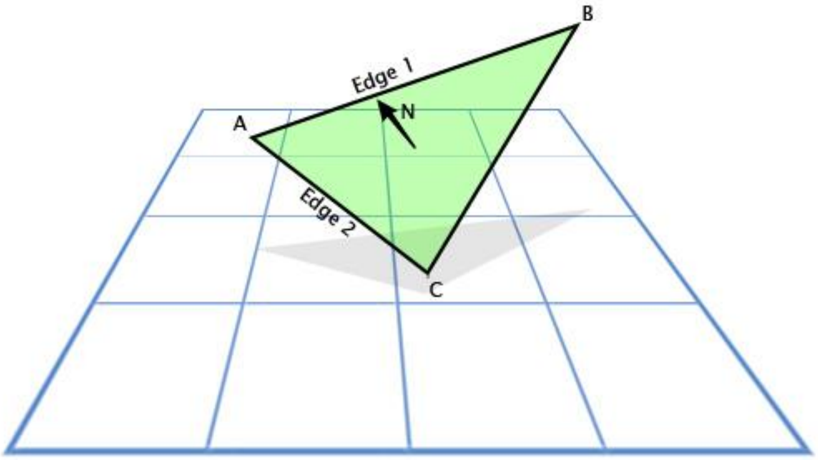
Research challenges (1)

- Complexity of the semantic classes and the lack of definition: CityGML only defines the surface normal.

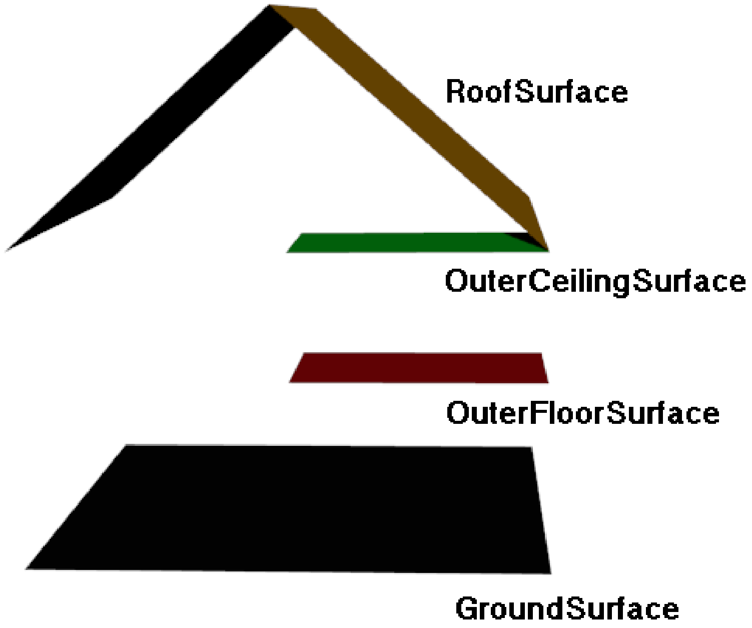


Research challenges (2)

- Limited applicability of utilisation the surface normal



Source: blog.wolfire.com



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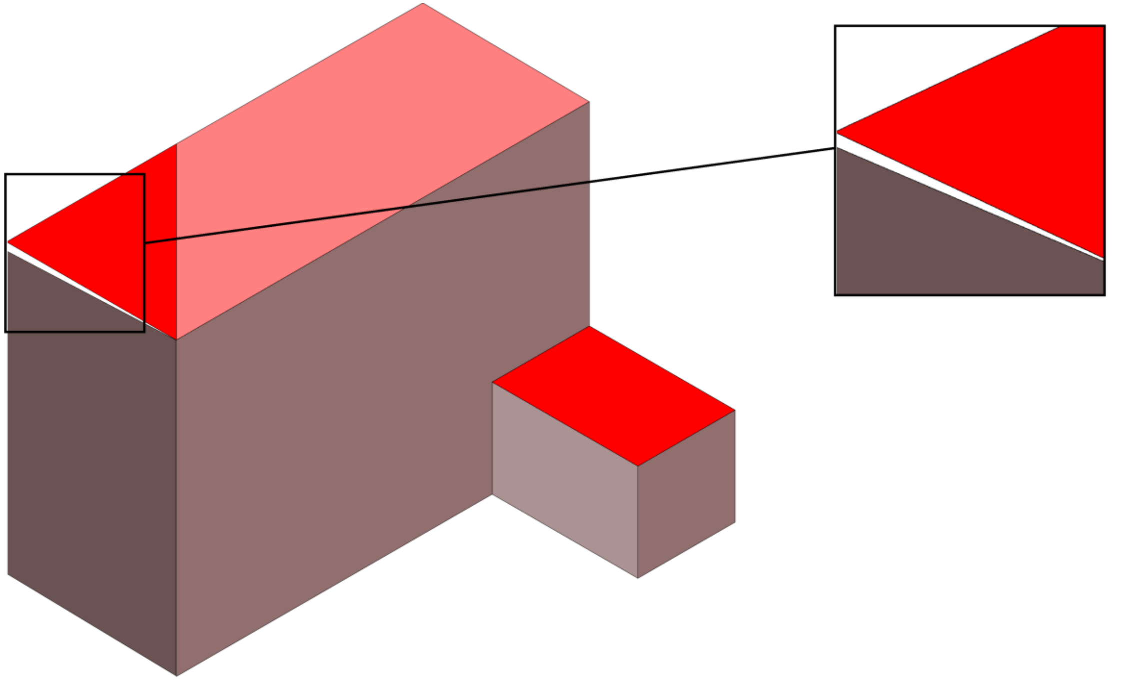
Research challenges (3)

- Topology and spatial index
  - Reconstruction of the topology is hindered by slivers and double stored vertices.



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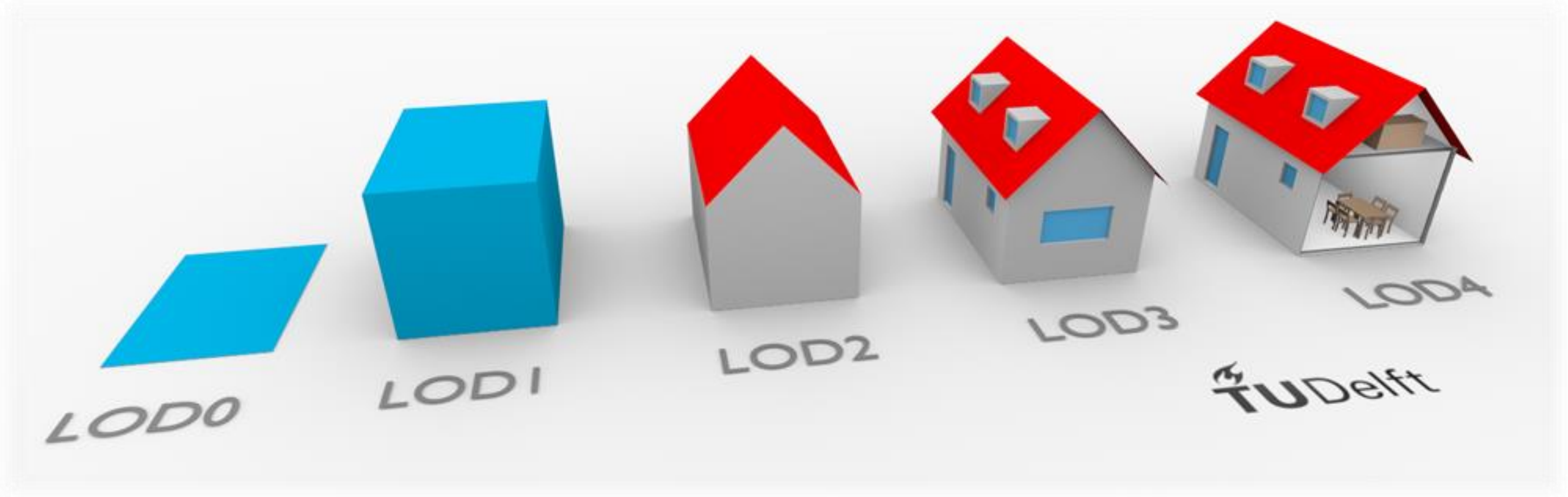
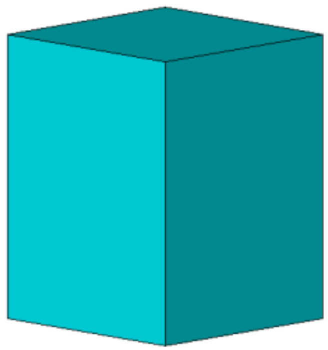
Research challenges (4): Level of Detail (LoD)



Source: Biljecki et al., 2016

- Only the classification of LoD 1 and 2 models is researched

Research challenges (4): LoD



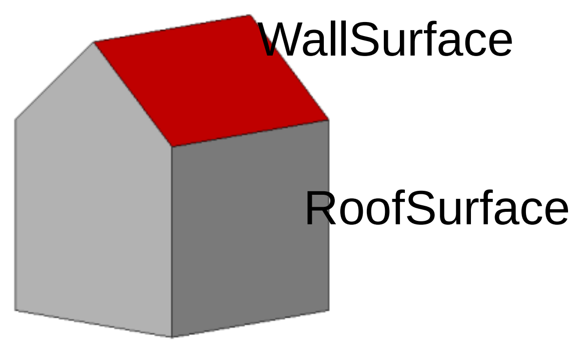
LoD1:

Only thematic information

LoD2:

Thematic and

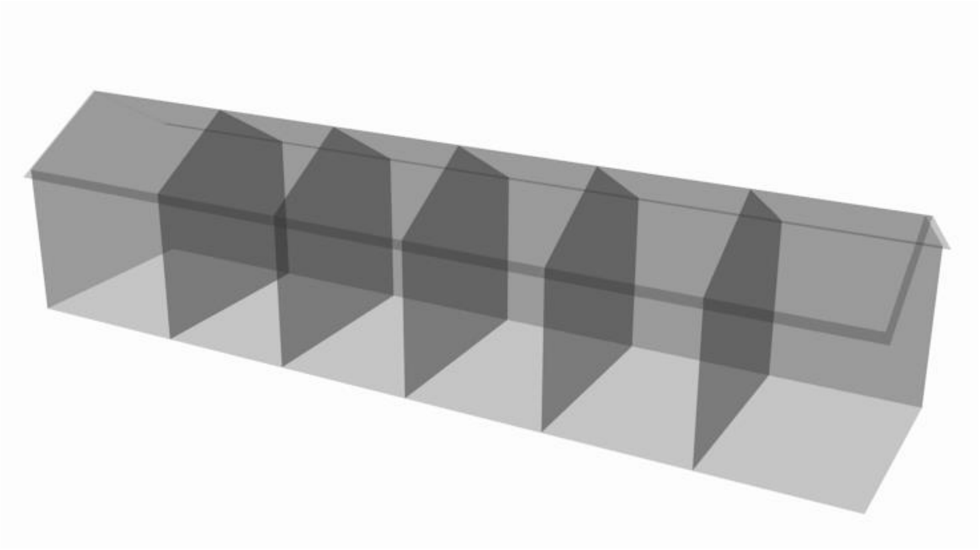
Semantic information



Source of figures: Häfele, K. (2011)

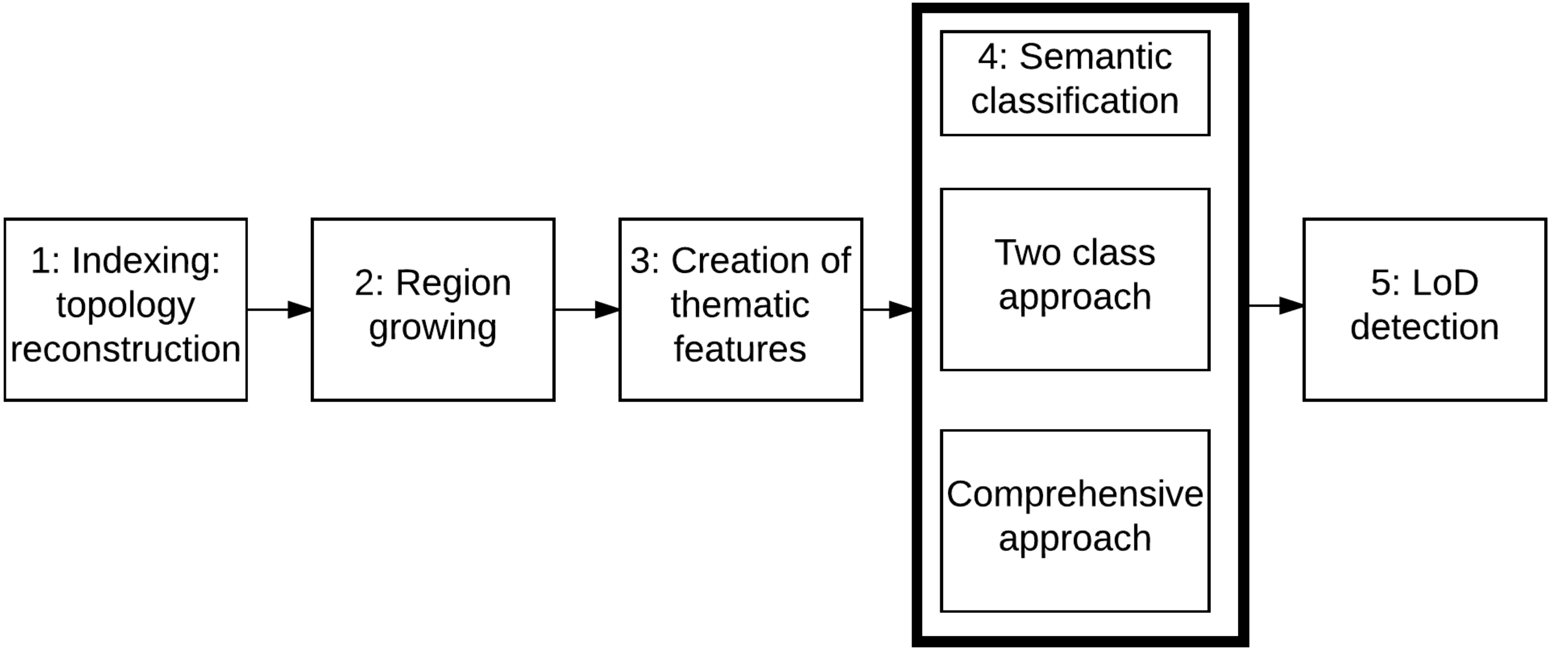
Research challenges (5)

- Lack of definition for the thematic features

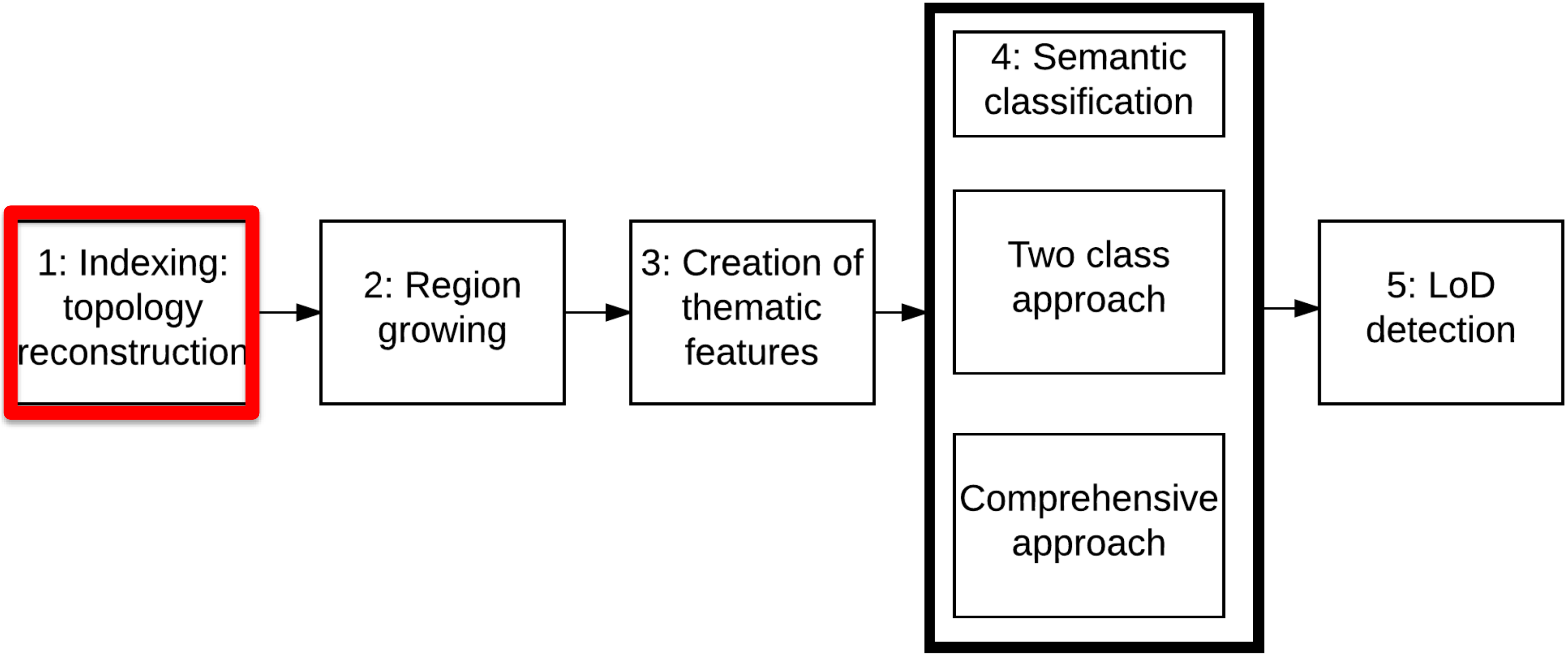


Data source: Rotterdam 3D

Methodology

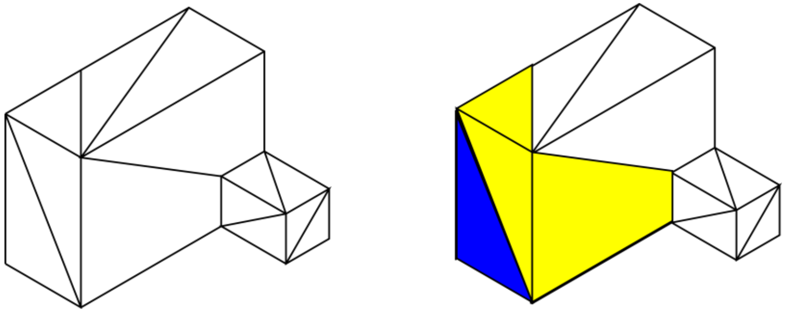


Methodology: Indexing

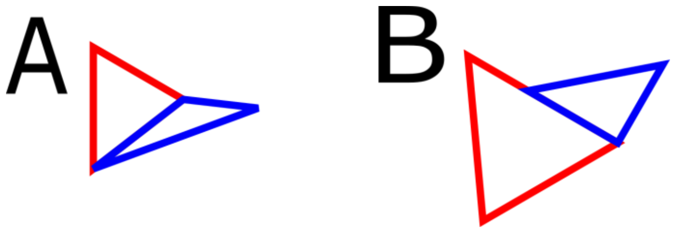


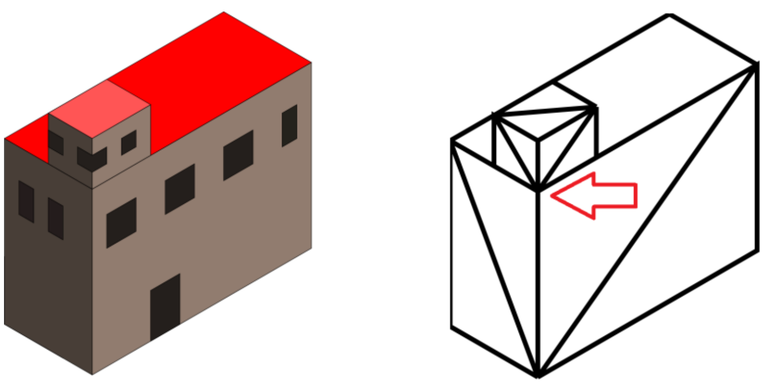
Indexing

- Index: stores the adjacency relations between triangles



- Relationship is adjacent if triangles share a vertex





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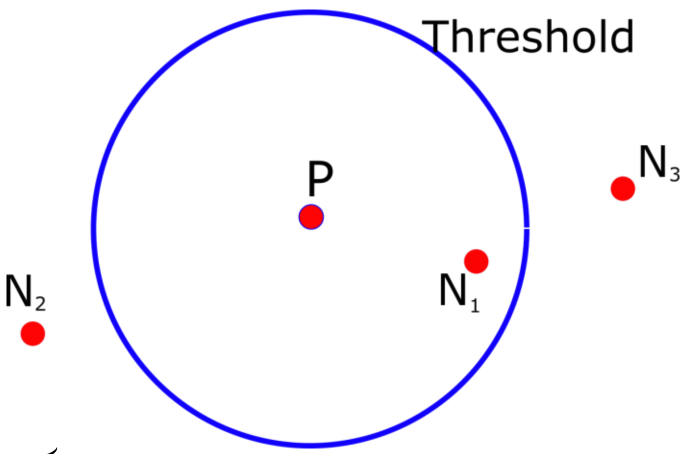
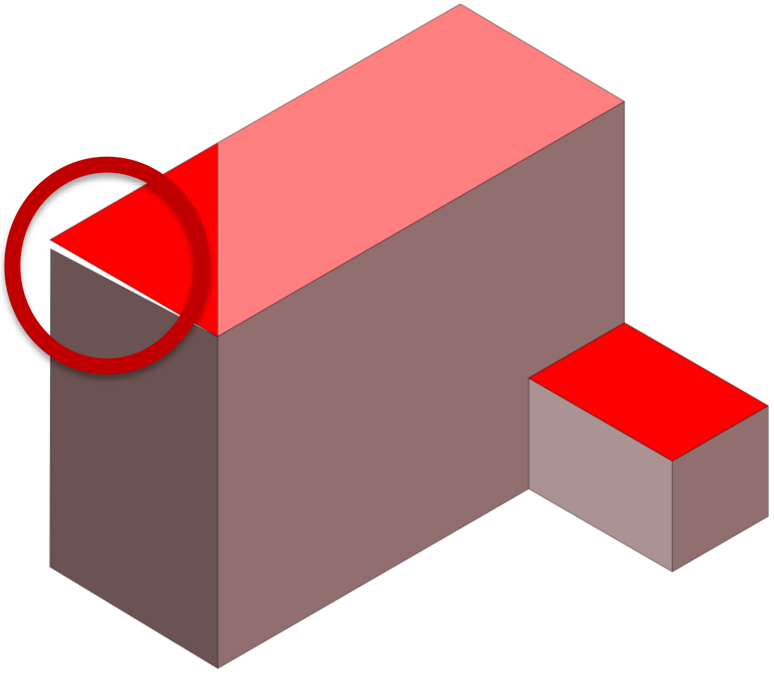
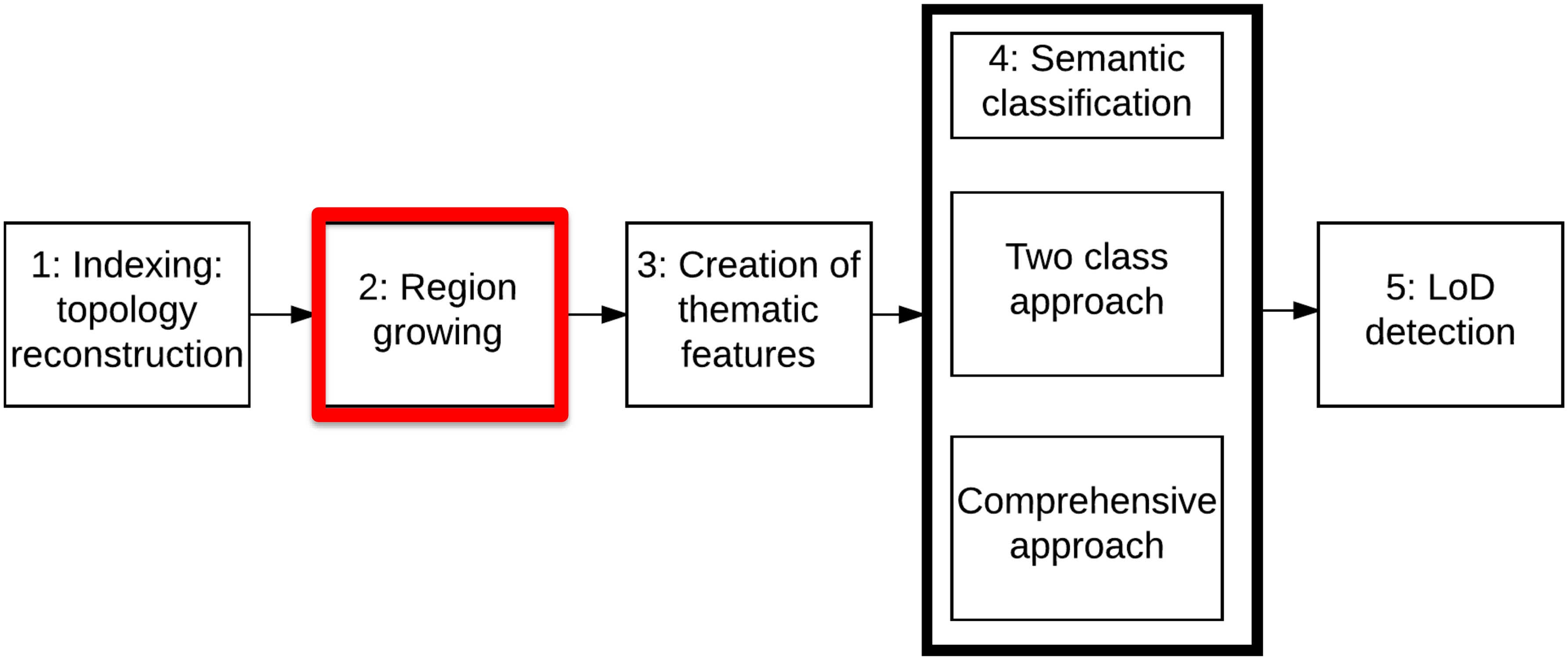
Indexing (2): KD-tree, used to reconstruct the topologic relationships

- Errors are repaired by setting a threshold and the distance to the k nearest neighbours



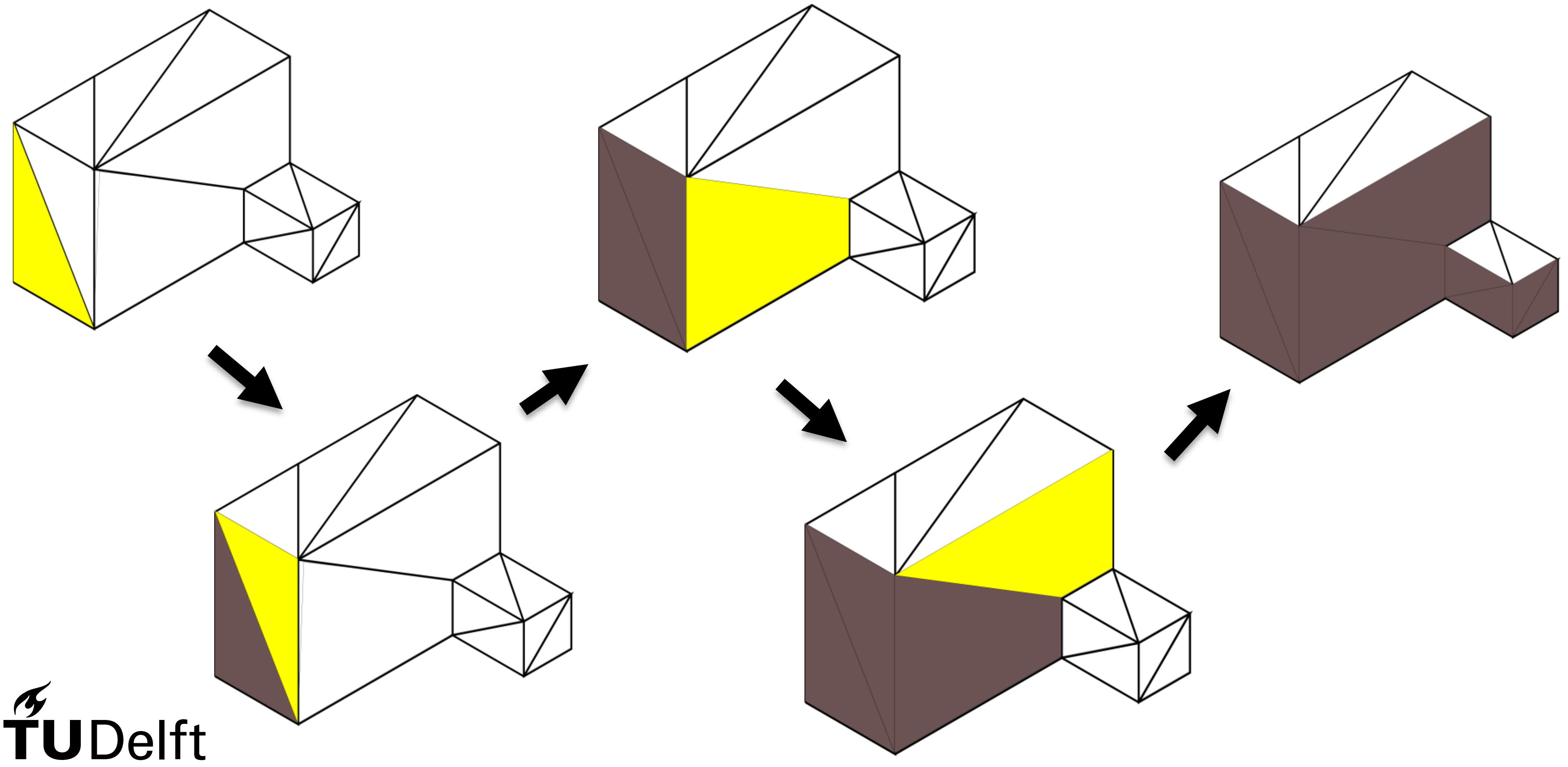


Region Growing



Region Growing(1)

- Clusters adjacent spatial features together if they have similar geometrical properties.



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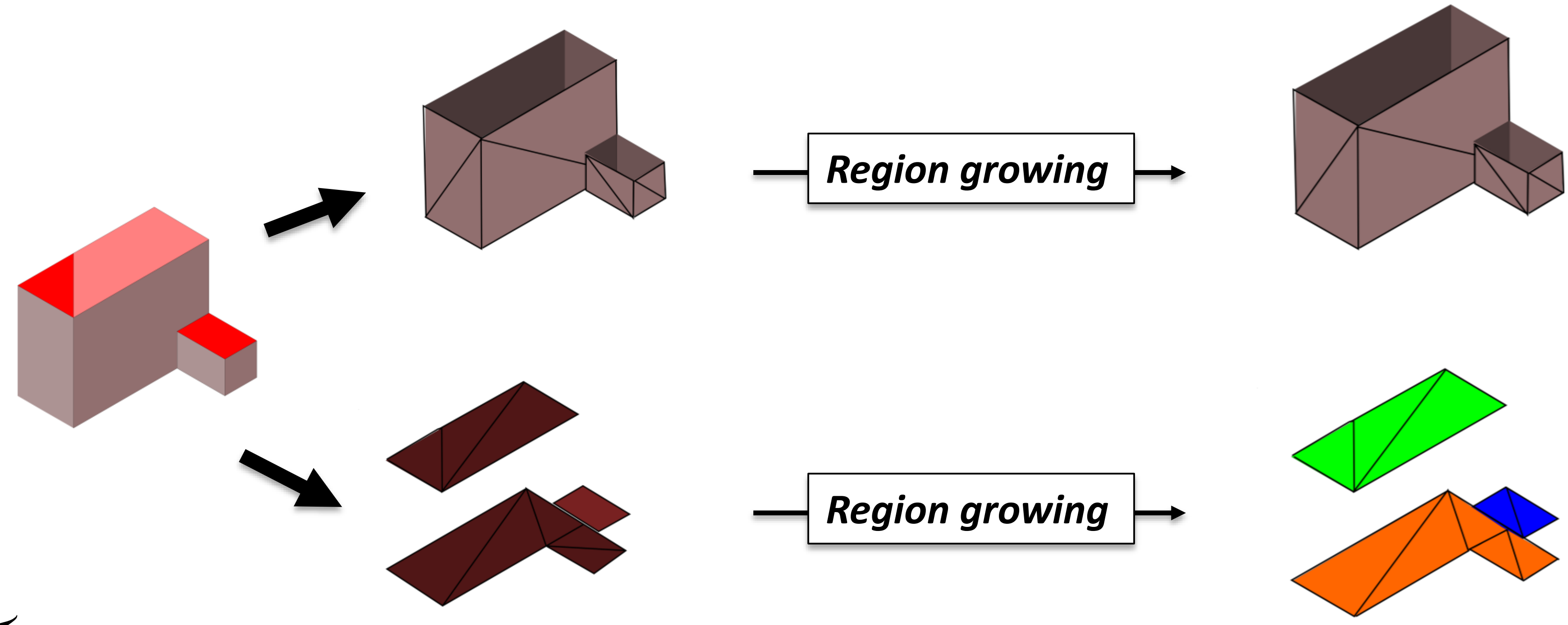
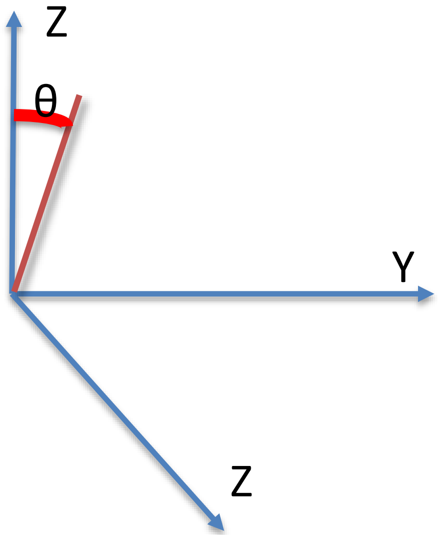
Region Growing (2); Selecting Wall and non-Wall triangles

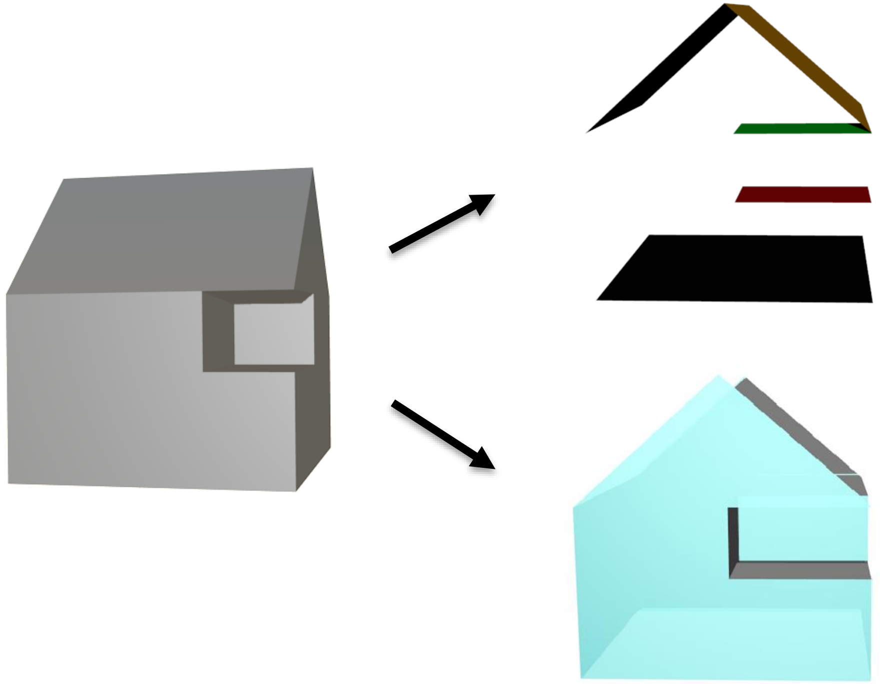
- Sets are individually processed in the region growing algorithm.



2 Sets, based on the semantic class: WallSurfaces

- Threshold to detect WallSurfaces is used in both approaches: implemented before the region growing
  - Threshold is based on the pitch angle of the triangle: defines verticality





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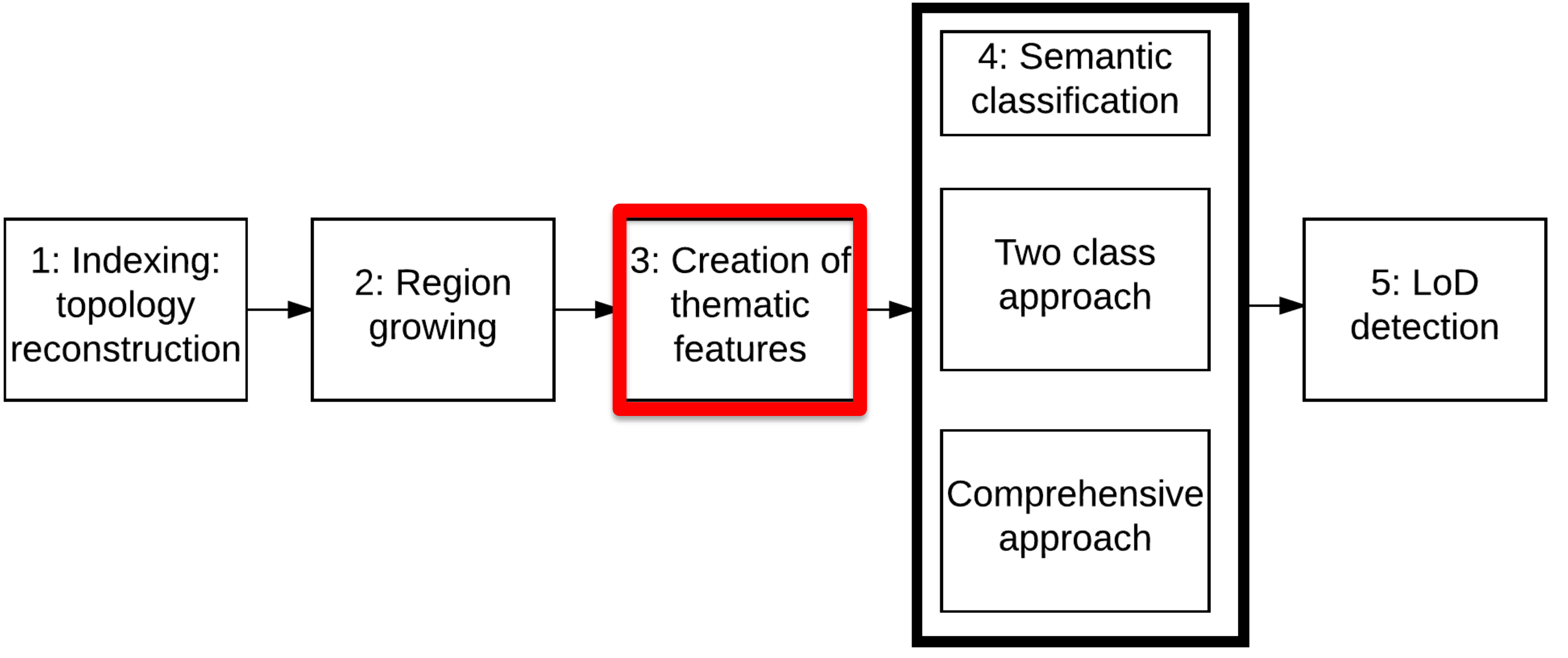
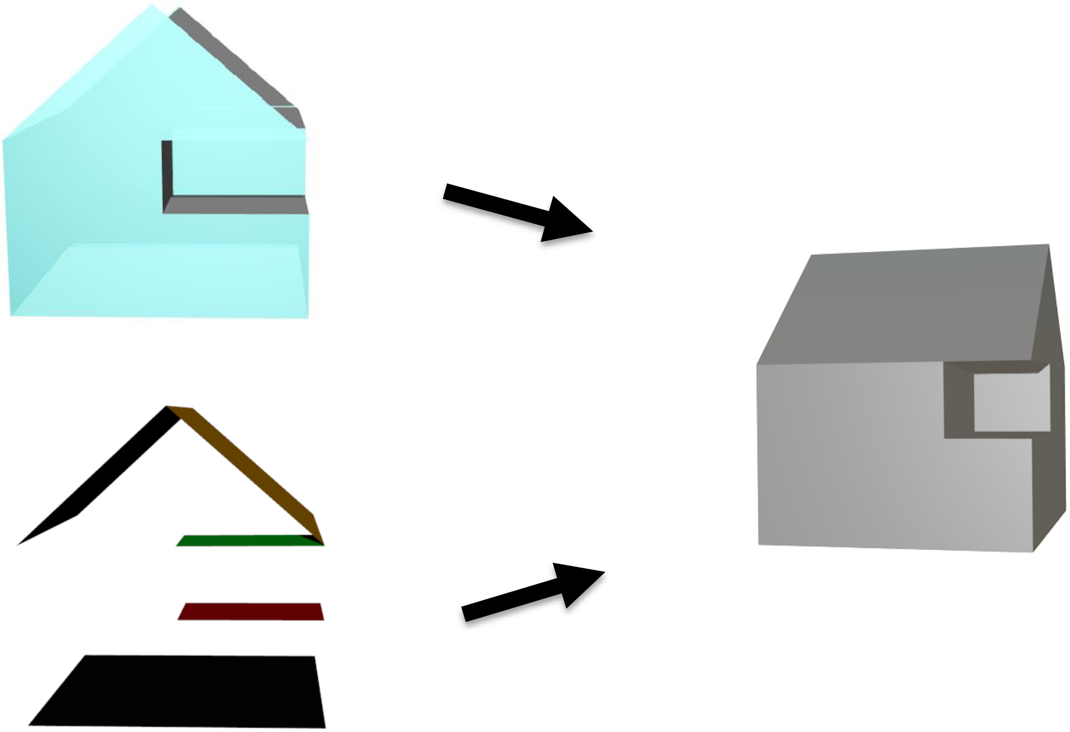
Creation of thematic features



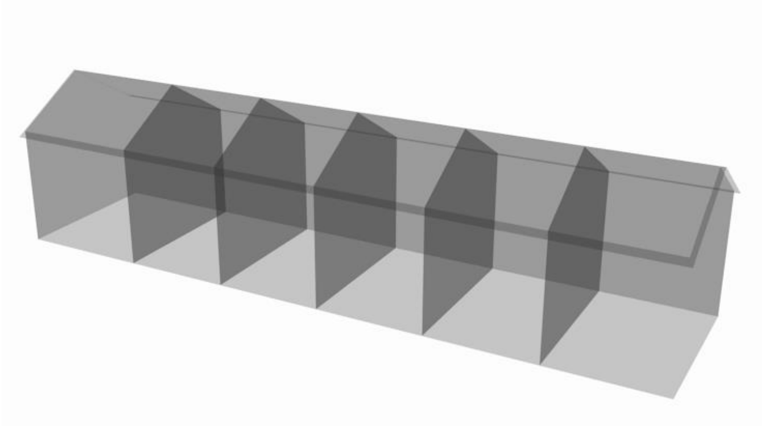
Creation of thematic features: building reconstruction

- Adjacent regions are clustered to recompose the single building entities.

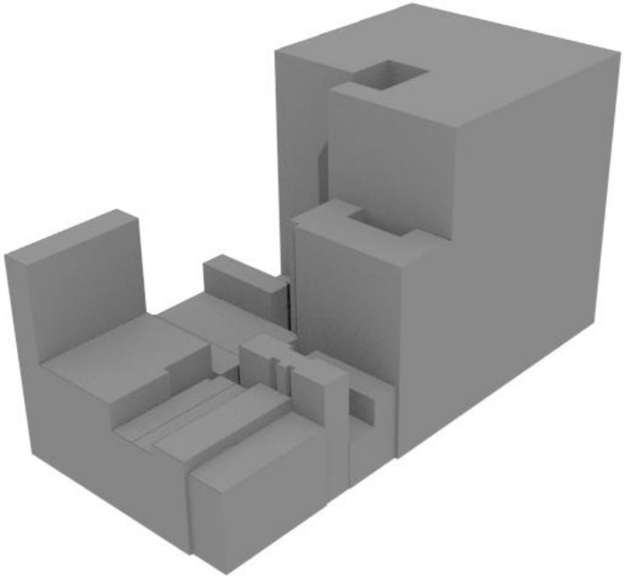


Creation of thematic features: building reconstruction (3)

- Single building consists out of a set of connected Wall and non-Wall regions.



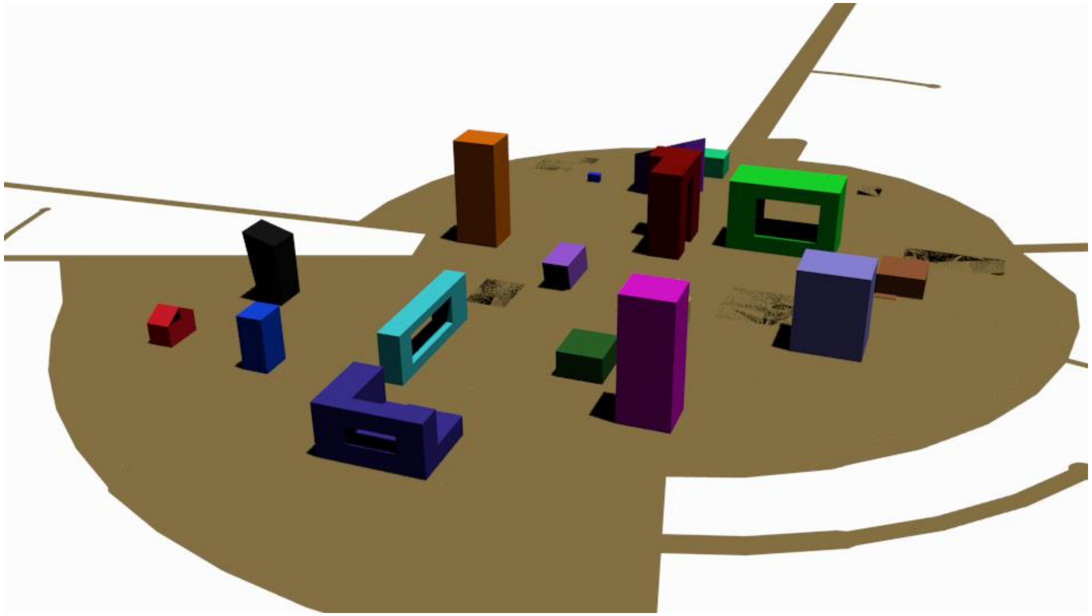
Data source: Rotterdam 3D



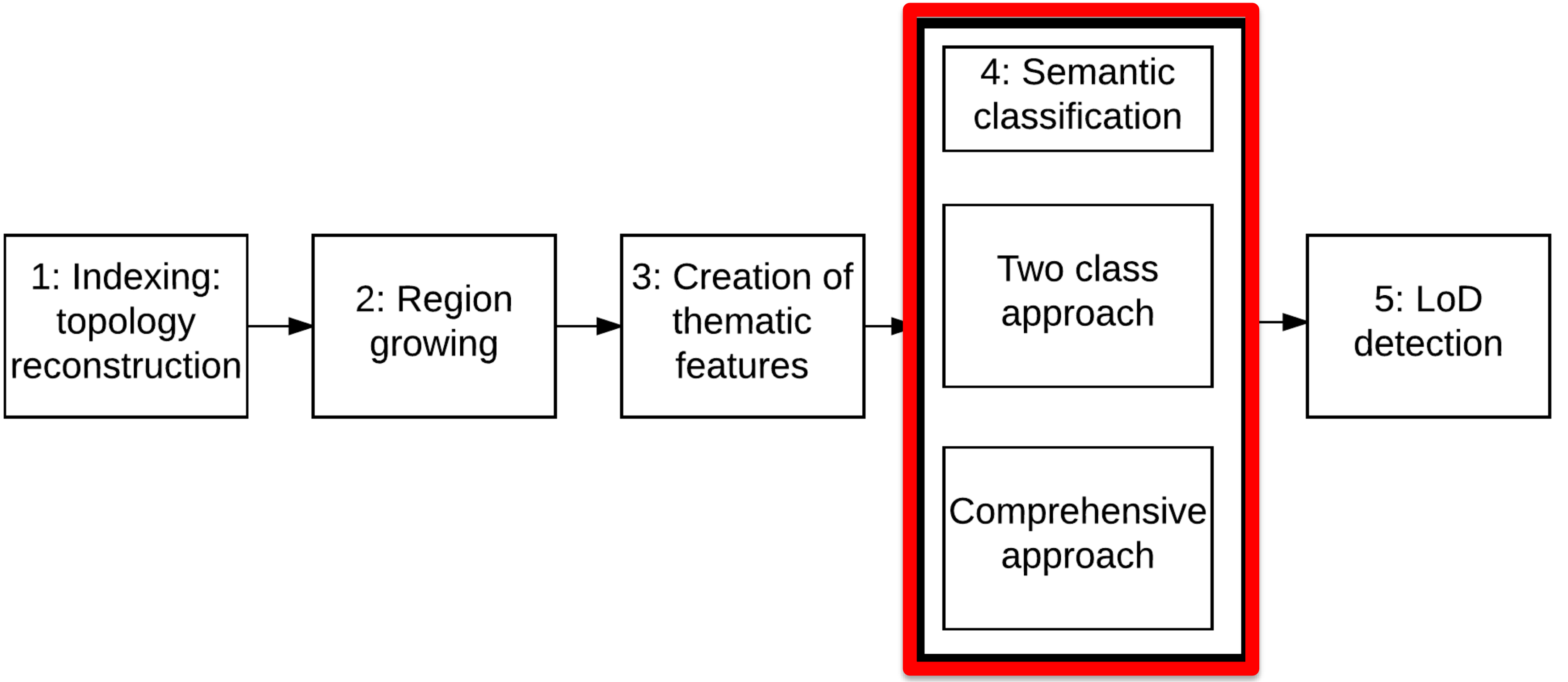
Data source: New York 3D

Creation of thematic features: the terrain

- Recognition of regions which contain terrain polygons.
  - 25% of all triangles
  - Connected to more than 4 WallSurfaces

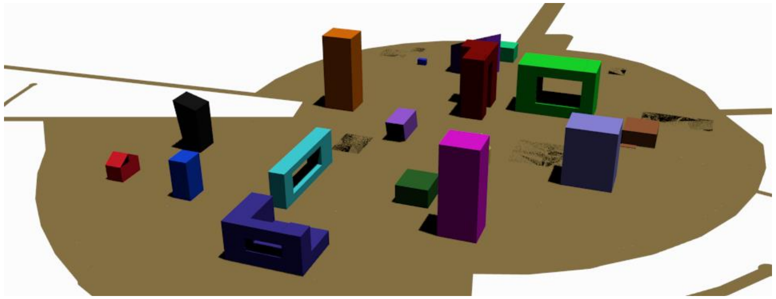


Semantic classification

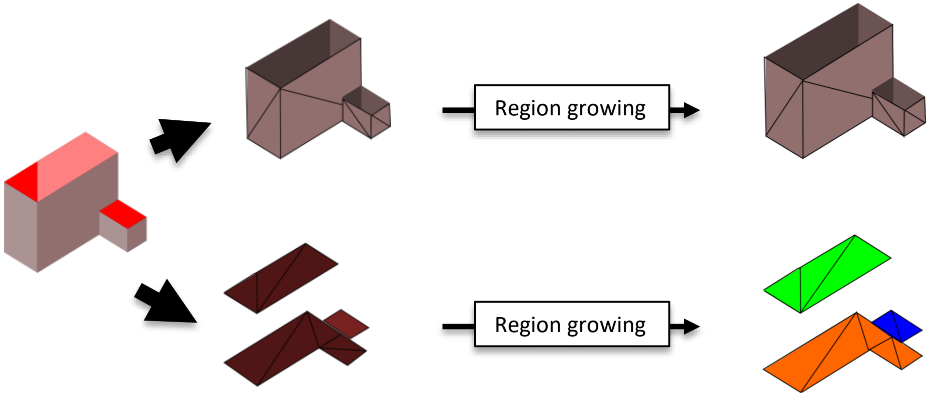


Semantic classification

- Both approaches take the reconstructed buildings from the previous step as input

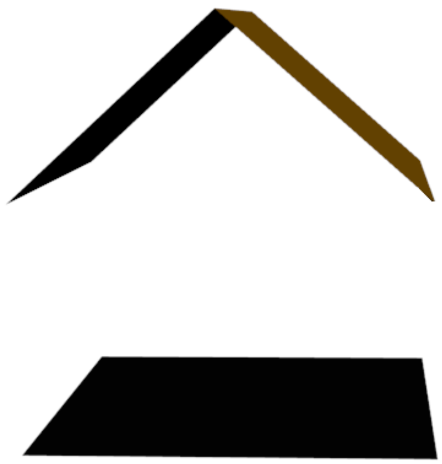


- Recognition of the WallSurfaces is used in the region growing

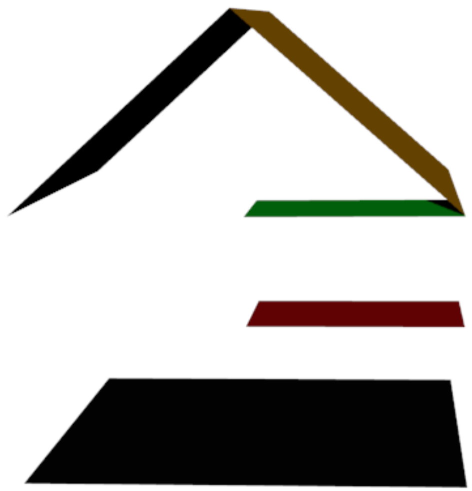


Semantic classification

- Two approaches are implemented:
  - **Two class approach:** Limited to Roof- and GroundSurface



  - **Comprehensive approach:** Additionally the classes OuterFloor- and OuterRoofSurface



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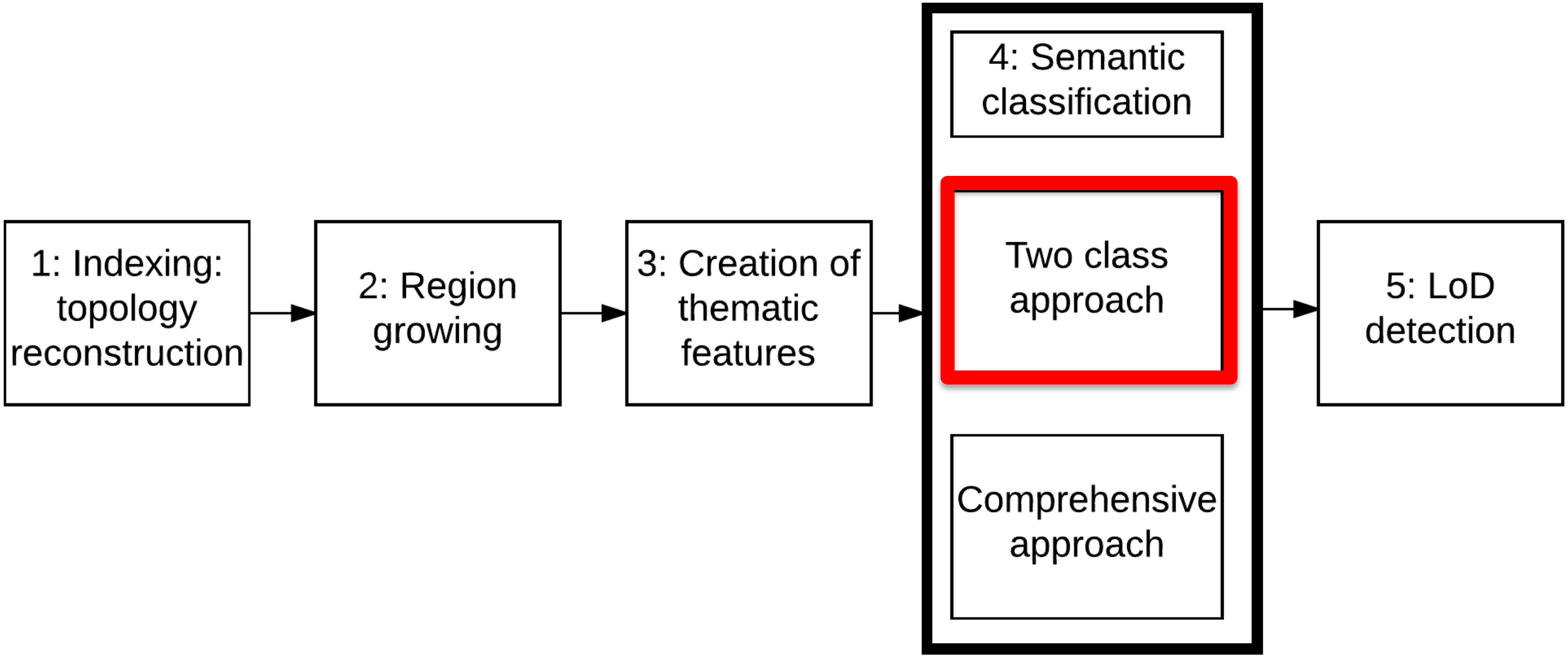
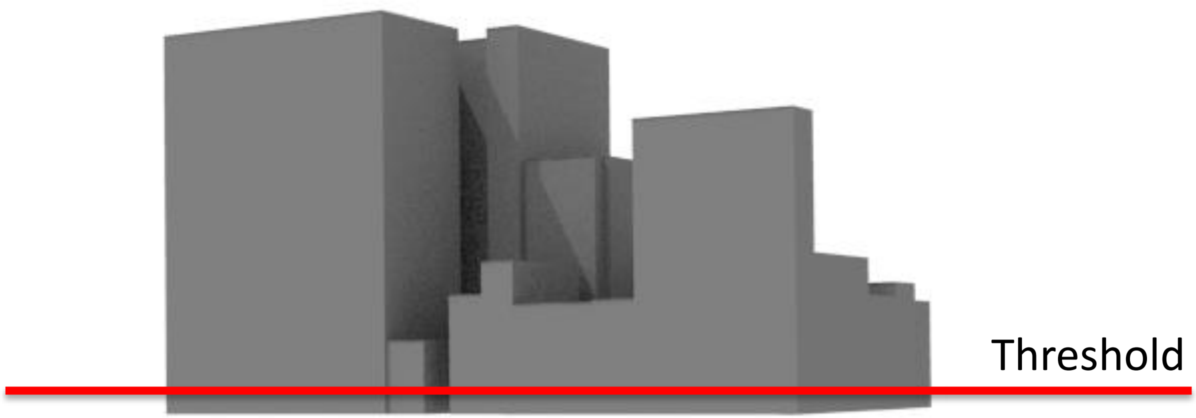
Semantic classification



Semantic classification: Two class approach

- Compute a threshold which is situated slightly above the GroundSurface.



- GroundSurface is situated below the threshold, RoofSurfaces above the threshold.

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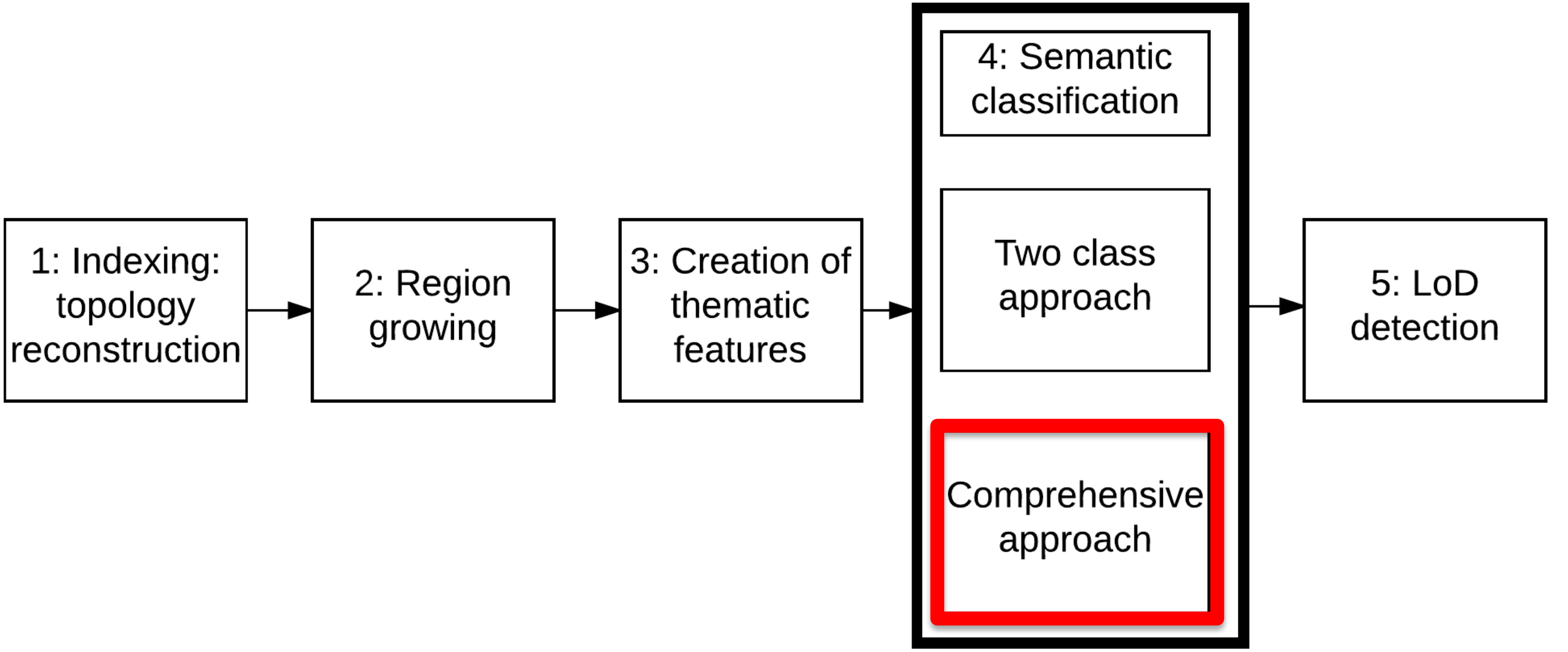
Semantic classification



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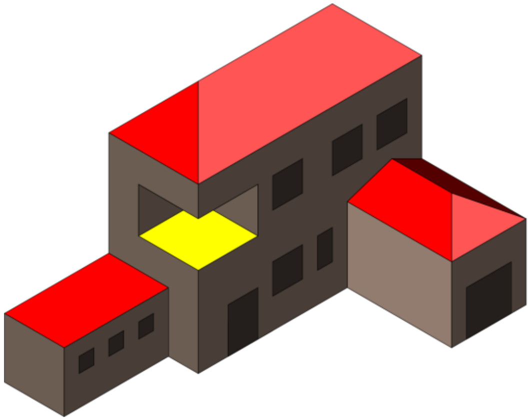
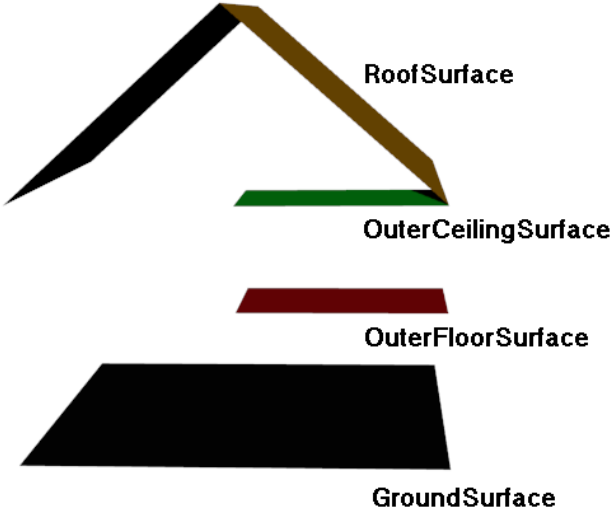
Semantic classification: Comprehensive approach

- Additional classes can not be classified based on height or surface normal





- An extension of the definitions for the semantic classes is needed

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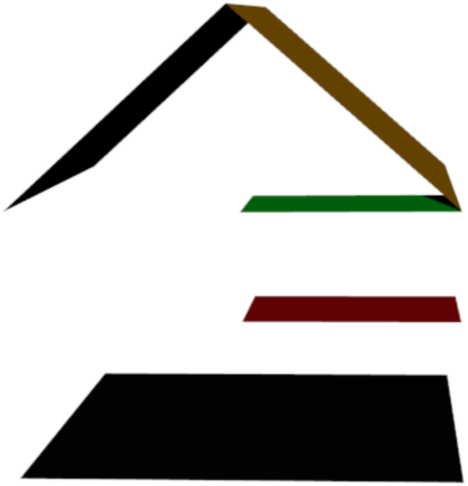
Semantic classification: Comprehensive approach (1)

- Extensions of the definitions for the semantic classes in CityGML:
  - **RoofSurface:** Encloses a building from above.
  - **GroundSurface:** The GroundSurface encloses the building from below



Semantic classification: Comprehensive approach (2)

- These definitions allow for a rule based classification, based on arguments:
  1. RoofSurfaces cannot overlap
  2. GroundSurfaces cannot overlap
  3. OuterCeilingSurface and OuterFloorSurface cannot enclose a building from below or above
  4. An OuterFloorSurface cannot be present without an OuterCeilingSurface

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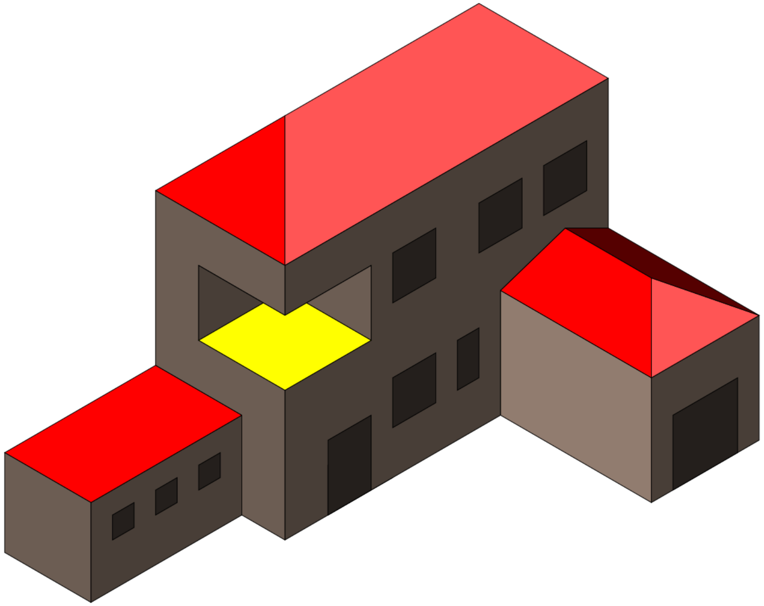
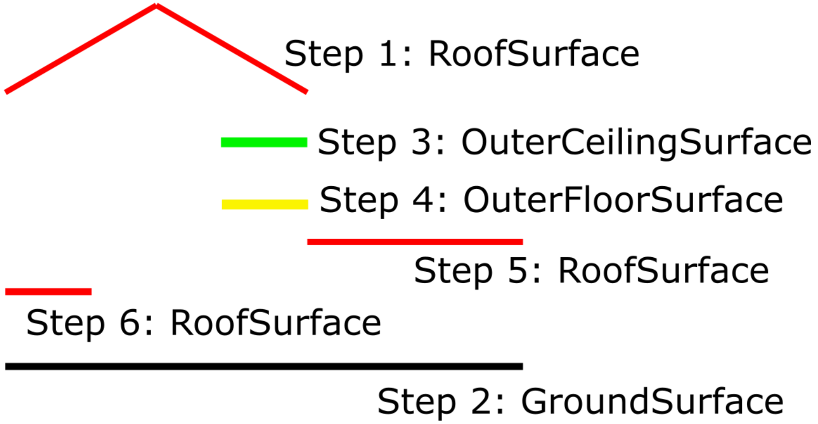
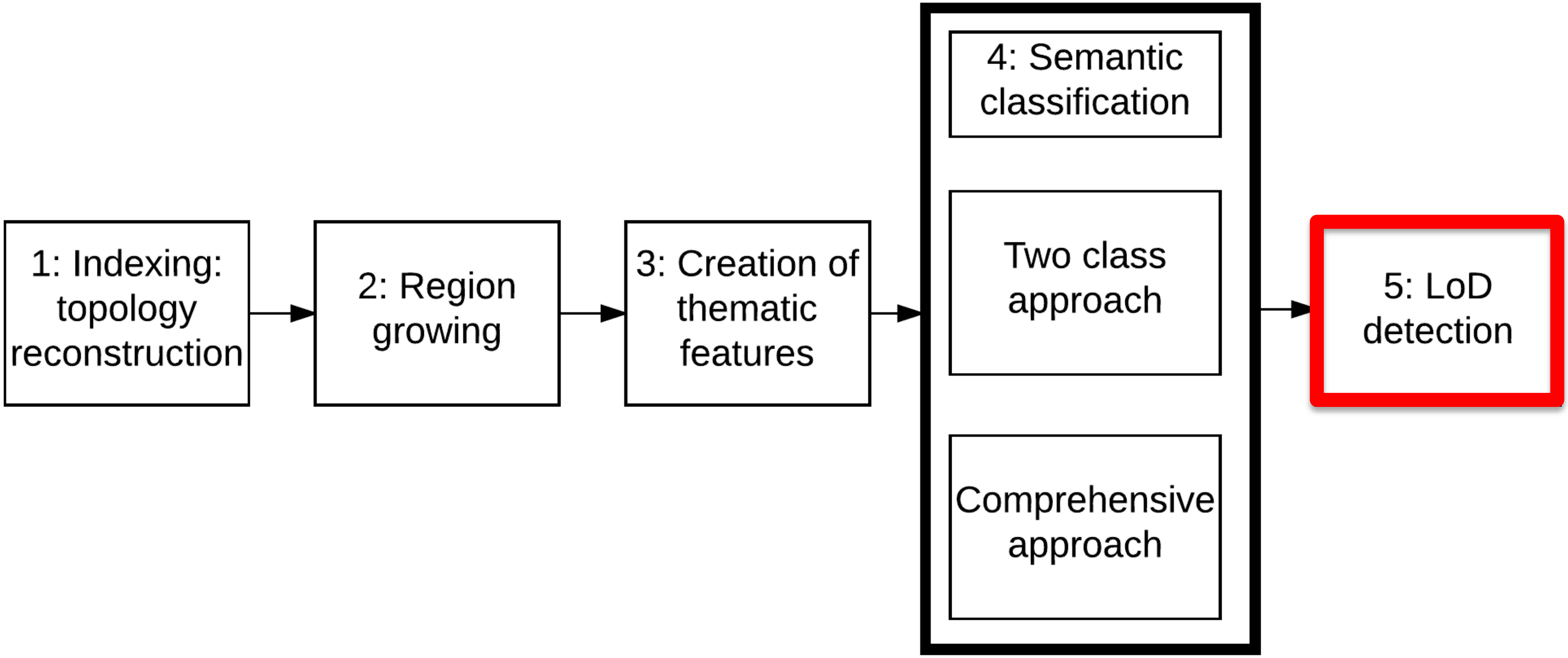
Semantic classification: Comprehensive approach (5)



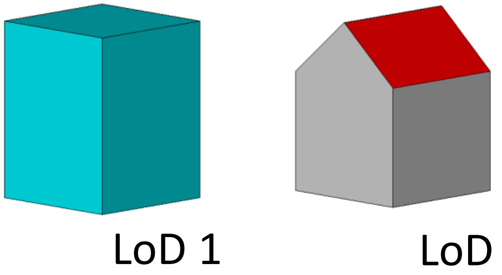


Methodology: LoD detection



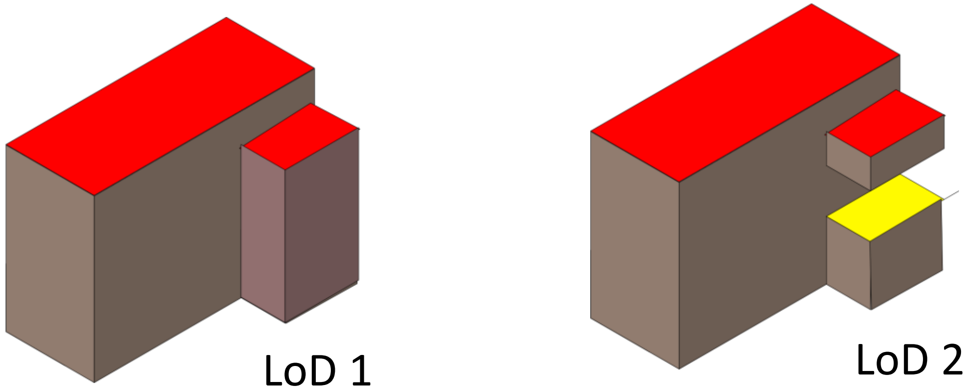
LoD detection

- Two properties are used:
  1. The slope of the RoofSurfaces



Source: Häfele, K. (2011)

  2. The presence of the semantic classes OuterCeilingSurface and OuterFloorSurface



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Results

1. LoD detection
2. Thematic classification
3. Semantic classification:
    1. Two class approach: 5 test datasets
    2. Comprehensive approach: 3 test datasets

Results: LoD detection and thematic classification

- For all models, the correct LoD is detected
- Thematic labelling:

City model	Buildings in original dataset	LoD	Reconstructed buildings
Rotterdam	1544	2	507
Montreal	384	2	191
Switzerland	3151	2	2218
Waldbruke	606	2	273
New York	Unknown	1	276
CityEngine 1	6	2	6
CityEngine 2	7	2	7

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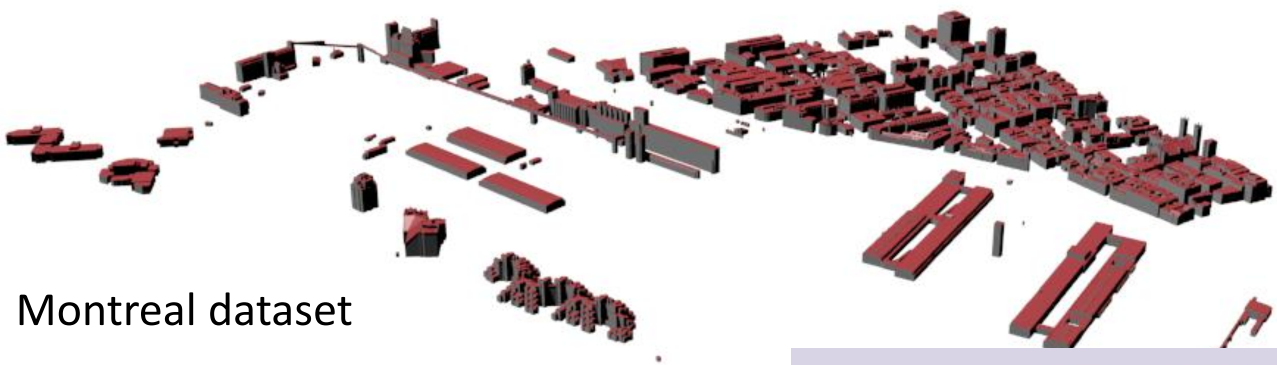
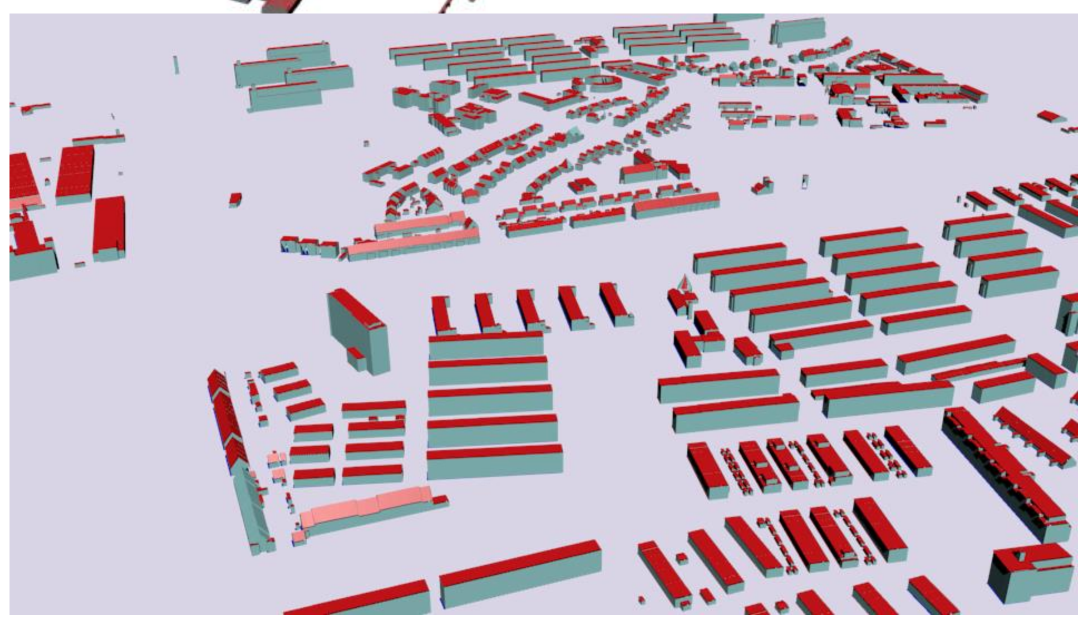
Semantic labelling, two class approach

99% accurate



Montreal dataset

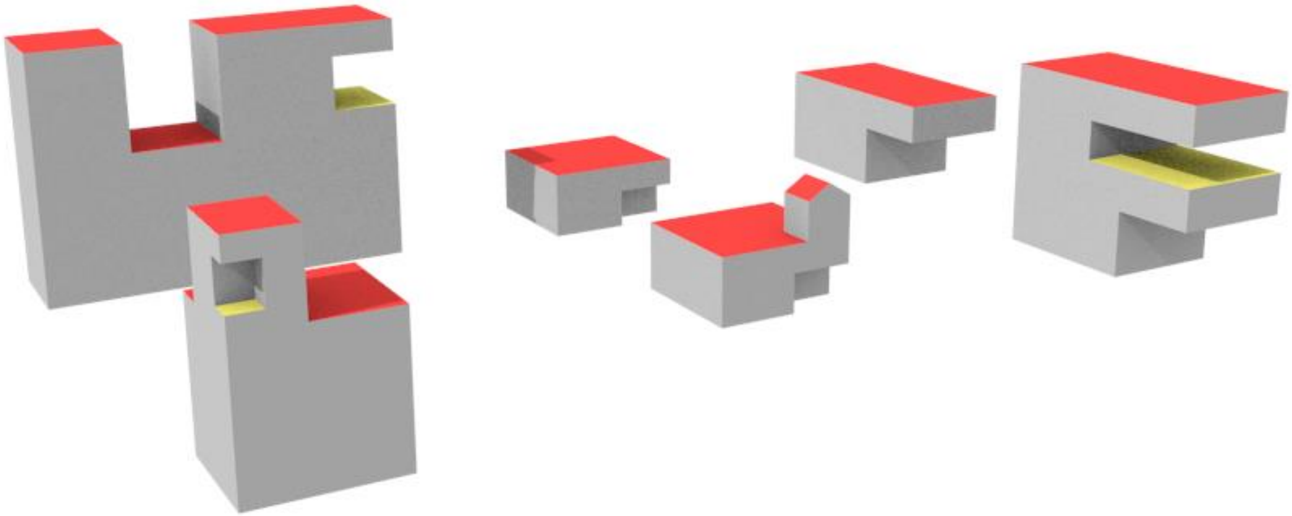
99% accurate



Rotterdam dataset

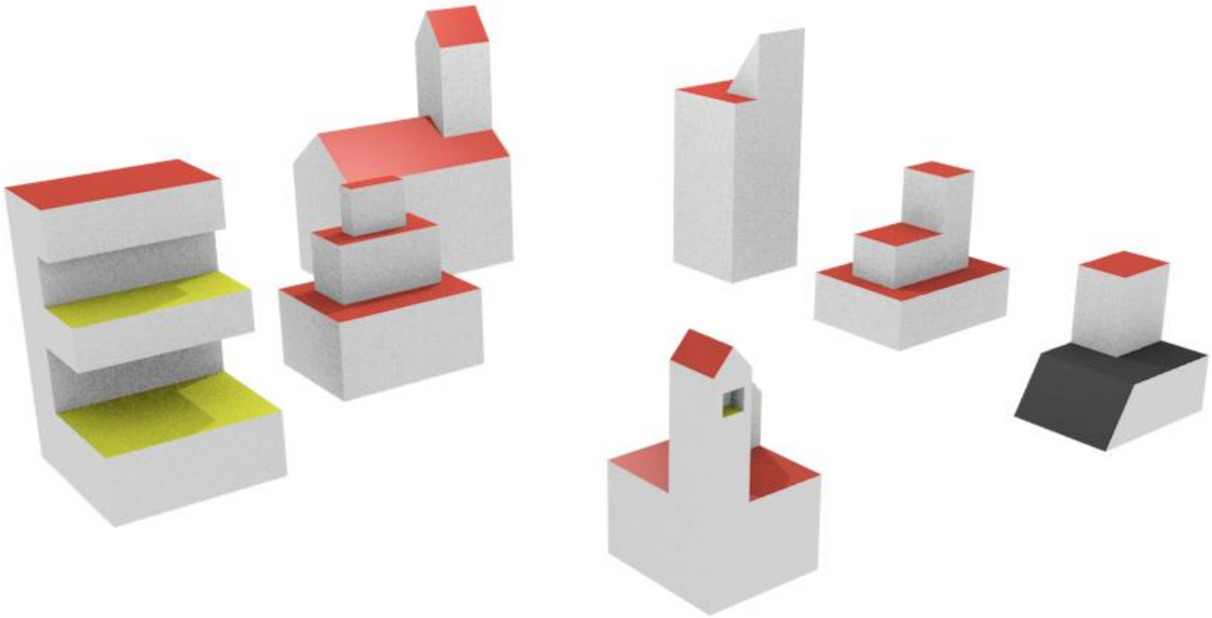
Semantic labelling, comprehensive approach

- CityEngine model 1: 100% accurate



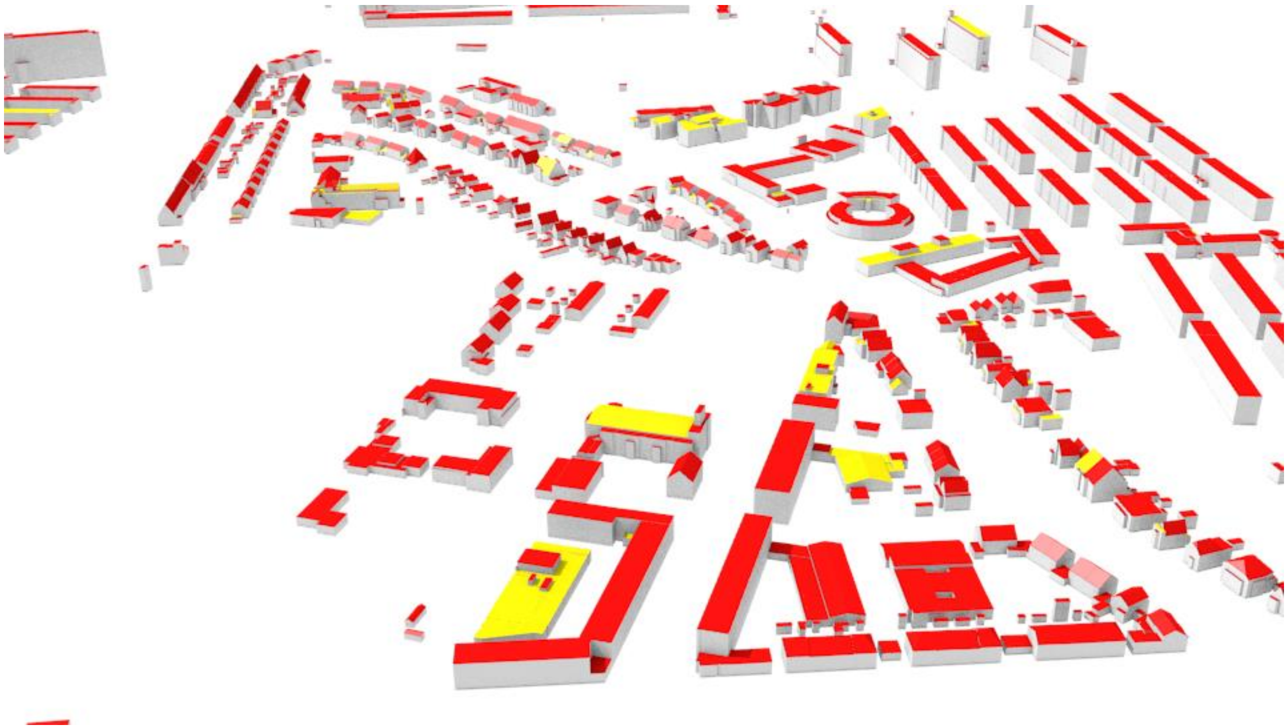
Semantic labelling, comprehensive approach

- CityEngine model 2: 97,1% accurate



Semantic labelling, comprehensive approach

- Rotterdam model: 97,1% accurate

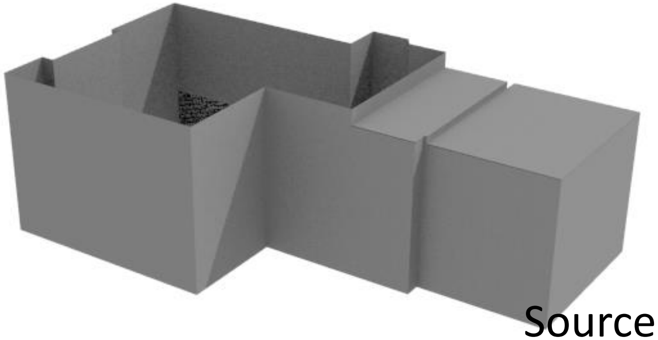


Limitations of both approaches

- Presence of other objects

Source: Ettenheim dataset

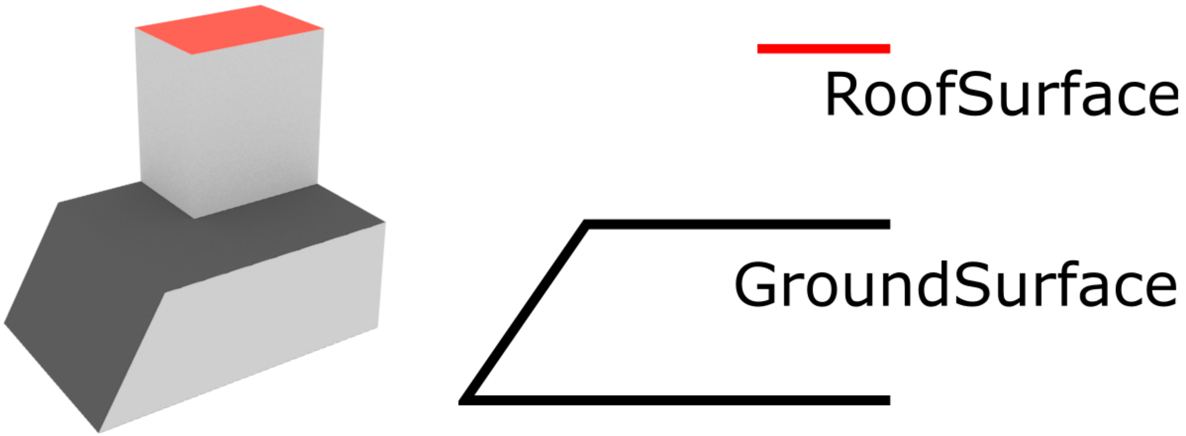
- Building reconstruction



Source: NY dataset

Limitations of both approaches (1)

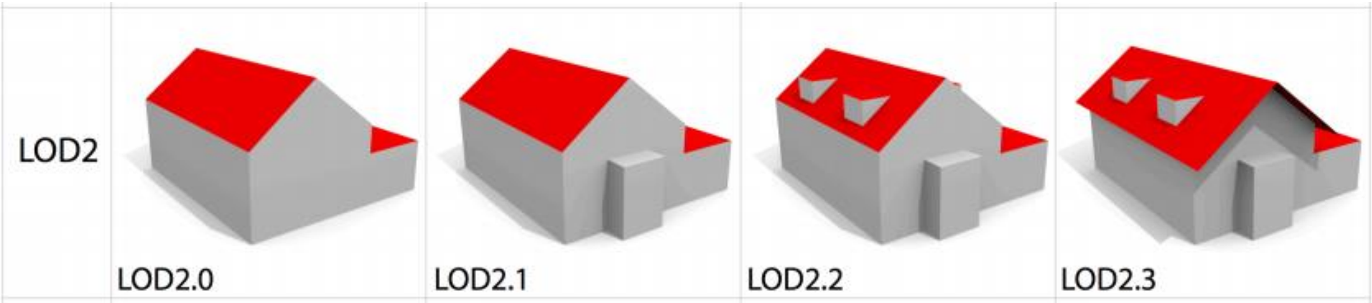
- One region can represent multiple classes



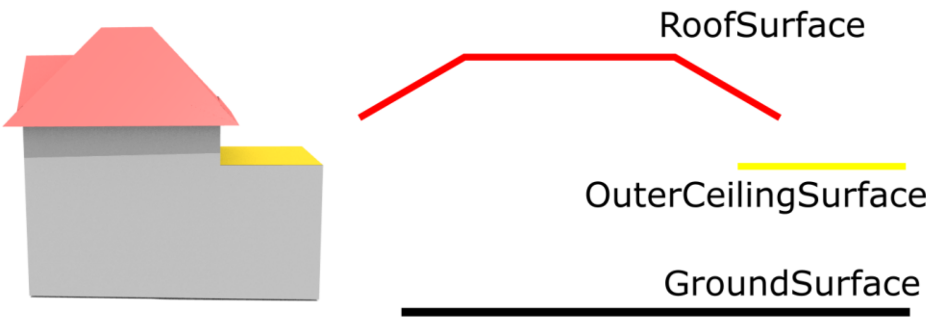
- Recognition of the terrain
  - Data dependent

Limitations of the comprehensive approach

- Float precision errors
- Methodology works on models till LoD 2.3



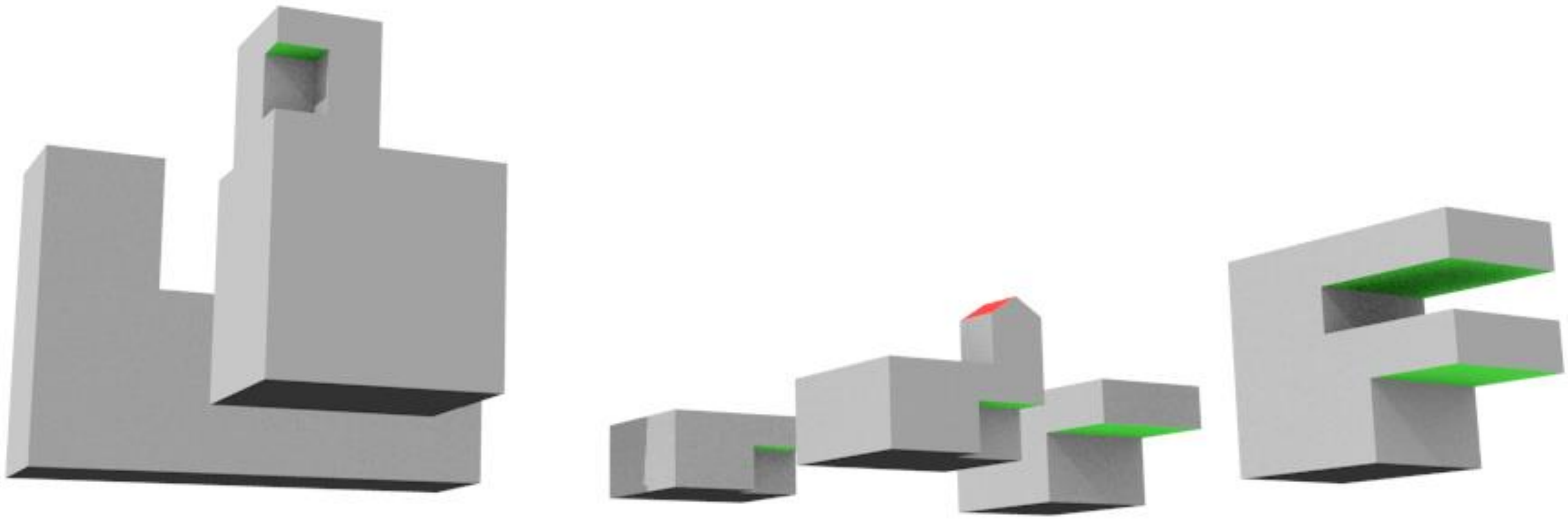
Source: Biljecki et al., 2016



Conclusions

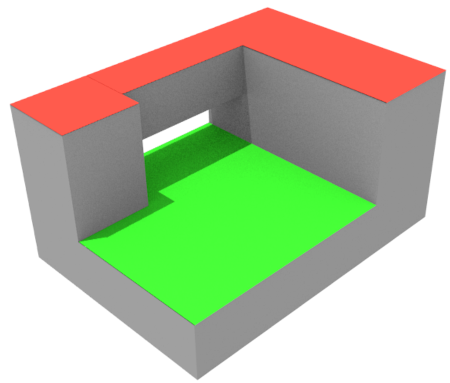
How to automatically enrich a 3D city model with thematic and semantic information as defined in CityGML, by only utilising the models geometry?

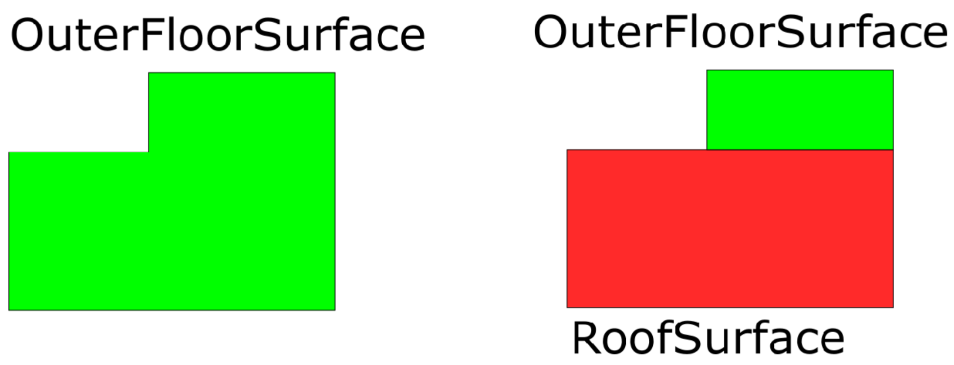
1. LoD detection
2. Semantic classes
3. Geometric properties
4. Remote sensing techniques
5. Thematic features
6. Accuracy



Limitation and future work(1)

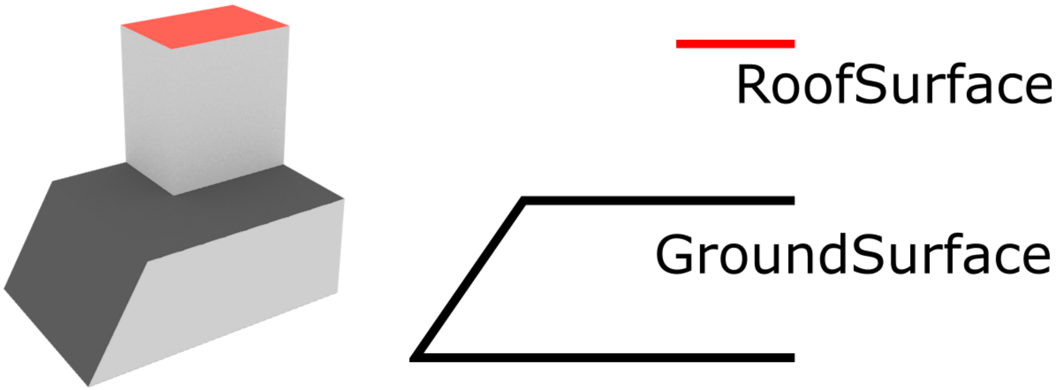
- Complete and partly overlapping surfaces





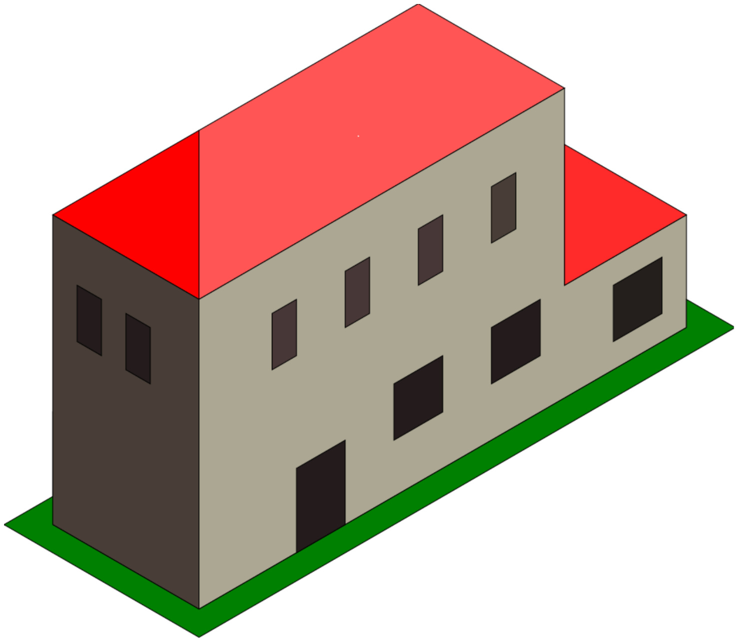
Future work(2)

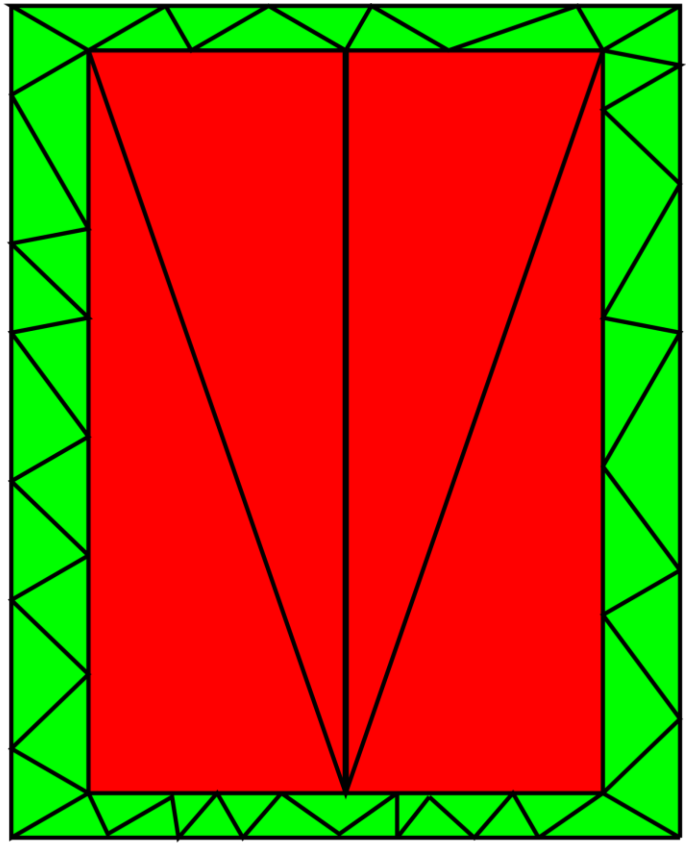
- Extend definitions of CityGML
- Improve the region growing algorithm



Source: Switzerland dataset

Seperating the terrain from the GroundSurface





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Methodology should work on all cases