Aggregation on the Basis of Structure Recognition

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1. Abstract

We can describe the sizes of objects around us in terms of their length, width and height (depth), We can also describe distance and orientation in terms of how near or far, leftward or rightward, and high or low etc., the objects are from each other. In 3D city model, which consists mainly of buildings and roads, their structure recognition requires these parameters to be studied in more details. Buildings, which are the major constituent of the city, are manmade objects and reveals a high variability in structure. These buildings can be represented as a combination of several simple building parts which in turn are represented by sets of points, lines and regions. Further these buildings can be divided into different groups based upon their roof style and shapes. When a given city model is viewed at reduced scale, these objects not only becomes small but tend to conflict due to small area. Generalization plays an important role to overcome these effects. Generalization based upon 3D structure recognition is a highly demanding task and involves not only of individual object structure recognition and spatial relation between them but also group recognition based upon perceptual grouping. We will study structure recognition separately based upon these both phenomenon.

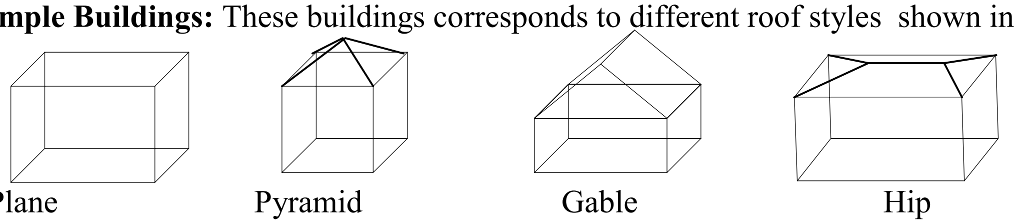
2. Introduction

Among the generalization [Burghardt D. and S. Meier, 1997] operations, aggregation groups a selected set of similar entities to form one entity over the original footprint. Though 2D aggregation which deals with polygons has been widely studied in the past, aggregation of 3D objects (polyhedral) has not drawn considerable attention until recently. While aggregating 3D city models, consisting of mainly buildings and roads, several issues are considered here. Apart from the existing rules and constraints from 2D aggregation, additional 3D constraints and consequently rules are studied based on structure recognition. The structure recognition plays an essential role in determining these local and global constraints, rules and identifying generalization operations and their calling sequences. Since a 3D city models consists of mainly buildings and roads, structure recognition of these objects, particularly of building is studied in details.

3. Building types: Though it is very difficult to describe all kinds of buildings using comprehensive building models, it is necessary to classify them into a known set of groups. These groups are based upon different roof styles and shapes. Following are the different types of buildings based upon these roofs and shapes

Following are the details of the various group of buildings based upon these roofs and shapes:

i. Simple Buildings: These buildings corresponds to different roof styles shown in figure 1.



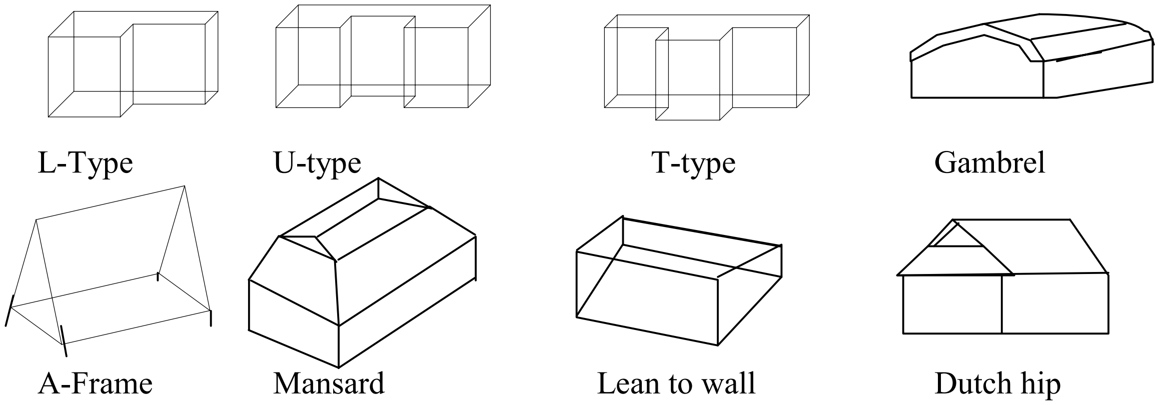


Figure 1. Simple buildings

ii. **Complex buildings**:

a. buildings which has a roof as a combination of same or different roof styles as shown in figure 2..

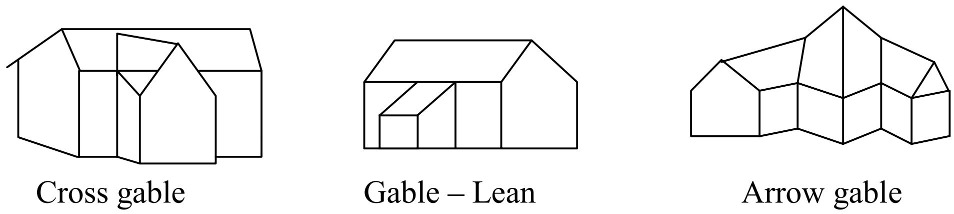


Figure 2: Complex buildings as a combination of roofs

b. building as a group of small buildings joined together forming a special shape

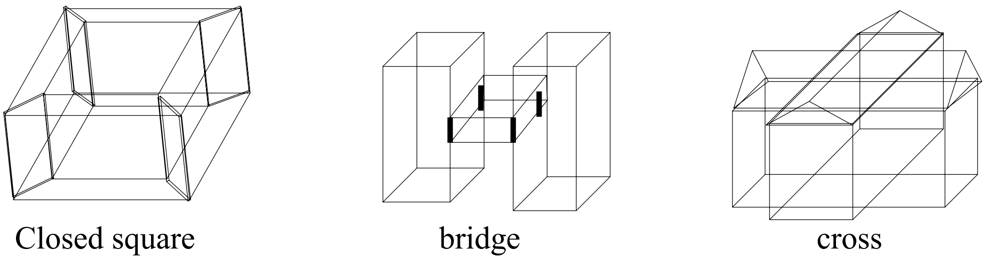


Figure 3: Complex buildings forming special shapes

These buildings along with their nearest roads have following set of spatial relationships:

i. Containment
ii. Connectivity
iii. Contiguity
iv. Coincidence
v. Proximity

4. **Structure recognition**: involves the identification of specific cartographic objects or aggregates as well as spatial relations, and measures of importance. A Neural Network (NN) technique is applied to recognise different types of buildings. It uses only the coordinates of the buildings to identify them. Details of this study are the beyond the scope of this paper. Spatial relations between these objects can be conducted on three levels:

1) **Micro Level**: It applies to individual objects and can be characterized by

- Positional parameters describing position and orientation.
- Form parameters like length, width, height, surface area, volume to describe the size
- Wall orientation involving orthogonal and parallel walls (in most cases)
- Roof types.
- General Shapes .
- Junction types i.e. L, U junctions.

As an object consists of nodes and arcs and these nodes are connected by arcs. One of the major relationship, a single object has, is connectivity.

2) **Meso level**: It applies to an object in relation to its neighbors. Out of the five relations described above, contiguity and proximity are very important relations among 3D buildings in neighborhood. Proximity can me obtained by measuring their mutual orientation, angle, distance between them and their height difference as shown in figure 4.

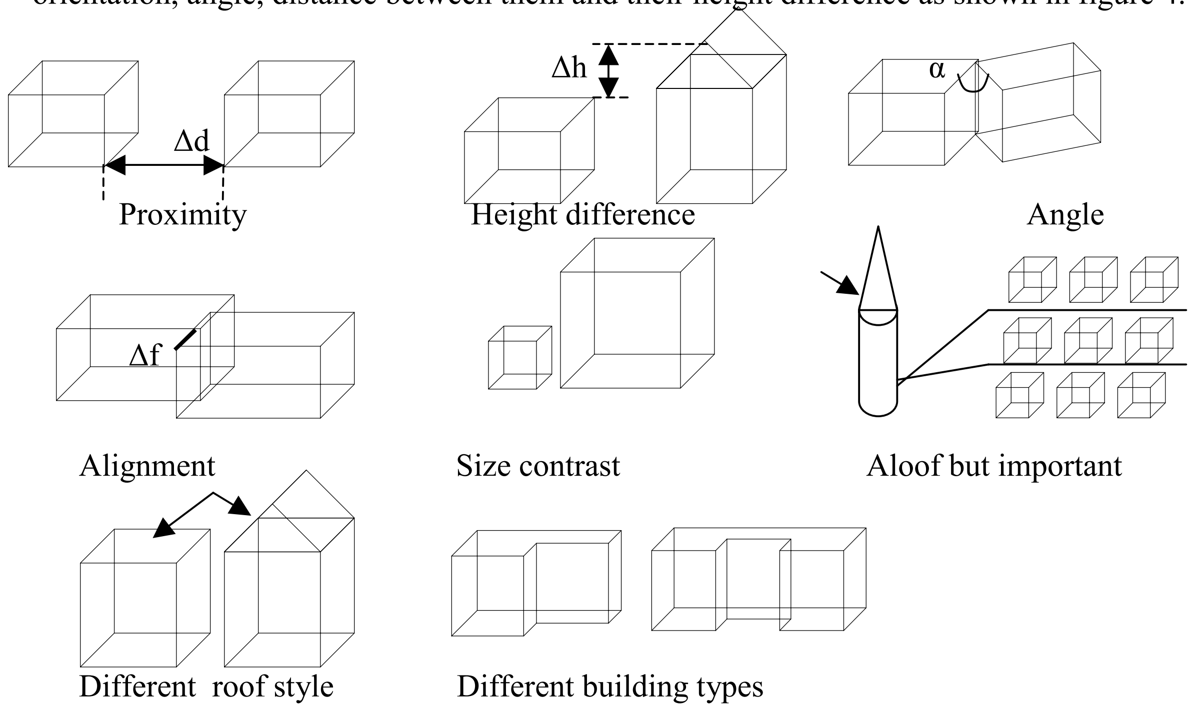


Figure 4: Neighborhood relations

3) **Macro level**: applies to clusters of objects having similar properties such as settlement blocks and is based on human perception and visual grouping behaviors. These perceptual grouping behaviors are an important aspect in understanding maps and therefore has to be maintained. 3D object recognition is not dependent upon only one level of perceptual grouping but must use the hierarchy of perceptual grouping processes based upon following concepts:

i. `Grouped by continuity`: There is a tendency in our perception to follow a direction, to connect the elements in a way that makes them seem contiguous or flowing in a particular direction as a line or a smooth curve.

ii. `Grouped by co-linearity:` Objects collinear with each other tend to be perceived together and should be grouped.

iii. `Grouped by similarity`: Similar objects tend to be seen together as forming a group

iv. `Grouped by symmetry`: The regions which are surrounded by symmetrical objects are perceived as coherent figures in the map.

v. `Grouped by closure`: Human vision tends to complete curves to form enclosed regions.

vi. `Grouped be shapes`: objects appear to be the same shape, even when we view them from different angles. Hence they are grouped together.

vii. `Grouped by orientation`: Object with common orientation should be grouped together

viii. `Grouped by parallelism`: Object placed along parallel lines should be grouped together

5. **Constraints :** A constraint, as defined by [Ruas,1998], can be specified as something to *maintain* or something to *avoi*d. Many constraints can be expressed either way, such as «maintain a certain separation between two buildings,» or «avoid overlapping of two buildings.». Further a constraint can be *independent* or *contextua*l. Independent constraints consider only one object, e.g., a building's area must exceed a minimum size. Contextual constraints consider relations between objects, e.g., two buildings cannot occupy the same location. Based upon the above structure recognition study, following constraints were found which leads to the aggregation rules.
   - ***Graphic constraints*** arise from feature and symbol geometry. They specify basic size and proximity (i.e. area and distance) properties and are mainly dictated by graphic limits as well as the shapes and sizes of features.

   - ***Topological constraints*** ensure that basic topological relationships (connectivity, adjacency, containment) between features are maintained.
   - ***Structural constraints*** define criteria that describe both spatial and semantic structure and inter-dependencies.
   - ***Perceptual constraints*** relate to complex visual aspects. They arise due to enforcement of visual balance (when typifying, aggregating etc.).

   Constraints form the basis of rules by defining the conditions with measurable parameters. Following rules were introduced which govern the aggregation operation.

6. **Aggregation Rules :**
   It consists of three sets - linkage, semantic and orientational rules.

- ***Linkage rules*** define the spatial relations between buildings that must exist for their aggregation. These rules include topological and metric relationships such as:

  - Proximity: Two buildings must be disjoint but within a certain distance of each other for their aggregation;
  - Alignment: Two buildings should be aligned or their alignment should not differ much and the difference must be below the permissible limits.
  - Angle: Two buildings should have minimum angle between them if they are to be aggregated;
  - Height: Two buildings should have minimum height difference if they are to be aggregated. However, if the two buildings vary much in height, it may be possible, depending on the requirement, that both are simply united;
  - Roof Type: Two buildings should have similar type of roof, i.e., planar or gable if they are to be aggregated;
  - Adjacency: Two buildings must have their adjacent faces close if they are to be aggregated

- ***Semantic rules*** define the semantic relationships that must exist for aggregation. Semantic rules include relationships such as:

  - Structural: a group of objects form a common geographic or perceptual structure.
  - Class: Two buildings must be of the same class.
- ***Orientational rules*** define the historical or local importance of the buildings. Important buildings such as monument, theatre, tower etc. reflect the city identity**.** Based upon their importance, we can define the following rules:
  - Buildings which are of great importance should have their identities preserved at maximum of its extent**.** Therefore two buildings having historical importance should not be aggregated.
  - If only one of the buildings is important, even then aggregation should not be done. Instead the important building should be exaggerated. The same rule applies to other local important buildings like TV towers, theatres, schools etc.

Based upon the above rules and constraints, an algorithm for aggregation was developed. It is basically a nested set of If..Else statements. For example:

If $\boldsymbol{d}(o_i,o_j) < \Delta d_{\mathbf{min}}$ then
If $\boldsymbol{h}(o_i,o_j) < \Delta h_{\mathbf{min}}$ then
If ***roof_type₁*** = ***roof_type₂*** then
If $\Delta\mathbf{A}(o_i,o_j) < \mathbf{A}_{\mathbf{min}}$ then **aggregate**
…
Else if **Ar*ea****ᵢ* is small and Object is ***important*** then **exaggerate**
… Else **unchanged**

7. Results: The algorithm was implemented in Visual C++ using ACIS as a graphic modelling software and was tested using a test set consisting of 250 buildings and roads.
Following figures (5 and 6) shows the results based upon above rules.

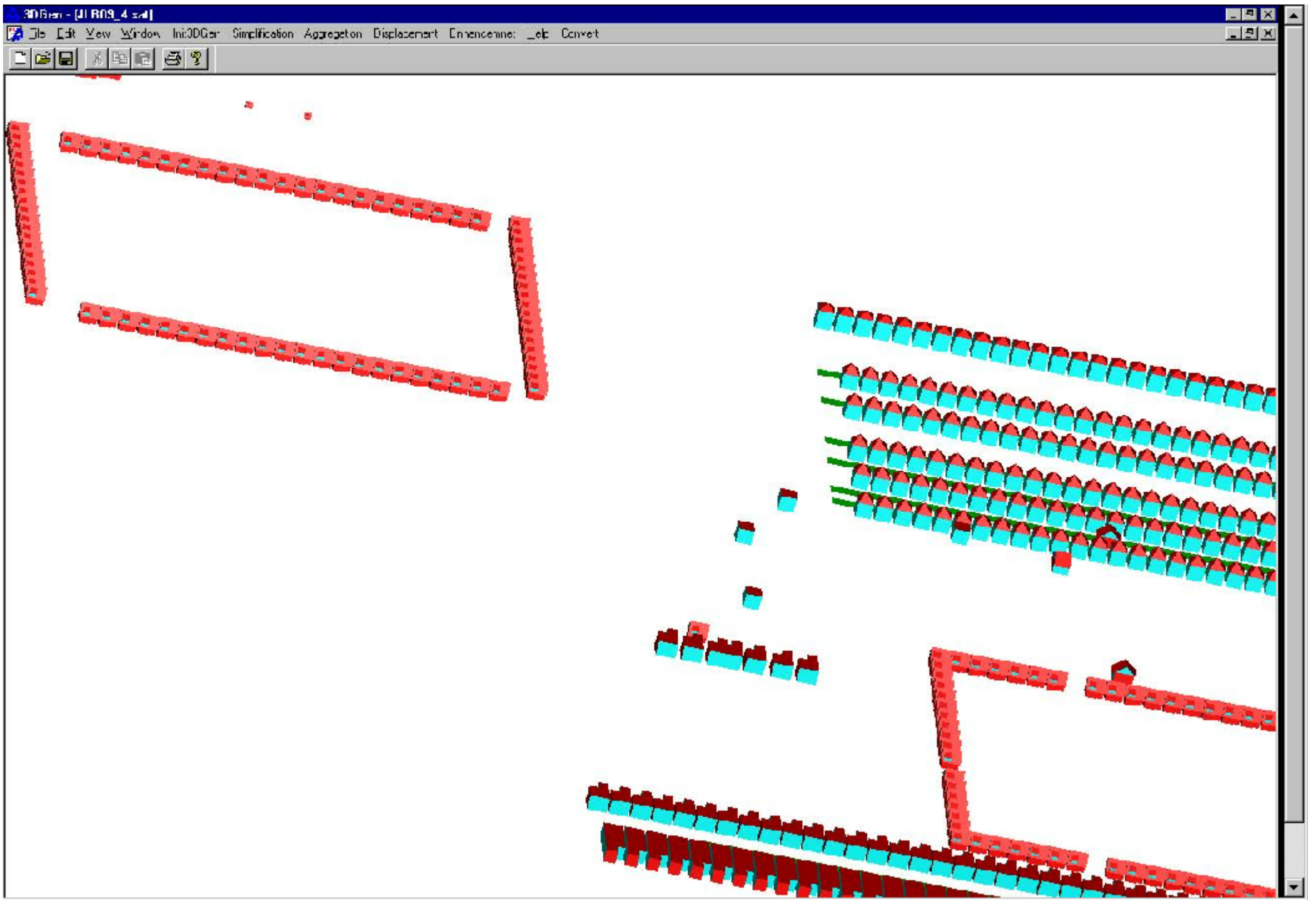


Figure 5: Original set of buildings

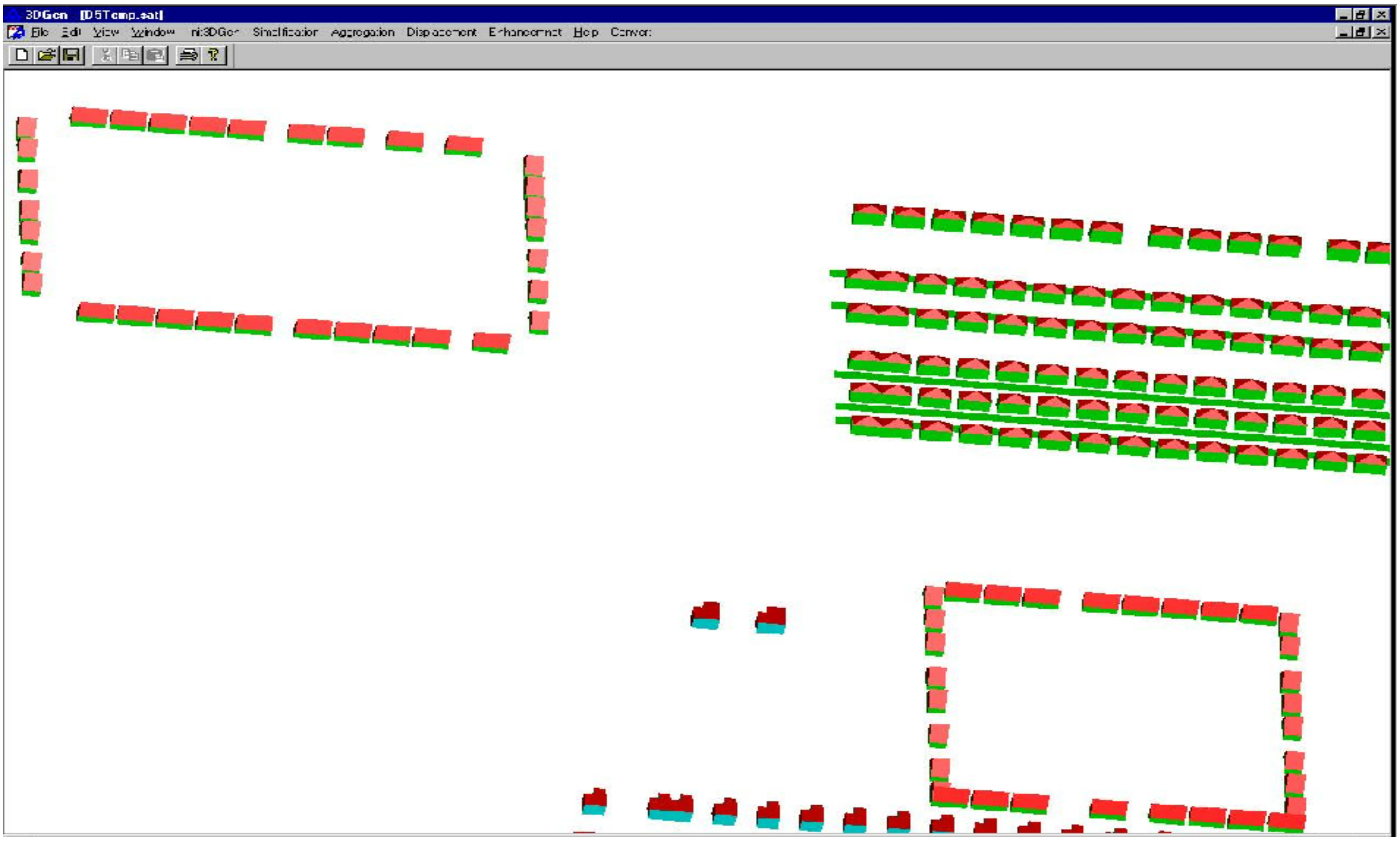


Figure 6: After aggregation

8. **Conclusion:** A comprehensive research on structure recognition of 3D buildings has been done resulting in development of set of rules pertaining to aggregation. discussed here. Additional constraints and rules arising from the third dimension have been introduced and consequently algorithm as been developed and implemented. Though the algorithm was tested using very simple test data but it has given good results. In future, efforts will be made to test the algorithm with real data.

9. **Acknowledgement:** This research is being carried out under the joint research project sponsored by German Natural Science Foundation, Generalization of 3D Settlement Structures on the Basis of Scale Space and Structure Recognition, between the Department of Cartography, Technical University of Munich (TUM), and the Institute of Photogrammetry and Cartography, University of German Armed Forces in Munich. The author would like to thank Univ.-Prof. Dr.-Ing. Helmut Mayer University of German Armed Forces in Munich (UniBw), for his valuable advice .

10. **References:**

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