Symbolisation of 3D city models for online visualisation

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1. Introduction

3D city building models can improve many applications such as urban planning, navigation, disaster management, traffic control etc., in various aspects especially in visualisation. However, compared with the data volume and complexity of 3D city models, the capability of devices and network band are still limited. To improve the visualisation efficiency, generalisation of 3D city models is required.

For 3D city models, generalisation creates models in lower Levels of Detail (LODs) from higher LODs. In CityGML standard, five LODs are defined from internal building to the overall digital elevation model (DEM) to describe the city objects. Considering the complexity of 3D city models, it is essential to generalise the models automatically.

The CityGML is suitable for representation 3D city models since it supports both geometry and semantic information, but it is not designed and optimised for visualisation. Therefore, X3D is employed for 3D city model visualisation. In X3D, we can define 3D objects and reuse them after translation to represent other object. In this paper, the 3D building models in CityGML are symbolised for more efficient visualisation with X3D.

The rest of paper is organised as follows. Related work is introduced in Section 2. Section 3 describes the proposed generalisation methods for different levels. Section 4 presents the experimental results and Section 5 concludes the whole paper.

2. Methodology

2.1 Generalisation framework

In this paper, 3D generalisation methods are employed to simplify 3D building models in different LODs. Since the LOD0 (2.5D models) can not reflect the full properties of 3D city models and LOD4 data is not as widely acquirable as others for the privacy reasons, this paper focuses on the generalisation of models in LOD1, LOD2 and LOD3. With the proposed representation structure generated for each LOD, the 3D city buildings can be continuously integrated together. Then in the visualisation stage, different models in different LODs will be selected based on the device capacity and network bandwidth. The overall structure of the proposed generalisation framework is given in Figure 1.

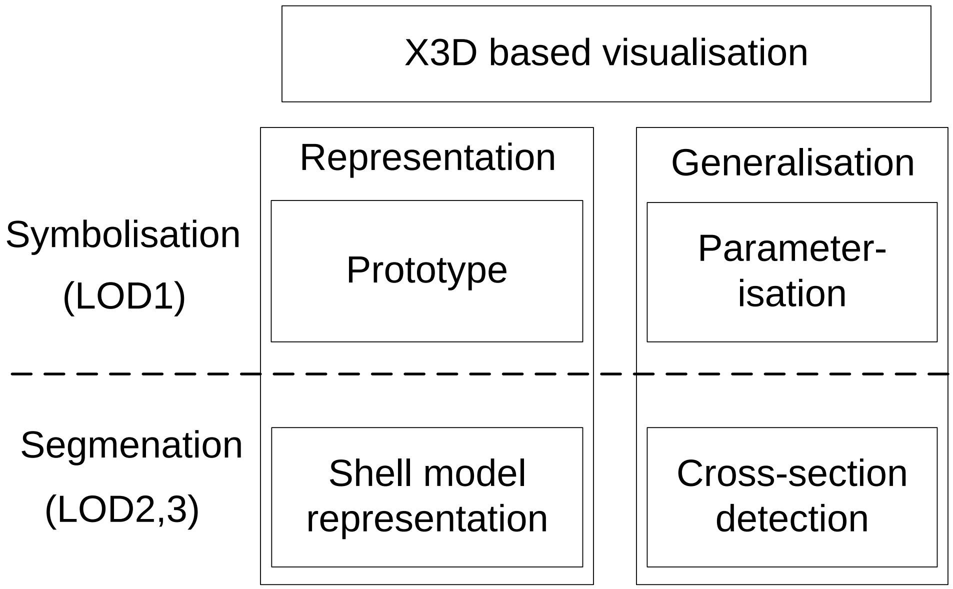


Figure 1. Generalisation framework for effective visualisation of 3D building models

First, the viewer tools for X3D is used to visualise the models in different LODs generated from CityGML files. Along with the incensement of building models, FPS will drop accordingly, which illustrates the necessity of the proposed generalisation methods.

To improve the visualisation efficiency, 3D city model generalisation methods are studied and multiple representation structures are created in each level to storing the automatically generated generalisation results for dynamic visualisation. In the facade level (LOD3), the generalisation of the texture is implemented by converting image textures into colours. In building level (LOD2 and LOD3), the exterior shell is represented by a set of key horizontal cross-sections which are generated from both walls and roofs. In the block level (LOD1 and LOD2), building or building parts are symbolized by per-defined prototypes. Since the building models are thoroughly segmented both horizontally and vertically, more buildings in the city can be represented by fewer kinds of prototypes.

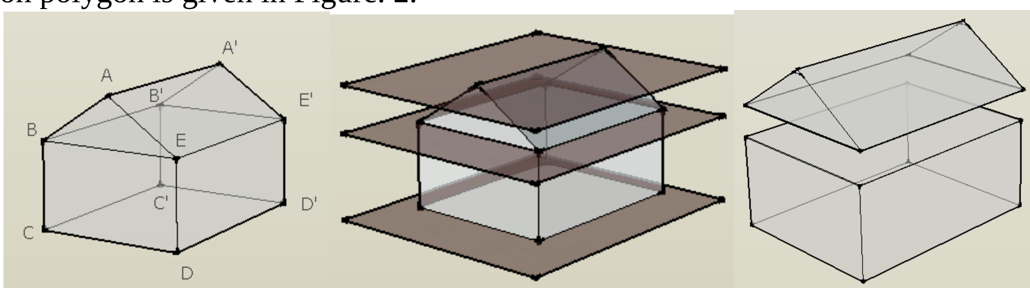
The test data of the proposed visualisation framework is in CityGML format, and come from the web site CityGML.org, the official homepage of CityGML.

3.2 Building segmentation

In many 3D city related applications such as road navigation, urban planning, etc., the indoor details are not necessary and should not be visualised for privacy considerations for most of the city buildings. The model appearances are enough for these applications. Therefore, 3D building models are first converted into the exterior shell models. By creating the exterior shell representations of the detailed 3D building models, not only the visual efficiency is increased the but also the user privacy is protected. Therefore, the shell model is an important bridge linking the models in higher LODs into lower LODs.

To extract the building exterior shell of the detailed 3D city models, Fan and Meng (2012) suggest three steps: (1) the ground plan is generated and simplified (2) roof polygons are merged and typified depending on their spatial relationships (3) building extract exterior shell is constructed by increasing ground plan in height and intersecting with roof structures. This approach is efficient for many simple structured buildings. However, this method depends on the definition of roof structure, and it can not deal with building models without such semantic information. Meanwhile, this method will fail if there are nor horizontal wall structures, since there may be no intersections according to step 3.

In this paper, the structures of building are further segmented and simplified in each floor. To generate the building floors, cross-section polygon is proposed. Similar to the transition polygon defined in Lu et al. (2011), the cross-section in this paper is the horizontal structures (polygon, line segment or point) that separate different parts of buildings. In building level, cross-section is the set of points. An example of key cross-section polygon is given in Figure. 2.

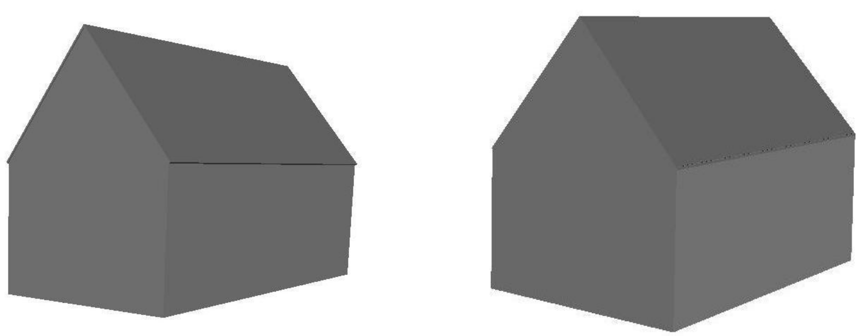


(a) (b) (c)

Figure.2 Example of cross-section polygons

3. Results

We generate the symbolised buildings from LOD3 models. Some selected representations are given in this section. In Figure. 3, a simple house with gabled roof is symbolised by one gabled and one box prototypes. In the original model, there are five surfaces containing 78 polygons or 394 points (394*3 numbers), on the contrast, the symbolised one only contains two prototypes defined by 2 translations (2*10 numbers). The data volume is reduced dramatically while the visual features are preserved according to the visualisation results.

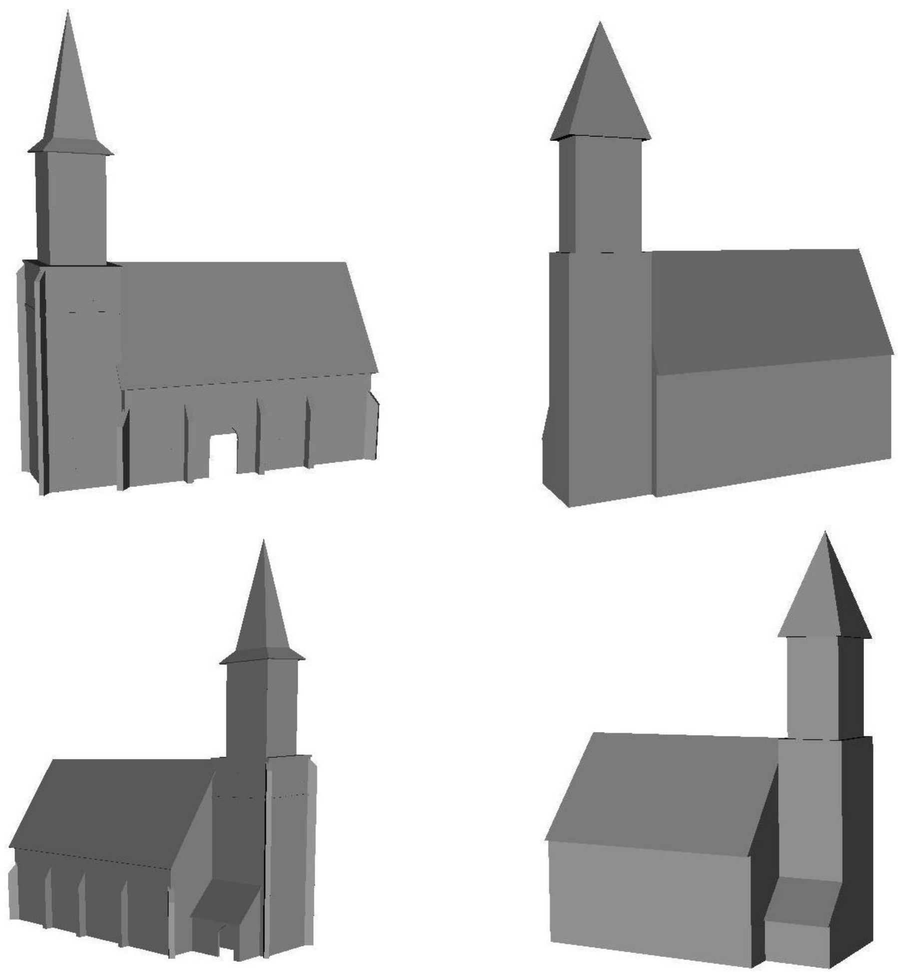


(a) Original building
5 surfaces, 78 polygons, 394 points

(b) Symbolised building
2 prototypes

Figure. 3 Simple house in LoD3 and its symbolisation

Figure. 4 gives a more complex church model which contains 35 surfaces with 743 polygons or 3805 points (3805*3 numbers). The symbolised one only contains translated 7 prototypes (7*10 numbers). The compression ratio is about 1:160.



(a) Original building
35 surfaces, 743 polygons, 3805 points

(b) Symbolised building
7 prototypes

Figure. 4 Complex building in LoD3 and its symbolisation

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4. Conclusions

This paper focuses on the visualisation and generalisation of 3D city models in multiple scales. An online visualisation framework is proposed based on CityGML and X3D to represent and present the 3D city models respectively. The experimental results indicate that the proposed framework can be implemented in the mainstream web browsers based online 3D city model visualisation without plugins. It is difficult, however, to support the detailed 3D city models with large data volume. Therefore, generalisation methods and multiple representation structures in different scales (block, building, and facade) are proposed to improve the dynamic visualisation efficiency. The results showed that the proposed generalisation methods in different levels can reduce the data volume of 3D city models and preserve the visual similarity from the original ones, which is essential for online visualisation of 3D city models.

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7. References

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