A USER PERSPECTIVE ON TYPIFICATION OF FACADE FEATURES OF 3D BUILDING MODELS

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Abstract

Using detailed geometric city model may suffer from the capacity limitation and too high computing intensity during the visualization, especially when the model should be visualized with changing resolutions or map scales. One of the solutions to alleviate these drawbacks is to generalize the building models by means of operators such as simplification, aggregation and typification. This paper is dedicated to typification of facade features. Although typification has been frequently applied in 2D map generalization, much attention was paid on how to typify the features instead of whether the typification result pleases the user's eyes. The authors present a user survey for the evaluation of different typification results under different constraints. The results showed that preserving the similarity after typification is the most important constraint for a reasonable typification process.

Introduction

Thanks to the rapid development of multisensor and multimedia technologies, virtual urban environments have become increasingly available. These environments typically consists of buildings with roof and facade features as well as trees, step structures and street furniture (Meng and Forberg, 2007). Users are able to use these models on their own terms of applications. For instance, they can combine existing models and geographic data to create new content. Many existing building models are draped with facade photos, thus render a nature-like impression of the underlying city or building (Jahnke et al., 2008). The nature-like impression of 3D buildings can also be reached by mathematically modeled facades containing facade features like windows, balconies, entrance areas etc. This latter way has advantages such as a reduced storage capacity, an enhanced network transmission of information to the user and the flexible integration of semantic information during the visualization process. So far it is possible to highlight specific buildings within a city model (Mass and Döllner, 2008) but not specific features of a building model e.g. the entrance areas or windows and balconies of flats for rent (Jahnke and Swienty, 2009). It is nearly impossible to use the inherent semantic information of photo textures in the rendering process and derive additional information for the visualization.

Using detailed geometric city model may suffer from the capacity limitation and too high computing intensity during the visualization, especially when the model should be visualized with changing resolutions or map scales. These drawbacks appear in connection with window sills or door lintels. Objects which are in close proximity with small size and details do not appear in large scales or if they are far away from the viewing plane. In small scales the user is not able to depict all objects or differentiate between them. One problem is mentioned by Swienty et al. (2008) concerning contoured buildings. Depending on the orientation and the extension of the third dimension, building contours may run into each other, making the user unable to distinguish facade features from each other. The problem will get worse on desktop visualization and small mobile displays on devices such as PDA or mobile phones. In this sense, generalization of facade texture is a necessary treatment that may cluttering effect of facade features and enhance the legibility.

The most frequently used generalization operators are simplification, aggregation and typification. They are specified for different kinds of input data. In this paper we focus on the typification of windows as facade features. Typification is one of the well-established methods for combining and replacing objects on a 2D map. To present 3D buildings in a reasonable way, in particular if they are viewed from a larger distance, 3D typification is necessary. Fan et al. (2009) presents a typification approach for facade features.

Amalgamation serves as a basis for typification. It causes the fusion of nearby polygons and is applicable for areal objects (Slocum et al., 2005). In our case, we have fused windows within a facade while applying different geometric constraints. The main constraints are: (i) preserving the area covered by windows, (ii) preserving the ratio of height and width of the windows, (iii) keeping the distribution of windows or (iv) preserving the distances between windows and between windows and the outline of the facade. To evaluate which constraints generate the most suitable typification result, a user test was conducted. A total of 21 undergraduate students from the Technische Universität München attended the survey. In the following sections we will present our apporach and the results of the user test in detail.

Generalization and 3D city models

In our approach, facades features are individually handled. These features are usually modeled as cuboids. They have to be projected on the exterior shell (Fan et al., 2009) to get a map-like basis for the generalization.

The existing map generalization operators can be applied for point, line and area features. For the purpose of grouping elements, only a subset of operators such as aggregation, amalgamation and simplification are applicable (Li et al., 2004). Typification can be added as a fourth operator. These operators can also been adopted for 3D generalization. In case of building facades which are mainly composed of windows, typification seems to be the most appropriate operator. To avoid the above mentioned drawback of overlapping contours in 3D city models every visible facade of a city building has to be typified. In our investigations, we use facades modeled in CityGMLwhich is an international OGC (Open Geospatial Consortium) standard for modeling urban objects, especially 3D buildings. An advantage of CityGML is to store geometrical as well as topological and semantic information (Kolbe, 2008). CityGML has a Level of Detail (LoD) concept which ranges from block models on LoD1 to detailed wall and roof structures including interior models in LoD4. Our work is based on facades from a LoD3 city model.

Typification of windows within a façade

To obtain a realistic impression of city buildings on small displays, similar facade objects should be typified. Typification is mentioned in many sources concerning generalization and several results of typification can be found in (Van Kreveld, 2001, Thiemann, 2002, Sester and Brenner, 2005, Li et al., 2004).
In traditional 2D mapmaking practice, typification operator is applied on “buildings with a typical distribution pattern, e.g. to represent groups of buildings aligned in rows (e.g. five rows) using fewer (e.g. three) rows” (Li et al. (2004) p.516). More generally, typification describes the process of replacing a large number of objects by a smaller number of uniformly shaped objects. In this sense, it is related to some other generalization operators like aggregation, simplification and amalgamation which group “individual areal features into a larger element” (Slocum et al. (2005) p.111). Having a look at the facades in Figure 1 both facades a and b reveal a clear structure with a typical distribution pattern. After eliminating the cuboid structure of the facade as described in Fan et al. (2009) the resulted “flat” facade bears a striking resemblance with a map. Therefore, we can directly apply typification operator on it.

Figure 1. Facades (a and b) which seems appropriate for a good typification.

Cognitive aspects for typification

Typification approaches so far have been predominantly driven by technology. Whether the results of typification are reasonable or not is less discussed (Fan et al., 2009). Features within a flat facade or on a ‘real’ map are visually grouped according to

‘Gestalt law of grouping’ (Wertheimer, 1925). One of the first attempts to apply the Gestalt law to the domain of GI Science is reported in Weibel (1996). He used the involved principles for the recognition of spatially distributed patterns. Based on Gestalt theory different thresholds for object separation and size can be empirically determined. (Li et al., 2004, Hake et al., 2002) suggest that two objects should generally have a minimum distance of 0.5mm in the visualization and the size of an object should be at least 0.4 x 0.6mm^2. Depending on special usage situations such as mobile environment, these thresholds may need some adaptation. Typification will be triggered when the object sizes or distances between objects in a flat facade are below the required thresholds. The principles of proximity, similarity, continuity and symmetry (Palmer, 1992, Palmer et al., 1996) are important for the identification of spatial pattern recognition. Neighboring elements tend to compose entities as well as similar and symmetric objects (Anderson, 1989, Sternberg, 2003). Keeping in mind these principles, we would assume that the windows in Figure 1 after rectification have different tendency directions which can be visually judged from different distances between the windows in vertical and horizontal direction. In order to keep the similarity between the typified facade and the original facade, the following constraints have to be satisfied:

- preserving the area covered by windows,
- preserving the ratio of height and width of the windows,
- keeping the distribution of windows similar,
- preserving the distances between windows and between windows and the outline of the facade.

By combining the above mentioned constraints we have identified different options for typification as summarized in Table 1. These options form the basis for the user test and are applied to three different facades extracted from the pictures in Figure 2.

Table 1. Options for typification based on the above mentioned constraints

Non Area-conform		
	The distances between windows and outline of the facade, as well as the topology among windows are preserved, however not area conform	**A**
Area-conform		
	The distances between windows and outline of the facade is preserved, but not among the windows.	**B**
	The distances between windows are preserved, as well as between windows and outline of the facade.	**C**
	The distances between windows are preserved, but not between windows and the outline of the facade.	**D**

Shape-conform		
	The distribution of windows is kept	**E**
	The distances between windows and the outline of the facade are preserved but not among windows	**F**
	The distances between windows are preserved, but not between windows and the outline of the facade.	**G**
Merging		
	In tendency direction, the distribution of windows is kept	**H**
	In tendency direction, the distances between windows and the outline of the facade is preserved.	**I**
	In tendency direction, the distances among windows is preserved, but not between windows and the outline of the facade.	**J**
	Only in tendency direction (horizontal = $\mathbf{k}_1$ or vertical = $\mathbf{k}_2$)	**K**
Automatic approach	Typification according to an automatic approach (Sester and Brenner, 2005)	**L**

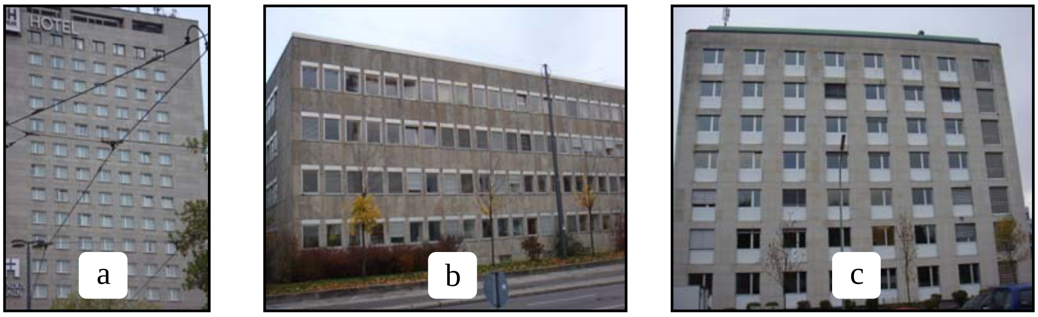

Figure 2. Pictures of facades for conducting the survey

Different kinds of typified facades

To conduct the survey we have photographed three different facades from our test site in Munich (Figure 2). All three facades have different tendency directions or they have no directions which tend to stay in the foreground. Facade (a) in Figure 2 has no tendency direction. The distances between windows in horizontal and vertical direction are almost equal. Facade (b) in Figure 2 has the tendency in horizontal direction however the distances between windows in horizontal direction are smaller than that in vertical direction. Facade (c) in Figure 2 has its tendency in vertical direction. The distances between windows in vertical direction are smaller than that in horizontal direction.

All three facades have a regular distribution pattern of their features arranged in a matrix. To prepare the test we extracted a vector-based representation in CityGML from the rectified facades as shown in Figure 3 and conducted the typification on it. Figure 4 shows alternative results after typification.

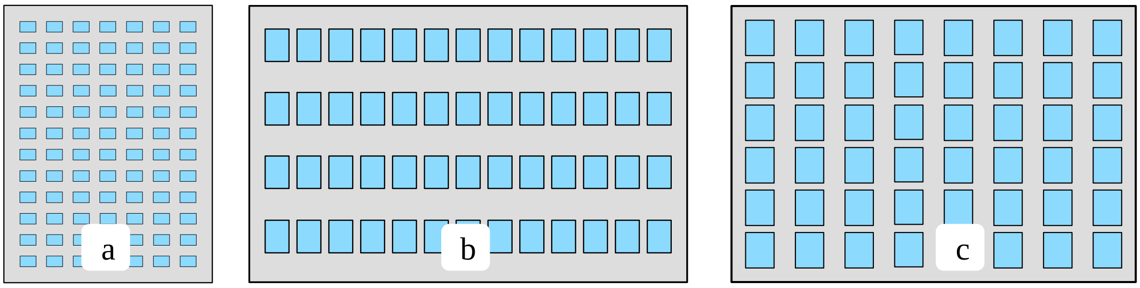

Figure 3. Extracted façade feaures from rectified photos in Figure 2 (a) no tendency direction, (b) horizontal tendency direction, (c) vertical tendency direction

User test

To conduct the user test we build up seven visualizations with appropriate questions which the participants had to answer. These visualizations are visually coded and the participants did not know which constraints were used during the typification. Figure 4. illustrate three alternative typification results to a given facade. The phrase for every question was "Please rank the given images in the order in which they will resemble the original image". The participants had to rank the facades in the order (from best to worst) of which typification is best associated to the original extracted facade and which is their second and third choice. Question one had two possibilities for ranking (1 = best, 2 = middle). The questions two to four contained three possibilities of typified facades. Therefore the participants have to rank the typification from 1 (best) to 3 (worst). For questions five to seven they had two possibilities for ranking (1 = best, 2 = middle).

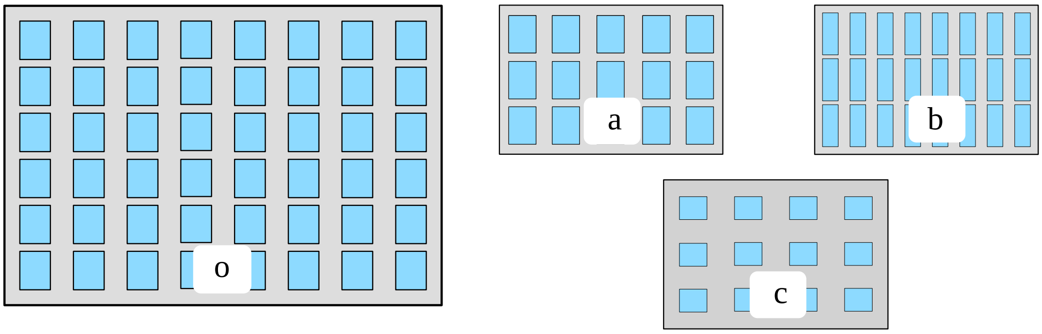

Figure 4. (o) the extracted vector graphic of an original facade, (a) shape-conform - the distribution of windows is preserved, (b) merging in tendency direction - the

topological distribution of windows is preserved, (c) typification achieved by an automatic approach (Sester and Brenner, 2005)

In every question a different topic stands in the foreground which was derived from different options from Table 1.

The topic of every question is listed below:

- Q1: Testing the typification in tendency direction (two possible answers).
- Q2: Testing the area conform typification.
- Q3: Like Q2 but different types of typification.
- Q4: Testing the shape conform typification.
- Q5: Like Q4 but different types of typification.
- Q6: Like Q4 but different types of typification.
- Q7: Comparing the automatic approach with other types of typification.

The participants had 15 seconds to look at the extracted windows and its two or three kinds of typification. Then they had to make their decision. The participation group consisted of 9 female and 12 male undergraduate students from the Technische Universität München with an age ranging from 19 to 26 years.

Results

The results of our user test are summarized in Table 2 for each facade. As an example for facade c from Figure 3 the results for question 2 can be found in the row indicated with 2 in the first column of Table 2. Every row is associated to one question (1 to 7). The columns indicated with O_1 to O_3 correspond with the options a to c from Figure 4. The black fields indicate that there were only two answering options, e.g. the 2nd question was ranked by 13 participants as best, by 4 participants as middle and by 4 participants as worst. The different options refer to the above mentioned list.

Table 2. Ranking results of the user test for one with the option O_1 to O_3 as referred in Table 1.

Question	O_1			O_2			O_3		
	best	middle	worst	best	middle	worst	best	middle	worst
1	1	20		20	1				
2	13	4	4	3	4	14	6	13	2
3	4	11	5	14	3	3	3	8	9
4	18	2	1	1	9	11	2	12	7
5	19	2		2	19				
6	12	9		9	12				
7	17	4		4	17				

To make these results more comparable and understandable for every option from Table 2 a weighted value was calculated. Subsequently we got average values for all three facades. The results are shown in Table 3.

Table 3. Average values for the options of different questions

Question/Option	O_1	O_2	O_3
1	7.2	10.3	--
2	8.7	6.5	6.1
3	6.7	8.5	5.5
4	9.8	5.7	4.9
5	9.7	6.8	--
6	8.5	7.5	--
7	8.2	7.9	--

The results in Table 3 reflect the degree of importance for the five constraints during the typification. The options are ranging from 10 = most important option to 4 = less important option.

Table 4: Results of the user test for typification in decreasing order of importance

	Value	**Summarization**
most important	10.0	keeping the shape conform
	7.0	keeping the distances between the windows and the outline among the windows
	5.3	keeping the distances between windows and the outline of the façade
	4.7	preserve distances among windows
less important	4.6	typification of windows only in tendency direction

Table 4 shows a decreasing order among the resulting values of each option from most important to less important. Obviously, keeping the similar shape of the facade features is most important. These results can be intuitively expressed by means of a graphic. As shown in Figure 5, a five-sided polygon clearly reveals the relative importance of the five constraints to be satisfied in the typification, whereby, every vertex of the polygon represents one option. The total length between the middle point and a vertex is corresponds to a value of 10. After projecting the values in Table 4 onto the five-sided polygon, we got the graphic in Figure 5.

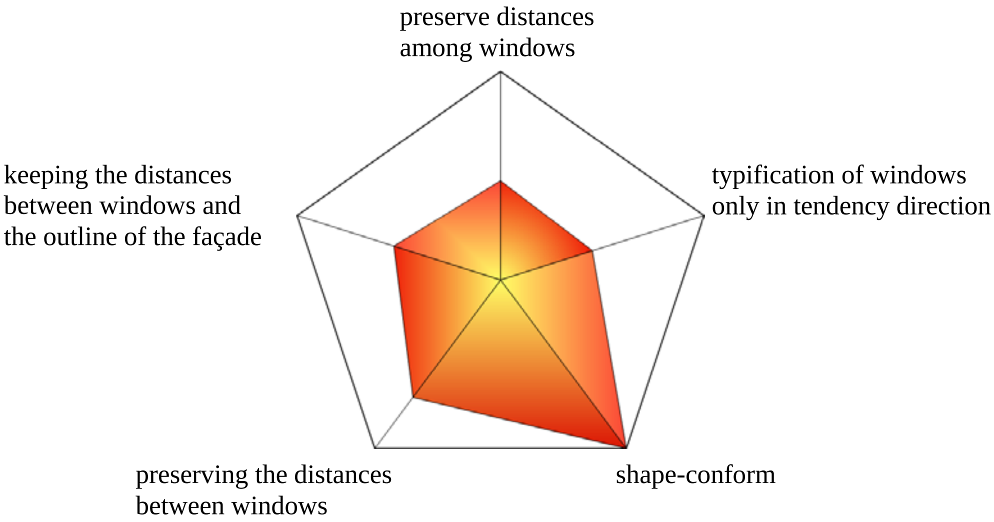

Figure 5. Graphical expression for importance of options for typification

The results of our survey reveal that the participants have certain preference among different options. This preference is a reflex of the human's visual system which is most sensible for recognizing particular patterns (Sternberg, 2003, Anderson, 1989). The visualization process can be enhanced by utilizing this kind of feedback from the user test.

Conclusion

The paper introduces the adaption of the well-established typification operator to facade objects. Based on the analysis of many generalization operators applicable to area objects, we focus on typification and its various alternatives for the treatment of "flat" facade features. A set of typification options in line with different constraints are applied to three different facades. According to the results of a user test, "preserving the shape conform" and "preserving the distribution of window features" are most important for a representation of the facade within the visualization process.

In the next step, our user test will be extended to a 3D environment. To this end, new options for typification along with new constraints need to be implemented in a 3D visualization. A further aspect of future work will be the cognition based study of facade patterns in addition to facade features.

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