

# Typification of Facade Elements for Virtual Three-Dimensional City Models

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**Abstract.** The visualization of virtual three dimensional city models is an evolving area. Having detailed city models is on the one hand a big advantage one the other hand visualizing these highly detailed models on small mobile displays brings a few drawbacks. In particular the information density becomes too dense. Therefore the city models have to be generalized this can be a model generalization and cartographic generalization. From the cartographic point of view the typification operator seems to feature good results when reducing the number of regular distributed elements. With this reduction the arrangements of facade elements becomes important. In this paper we investigate the distribution pattern for facade elements with a user survey.

**Keywords:** 3d City Models, Generalization, Typification, Visualization

## 1. Introduction

The visualization of virtual three-dimensional environments is an evolving area in cartography. City models ranges from block models to very detailed architectural models. Therefore the question of interest is how visualizations should look like in general or in particular context? To answer this question the target user or the target user group and the circumstances under which the visualization should be used has to be taken into account (Meng et al., 2008). On the one hand city model visualization can be used in a stationary and on the other hand in a mobile environment. To find feasible city model visualizations for a mobile user seems to be the more demanding task. To achieve the goal of user oriented visualizations on small displays, the theories, concepts and approaches of the traditional cartography have to be expanded (Meng, 2003, Buziek, 2001). The usage of city models as an information system in a mobile context is one of the tasks we

have to cope with. Another task is to ensure the usability of such visualization on small mobile displays. To create user oriented visualizations a non-photorealistic visualization approach seems to be a feasible solution (Jahnke et al., 2011a). The non-photorealistic visualization approach originates from computer-graphics (Gooch and Gooch, 2001, Strothotte and Schlechtweg, 2002) and was adapted to city models by Döllner and Walther (2003). The non-photorealistic approach stand for the ability of a generally better accepted and understood visualization due to their clarity, legibility and aesthetic appeal (Plesa and Cartwright, 2008).

To what extent can we apply city models in planning and decision-making? As Jahnke et al (2011b) investigate the relation between variables of (1) level of abstraction, (2) information density and (3) the storage capacity within the context of three-dimensional city models. Their idea is to place different city models in a cube with the variables and investigate the 'extremes' located in the corners. Eventually this may help to answer questions like, is it possible to visualize a 3d city model using a very low storage capacity with a very high information density and a very high level of abstraction? (Jahnke et al., 2011b). This typological try divides different 3d city models by somewhat "measurable" or "technical" specifications. An increasingly important aspect of 3d city models is the user and the usage of these models with respect to cognitive aspects. Do users of 3d city model recognize particular buildings? Are the aware of the distribution and generalization of facade elements in the models?

This visualization technique provides the freedom not to stick directly to the real world building therefore it gives the freedom to choose facade colors, line styles and distribution patterns of facade elements independently (Jahnke, 2013).



**Figure 1:** typical facades for typification

Together with the level of detail, used in computer-graphics and the generalization of 3d buildings the number of facade elements has to be reduced to fulfill the goal of a clear and useful visualization. Therefore we concentrate in this work on the distribution pattern for regular facade elements as shown in *Figure 1*

### **1.1. User Oriented Visualization**

According to Nielsen (1993) the usefulness of a system can be reflected by two fundamental aspects – the utility and the usability. While the utility describe the fitness or suitability of a distinct system the usability defines how well a user is supported by the system in fulfilling their task. In particular in cartography the usability orientation has started with the beginning of this decade (Meng, 2006). Hermann and Peissner (2003) have formulated the need of usability evaluation in cartography. Therefore many usability evaluations can be found in this area (Heidmann et al., 2003, Lobben et al., 2005, Kramers, 2008, Swienty, 2008, Burghardt and Wirth, 2011) a feasible system or in our case visualization has as well to be purpose oriented (Jahnke, 2013).

For usability testing different methods provide valuable results based on the effort for the test method. Usability engineering distinguishes between questionnaire evaluations, video observations of the user, the “thinking aloud method” and the “cognitive walkthrough” (Sarodnick and Brau, 2011). In our case we choose the questionnaire methods because it seems to be the most fitting method for city model visualizations.

### **1.2. Data and Models**

A building model from our test site in Munich is used as a starting point for this visualization task. The model was created using Trimble Sketch-Up. *Figure 2a* shows the photography of the real world building blocks, *Figure 2b* shows the created scene from *Figure 2a* which are modeled according to the real world buildings. This particular scene consists of six buildings to get a real world impression with modeled balconies, windows and entrance areas.

In a first step to test and find the most valuable distribution pattern for facade elements the number of facade elements after generalization according to Töpfer’s radical law (Ogrissek, 1983) has to be determined. The facades of the buildings have to be flattened (*Figure 3*) to have flat map like facades.



**Figure 2:** a) shows the real world scene from which we derived our model; b) the modeled buildings with balconies, windows and entrance areas.



**Figure 3:** a) one Building of the model from Figure 2, b) the reduced and flattened building as basis for the typification

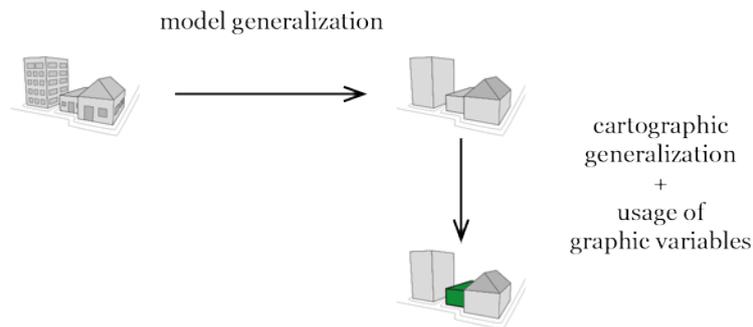
With this step we have generated generalized building models of our scene to which we can adapt the different distribution pattern.

## 2. Generalization and Facade Features

From the cartographic perspective generalization can be divided into two modes (Hake et al., 2002). The first mode belongs to the object generalization. It includes the generalization during the acquisition (survey) of the real world objects and the model generalization which is comparable to the generalization during acquisition but converts an object model into a new object model with reduced semantic and geometric resolution (Hake et al., 2002). The second mode belongs to the cartographic generalization. It aims at generating sufficient visualizations and deals with problems created by symbology (Basaraner, 2002). As (Jahnke, 2013) mentioned the visualization process for city models consists of model generalization, cartographic generalization and the usage the cartographic variables (Bertin, 1967) to feature a suitable visualization (*Figure 4*).

Presenting a city model the visualization process needs generalized buildings for a fast (rendering times) and user oriented representation of the model. The simplification and aggregation approaches from computer graphics does not take the building characteristics into account (Kada, 2007) these methods can only be used for buildings which are far away from the viewing plane.

Therefore many 3d generalization approaches evolved in the recent past. The rule based generalization (Sester and Klein, 1999), the tree structure based generalization (Thiemann and Sester, 2006). Kada (2007) introduced the generalization of 3d buildings by a global shape simplification taking the building characteristics into account and Fan et al. (2009) generalized the building to an outer shell. These approaches do not give an answer how about placing windows on the new simplified facade? or how the facade elements should be distributed when the number of elements is reduced due to the generalization?



**Figure 4:** the visualization process of 3d city models

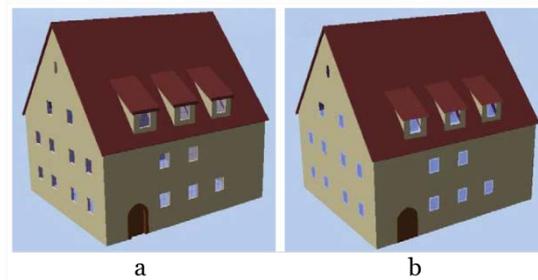
## 2.1. Generalization and City Models

In this work we divide the complex and demanding tasks of 3d generalization into two steps. The first step consists of flattening the facade (Fan et al., 2009) and reducing the number of facade elements (Jahnke et al., 2009a).

In this step all non-visible elements are eliminated and to flattening all stick out elements to get the outer shell of the building (*Figure 5*).

The second step we use 2d cartographic generalization operators like typification (Li et al., 2004) to come from one regular distribution to another

regular distribution with a reduced number of elements. We use the typification operator for the arrangement of the fewer facade elements. The generalization of the building and in particular the reduced number of facade elements can enhance the clarity of such city models if they are visualized on small mobile device like smartphones (Jahnke et al., 2009b).



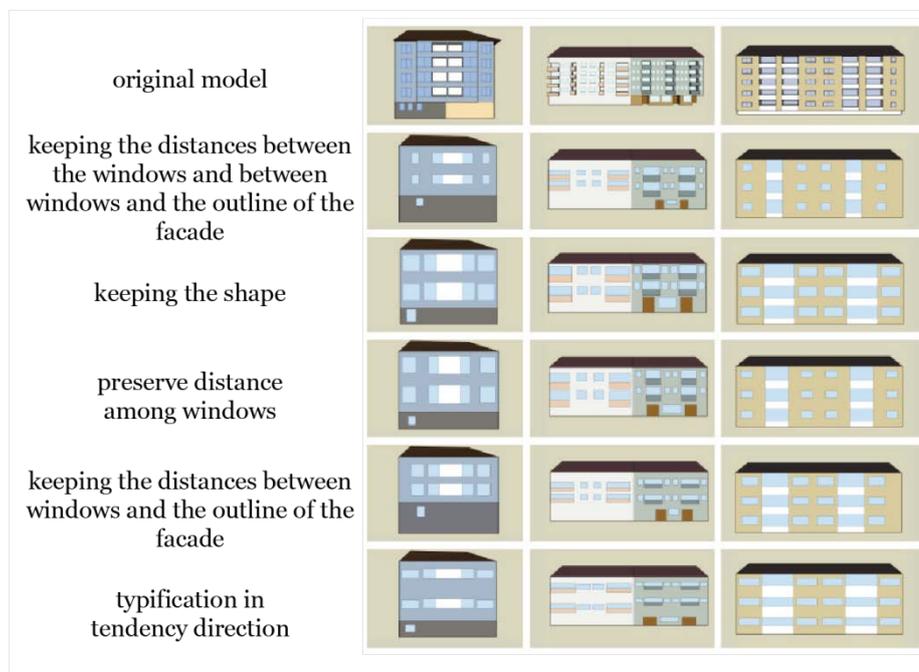
**Figure 5:** a) the modeled building and b) the outer shell of the building from Fan et al. 2009

## 2.2. Typification of Facade Features

A first attempt including a small user survey of typifying facade elements can be found in Fan et al. (2009). There are two different kinds of typification possible. The first one is “...the shape of the windows is conformal and the ratio of the distance between windows in horizontal and direction to that in vertical direction is preserved...” and “...the area is conformal and the ratio of the distance between windows in horizontal direction to that in vertical direction is preserved...” (page 12). In (Jahnke et al., 2009a) this user test is extended to five different options of how the facade elements should be distributed after typification. These options are (in decreasing importance) keeping the shape of the facade elements, keeping the distances between the windows and between windows and the outline of the facade, keeping the distances between windows and the outline of the facade, preserve distances among windows and typification of windows in tendency direction *Figure 6*. This survey is based on sketched facade pictures and not on a real world model as shown in *Figure 2* in this work we have conducted another user survey based on buildings like in *Figure 2b*.

### 2.3. Different Compositions of Facade Features

The facade elements are flattened to get a 2d plane to use the typification operator. Within our example the typification is not build into an automatic process. Trimble SketchUp was used to flatten the facade elements as well as the reduced numbers of elements which have to be redistributed are set manually. Nevertheless the above mentioned distribution pattern (*Figure 6*) for the typification operator results in distinct visualizations as shown in *Table 1* on which we based our survey. For the survey we were using two different views onto the building a front view and an oblique view to bring the three dimensional aspect into the survey.



**Figure 6:** different typification options

### 3. The Usability of City Model Visualizations

As previous researches have shown (Jahnke et al., 2011b, Rakkolainen et al., 2000) the use of 3D city models is case specific. For example city planning or mobile tourist information systems require different kinds of in-

formation. If these models are included into an information system formal user test can be applied to somewhat measure the information flow and the overall usability of the visualization (Nielsen, 1993). The design of a 3D city model has to fit the intended habits of the users. The depiction of a non-photorealistic model including different facade elements has to consider the usage. In our case the facade elements are illustrating one particular part of a street. A formal questionnaire on facade elements gives valuable hints on how to design the 3D model for this particular case.

Our goal is to have sample size of more than 50 participants. In this case we choose questionnaires to ask the users which distribution pattern gives the best visualization of a building's facade. We prepared a three sided questionnaire with a short introduction about the reason of this questionnaire. At the beginning the attendees were asked about their age and their gender. Afterwards we asked the participants about the distribution pattern for these questions we have chosen an even numbered scale (1 to 6) for the answers. For the three buildings from *Figure 5* of our model they have to answer two questions one for a front sided view and other for an oblique view on the facade.

We asked 30 female and 37 male participants in the age from 14 to 26 years. We conducted the survey with people from an elementary school and with university students from diverse study fields. Due to these two groups we have an age gap because we have no participants in the age of 17 and 18. With these 67 participants we reached the goal of minimum 50 participants to get a valid and reliable result.

#### **4. Results and Conclusions**

The results of our user survey are summarized in *Figure 7*. Within our participants we build different groups based on their age. The university student's shows similar results in judging the distribution pattern while the group from elementary school judges the distribution pattern quite different. Nevertheless this user survey shows that in average the pattern of keeping the shape and keeping the distances between windows are judged equal. All groups judge the typification in tendency direction as the worst one.

This survey shows that there are differences in the perception of different distribution pattern and that they please the user eyes in different ways. Another outcome of this survey shows that the differences between these distribution patterns are not as big as mentioned in the survey conducted by Jahnke et al. (2009).

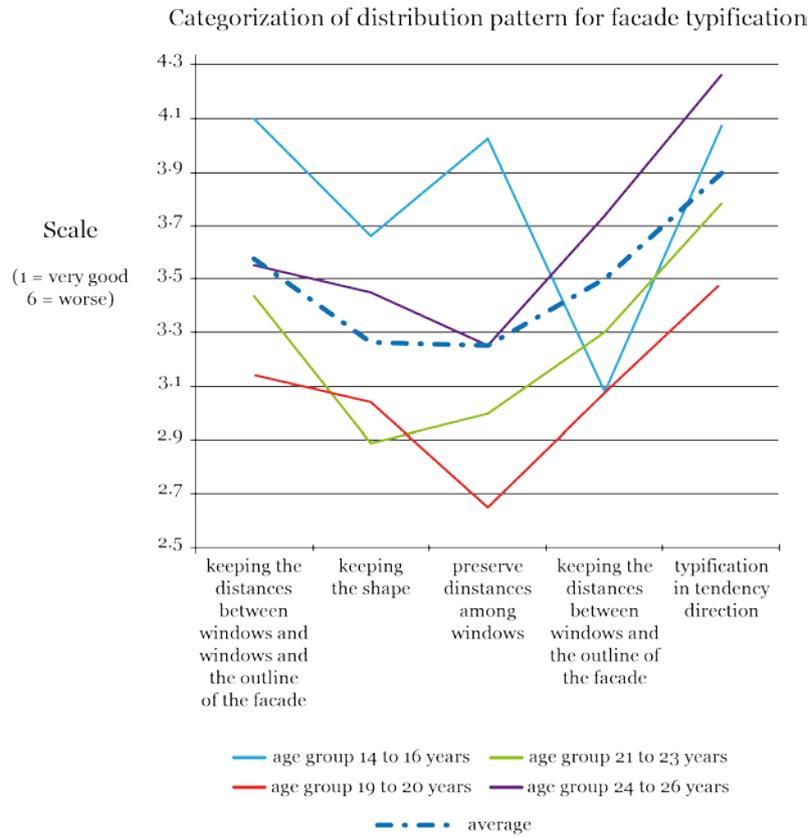
The best and the worst evaluated distribution pattern in both surveys are equal (*Table 1*). This shows that it is most important to keep the shape of the facade elements therefore the elements should not be distorted in any way.

For comparing reasons with earlier surveys the values from Figure 7 are projected are on a range from 10 (good representation) to 1 (poor representation). This projection shows that the participants in this survey have ranked the distribution pattern more equal and in average they judged the “keeping the shape” and “keeping the distance between the windows and the outline of the facade” the same.

	This evaluation		Evaluation from Jahnke et al. 2009	
 <p>good representation</p>	10.0	keeping the shape	10.0	keeping the shape
	10.0	keeping the distance between the windows and the outline of the facade	7.0	keeping the distances between the windows and between windows and the outline of the facade
	9.3	preserve distance among windows	5.3	keeping the distance between the windows and the outline of the facade
	9.0	keeping the distances between the windows and between windows and the outline of the facade	4.7	preserve distance among windows
	8.0	typification in tendency direction	4.6	typification in tendency direction
poor representation				

**Table 1:** Comparison of the results of the this user survey with that conducted by Jahnke et al. (2009) from 10.0 = good representation to 1 = poor representation

As technological possibilities, in particular visualization devices, like pads, foldable displays or augmented reality glasses occur, the visualization and usages of three-dimensional city models have to adapt. As current 3d city models are designed to be viewed on desktop computers, future design and implementations of city models may be designed increasingly device and usage specific.



**Figure 7:** Categorization of distribution pattern for facade typification

## 5. Acknowledgments

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