3D Urban Areas Scenes Based on a Hierarchical Clustering Approach and Information Theory

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Who am I

- Background: Civil Engineering (BSc) and Geomatics Engineering (MSc, DSc)
- Until 1995: was involved in geodetic and mapping projects and consultations within the private and public sectors in Israel and abroad
- Since 1996: faculty member at the Technion – Israel Institute of Technology (Full Professor)
- Served as Head of a Department, Dean of a Faculty, and currently, Heading the Geodesy and Mapping Research Center at the Technion
- Research and Teaching are focused on the fields of geodesy, cadastre, cartography, photogrammetry, computerized mapping and GIS
- Advised more than 60 M.Sc., Ph.D. and postdoctoral students
- Published some 300 papers (professional peer-reviewed journals, proceedings of professional conferences and research reports)
- Active in International forums, inter alia, FIG (International Federation of Surveyors) Council member and Head of FIG Commission 3 on Spatial Information Management

Outline

Introduction

Stage 1. Raster-based approach to 3D generalization of groups of buildings.

Stage 2. Calculation of quarters' hierarchy.

Stage 3 . Evaluation of quality of 2D footprint generalization and compilation 3D scene using information theory.

Conclusion

Introduction

Cartographic Generalization

Different definitions:

"Cartographic generalization aims at simplifying the representation of cartographic data to suit the scale and purpose of the map."

Another definition:

"Generalization is the process of reducing the information content of maps due to scale change, map purpose, intended audience, and/or technical constraints."

Generalization Operators

The classical generalization operators:

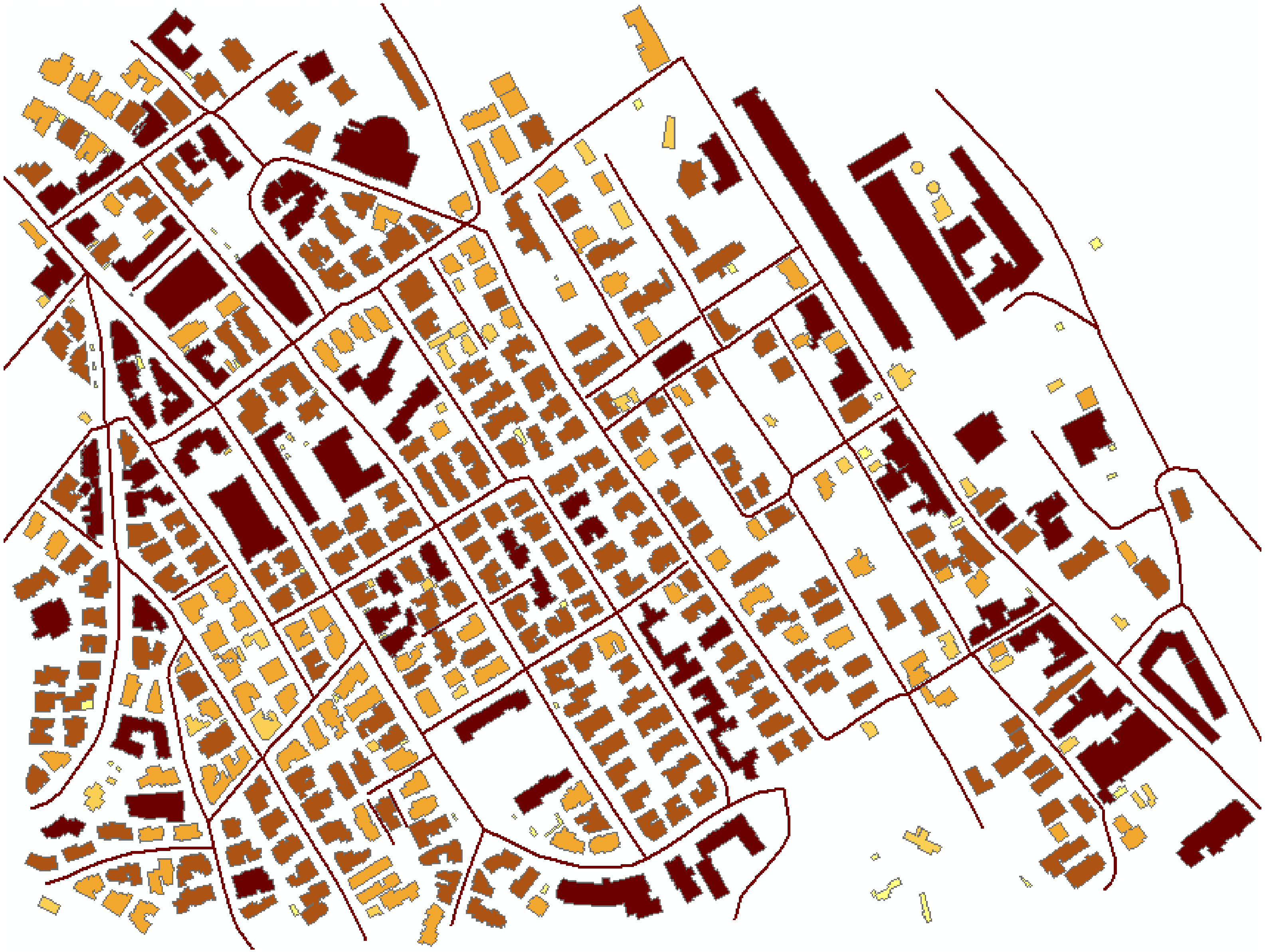
- Aggregation
- Collapse
- Displacement
- Exaggeration
- Selective omission
- Simplification
- Typification

This applies both to:

- Manual 2D generalization for centuries
  as well as
- Automatic 2D generalization in the last decades

Cartographic Generalization - Source

Cartographic Generalization - Results



From 2D to 3D Generalization

- The digital world of maps and geo-information is moving very fast from the previous 2D environment toward the 3D environment
- 3D models of cities and landscapes are getting increasingly popular and widely used.

➔ **3D generalization of the urban model is therefore necessary and is a fast-growing topic.**

Motivation of 3D Generalization

Two common problems which usually arise are:

- Huge computer resources are required for drawing 3D models based on the original, non-simplified buildings.
- 3D models based on the original non-simplified buildings are very detailed and often appear unreadable and overly complex.

➔ **3D generalization methods and sophisticated algorithms are needed.**

3D Generalization of Buildings

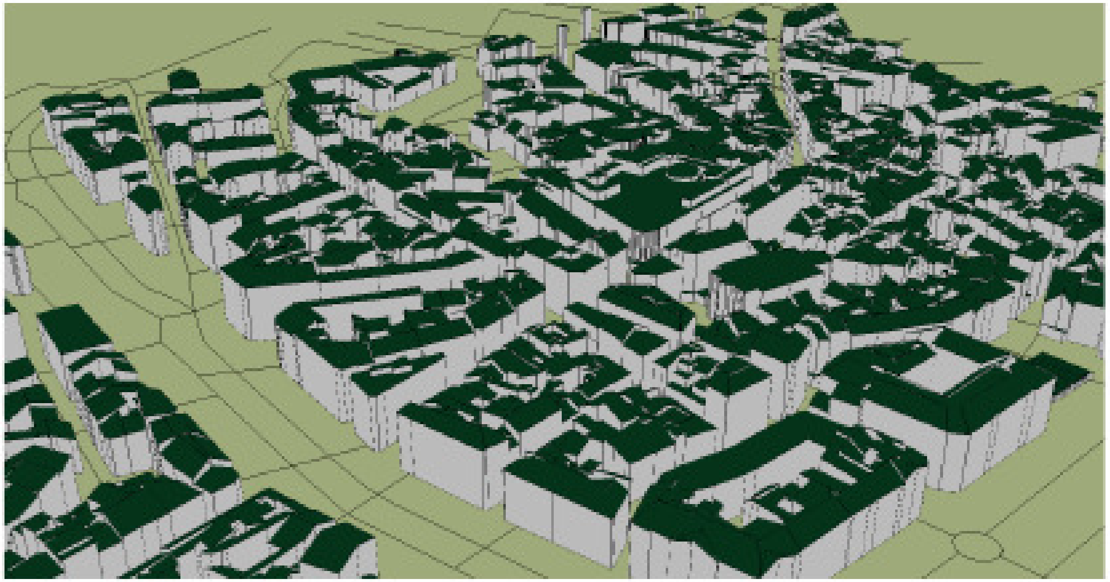
Buildings are the most complex layer for generalization.

There are two different tasks in the building generalization process:

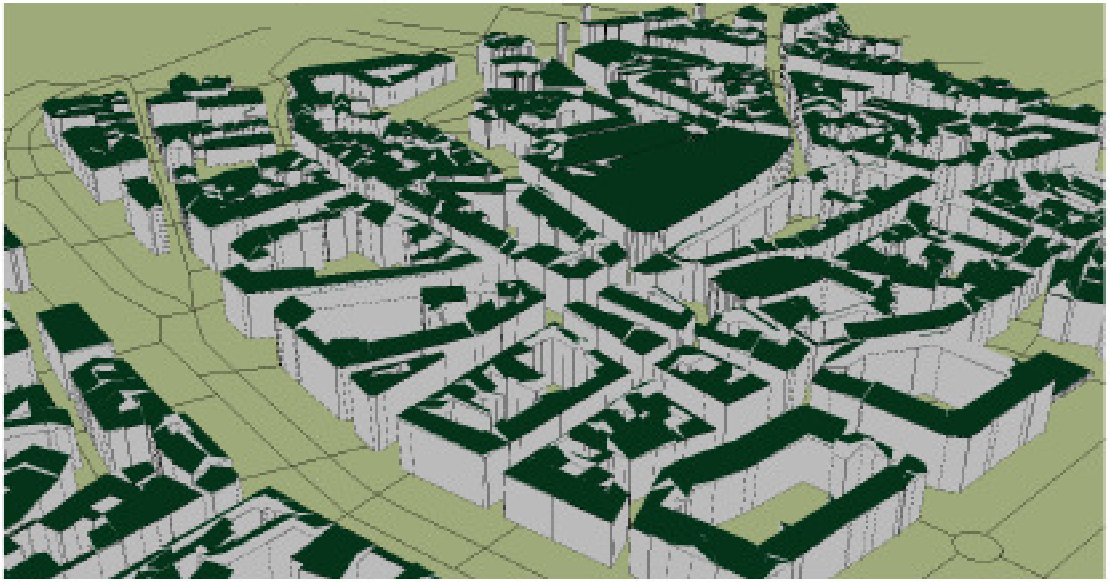
- Simplification of a single building
- Generalization of groups of buildings

The topic of “simplification of a single building” is a widely researched topic.

Generalization of group of buildings



a) Original model (© IGN BATI 3D)



b) Generalized model

Footprint-Based 3D Generalization of Building Groups for Virtual City Visualization.

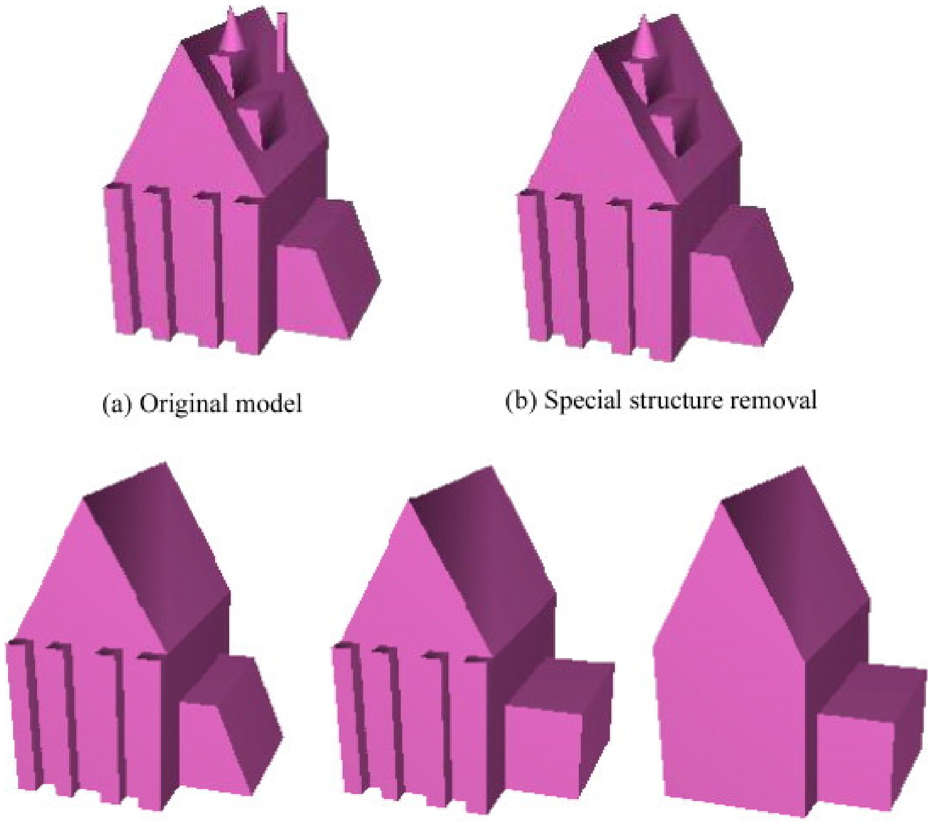
(Shuang He et al. 2012)

Example of holistic approach

Automatic simplification and visualization of 3D urban building models.

(Jinghan Xie et al. 2012)

The main idea assumes that buildings closer to a view point (based on a predefined threshold) will be the result of single buildings simplification, whereas buildings further than the threshold will be based on simplified groups of buildings as a single building.



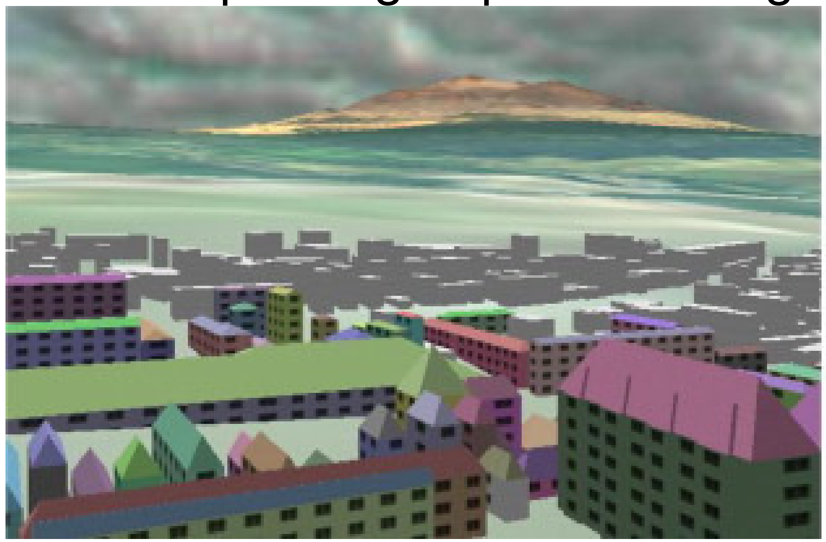
(a) Original model

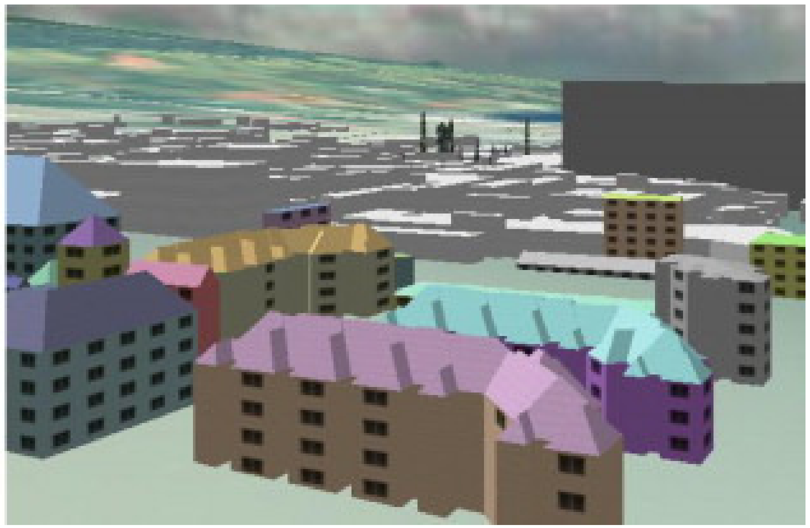
(b) Special structure removal

(c) Roof simplification

(d) Rectification of oblique walls

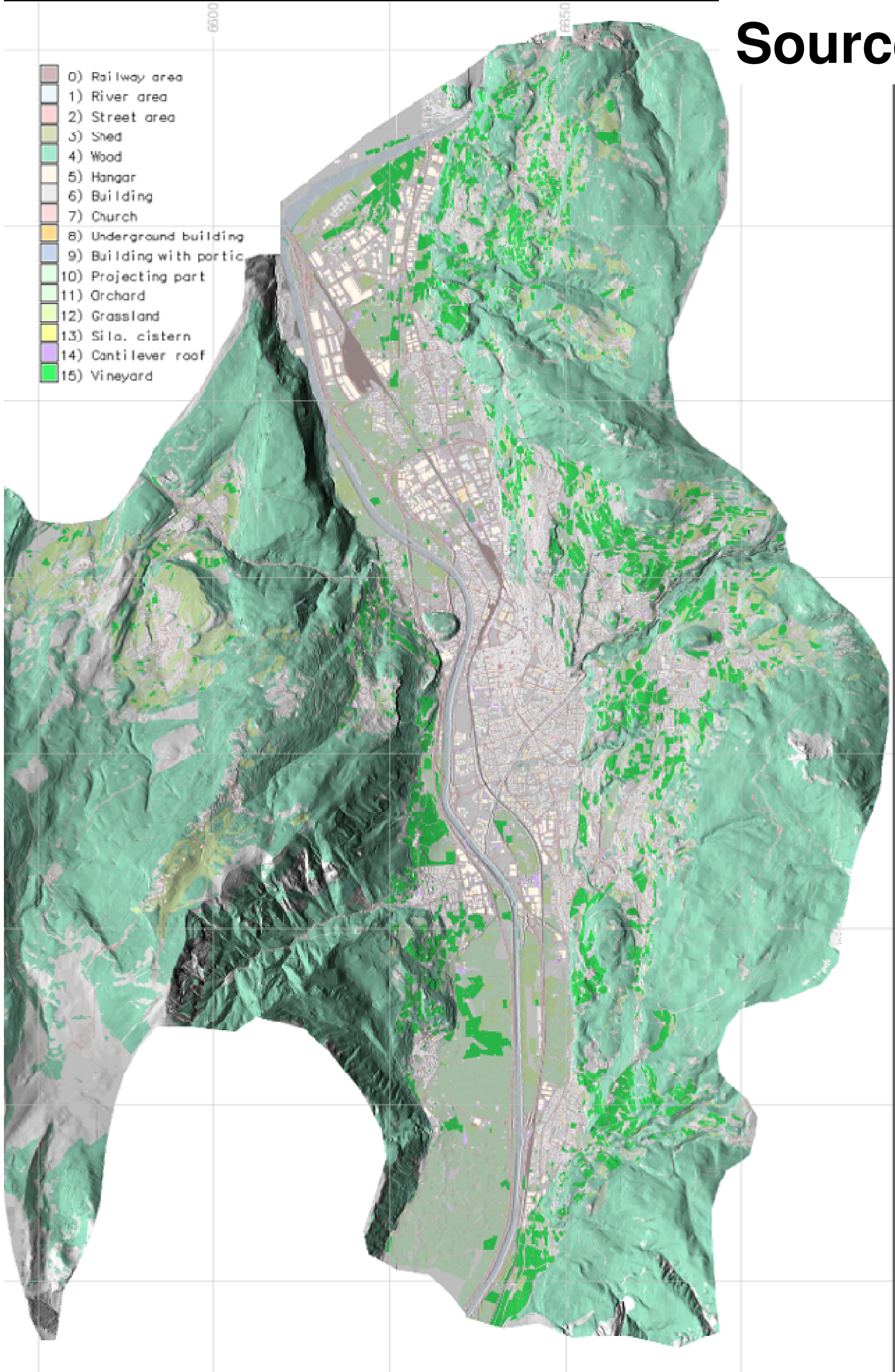
(e) Facade shifting



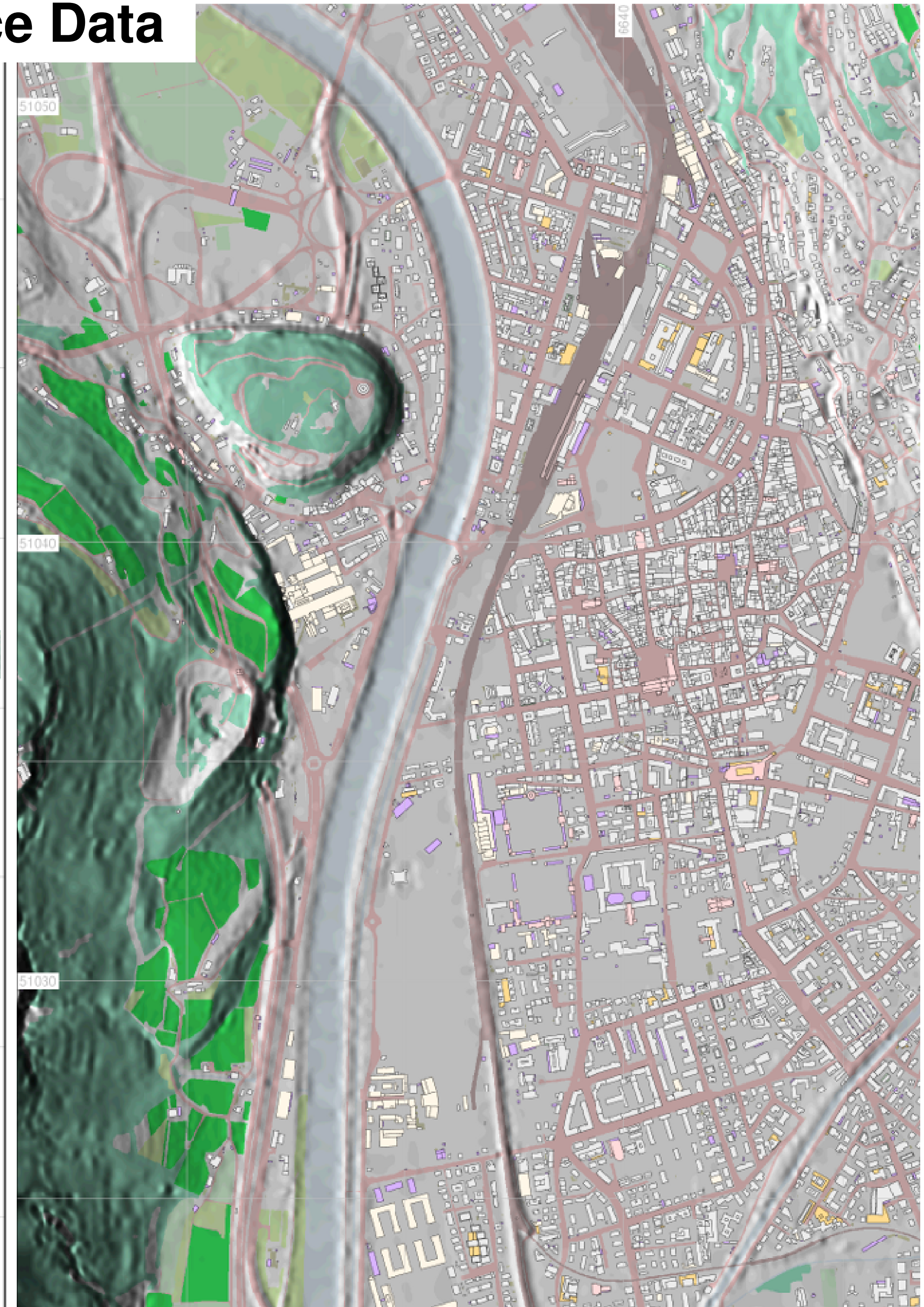


Stage 1. Raster-based approach to 3D generalization of groups of buildings.

Source Data

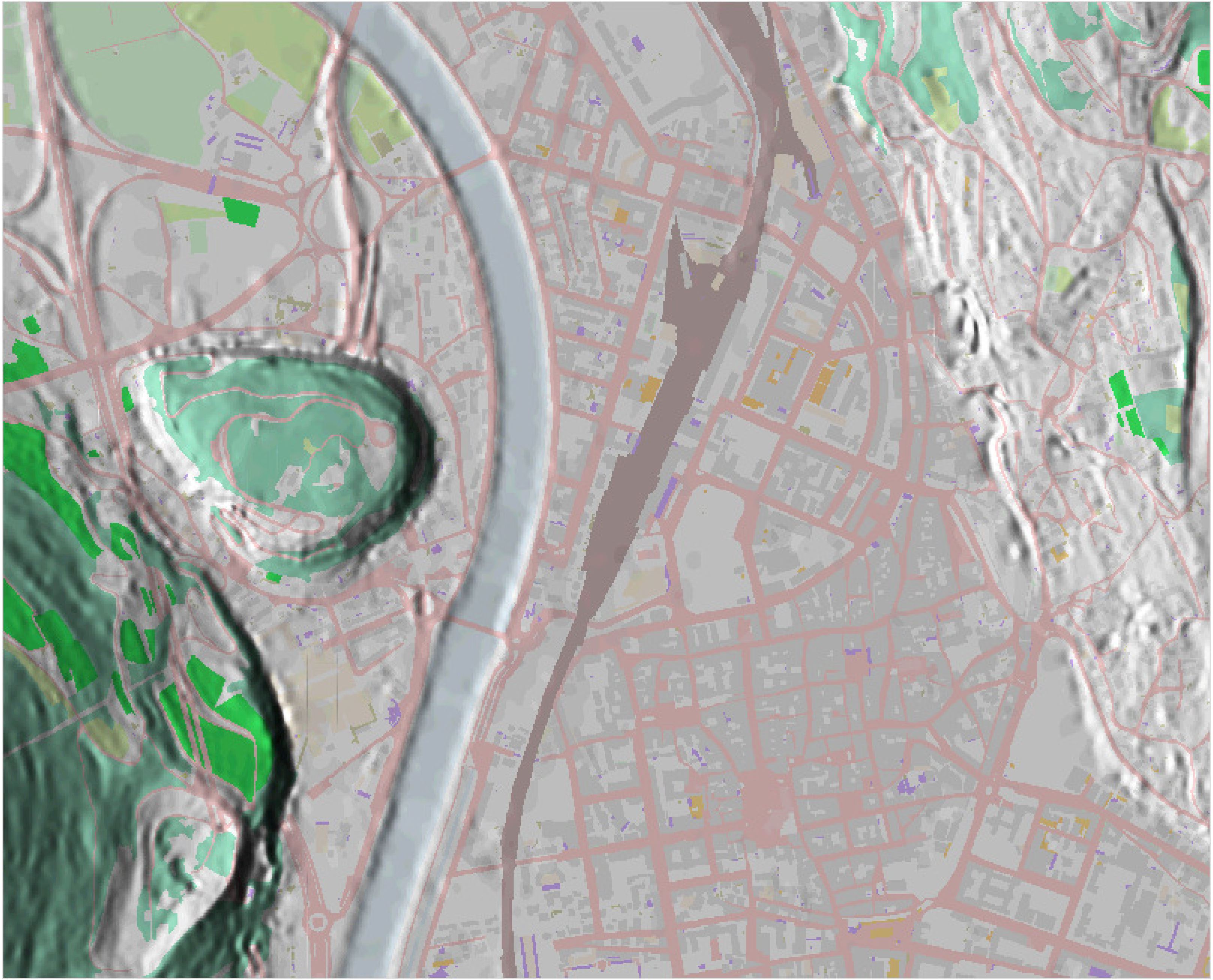


0) Railway area
1) River area
2) Street area
3) Shed
4) Wood
5) Hangar
6) Building
7) Church
8) Underground building
9) Building with portic
10) Projecting part
11) Orchard
12) Grassland
13) Silo, cistern
14) Cantilever roof
15) Vineyard
6600
6650



51050
51040
51030
6640

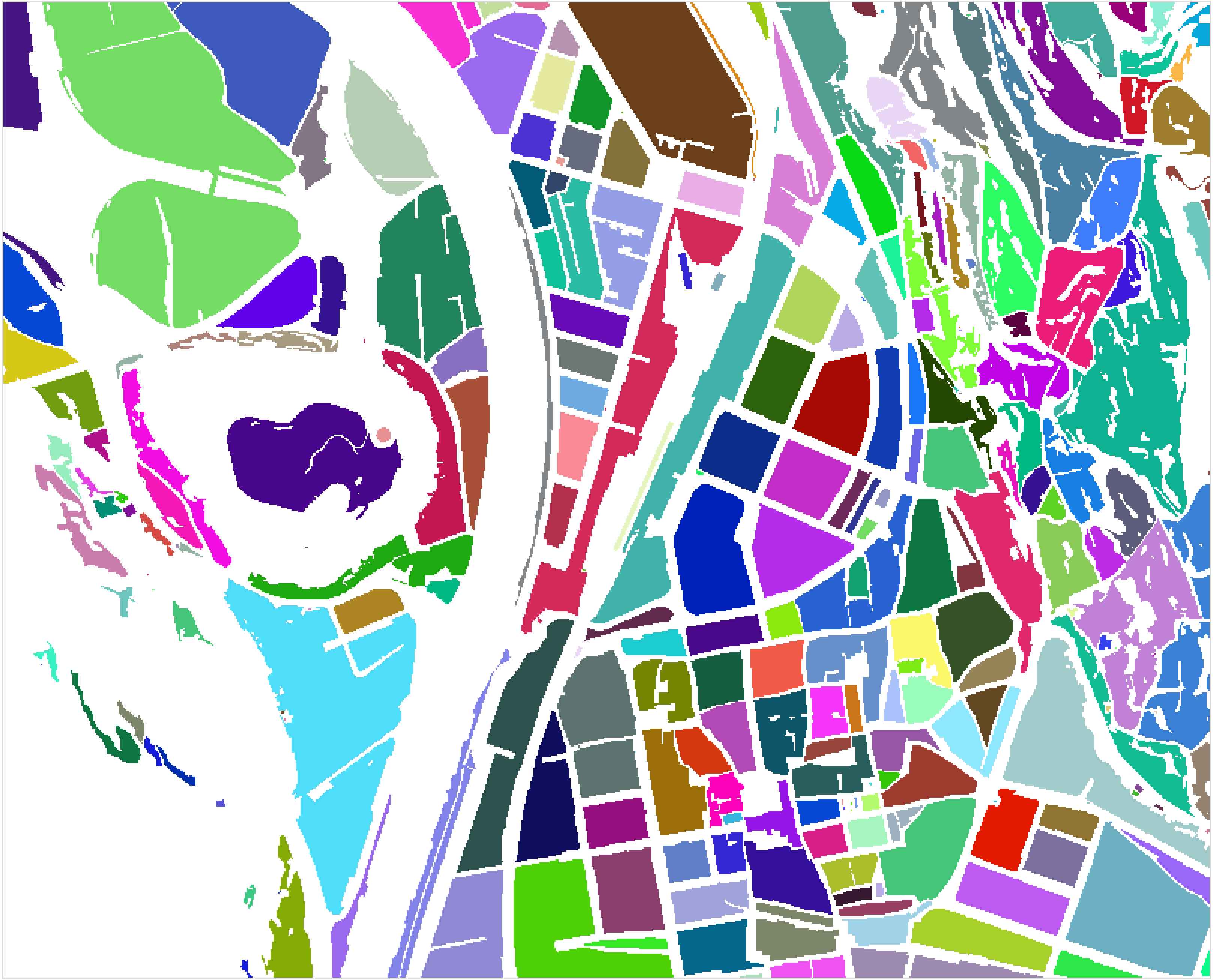
Original landuse map overlayed with shaded DEM map



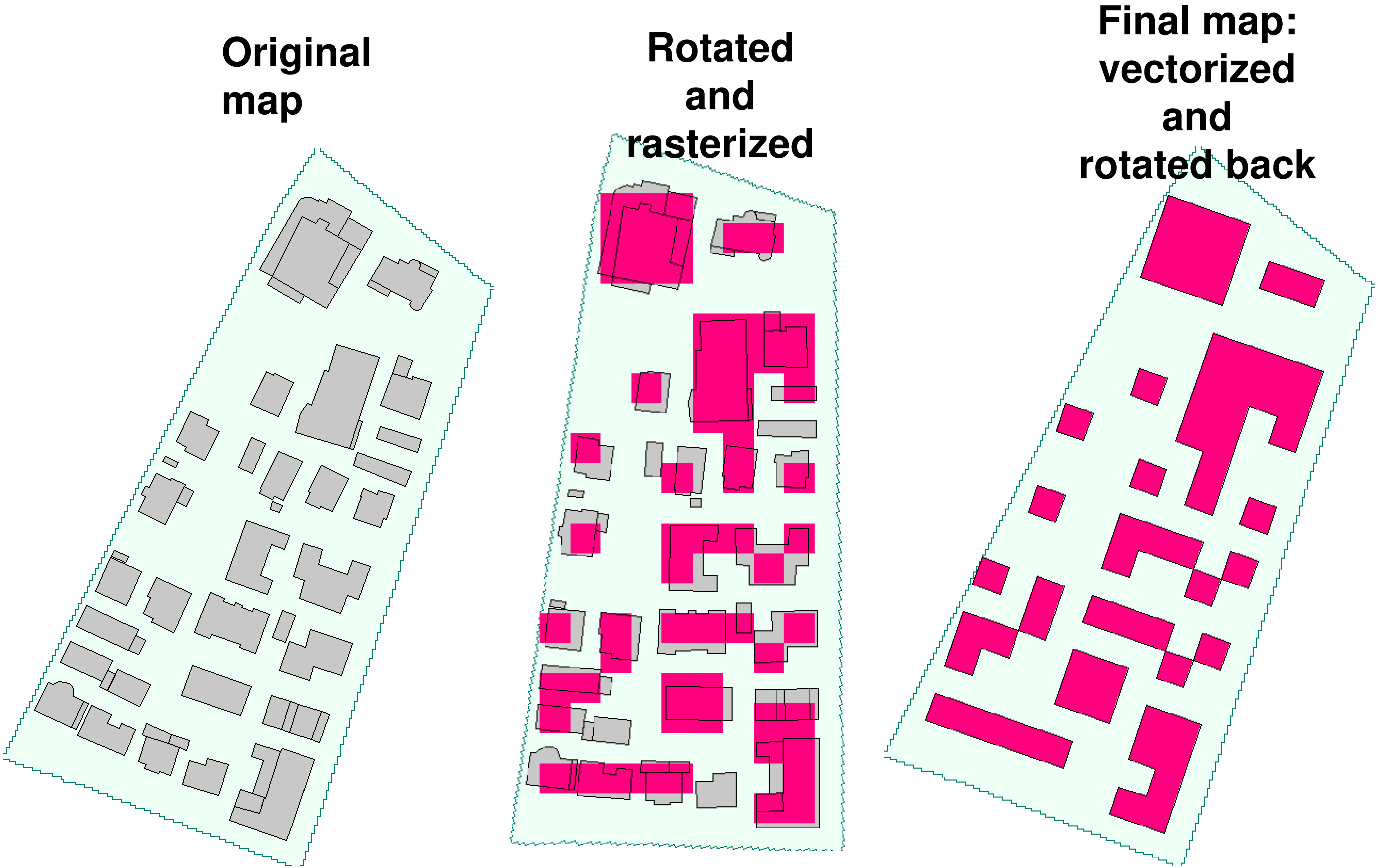
Merging of roads, water object layers and areas with slope more than 30 degrees

Inverting of pixel values (Null <-->1)

Map of raw quarters

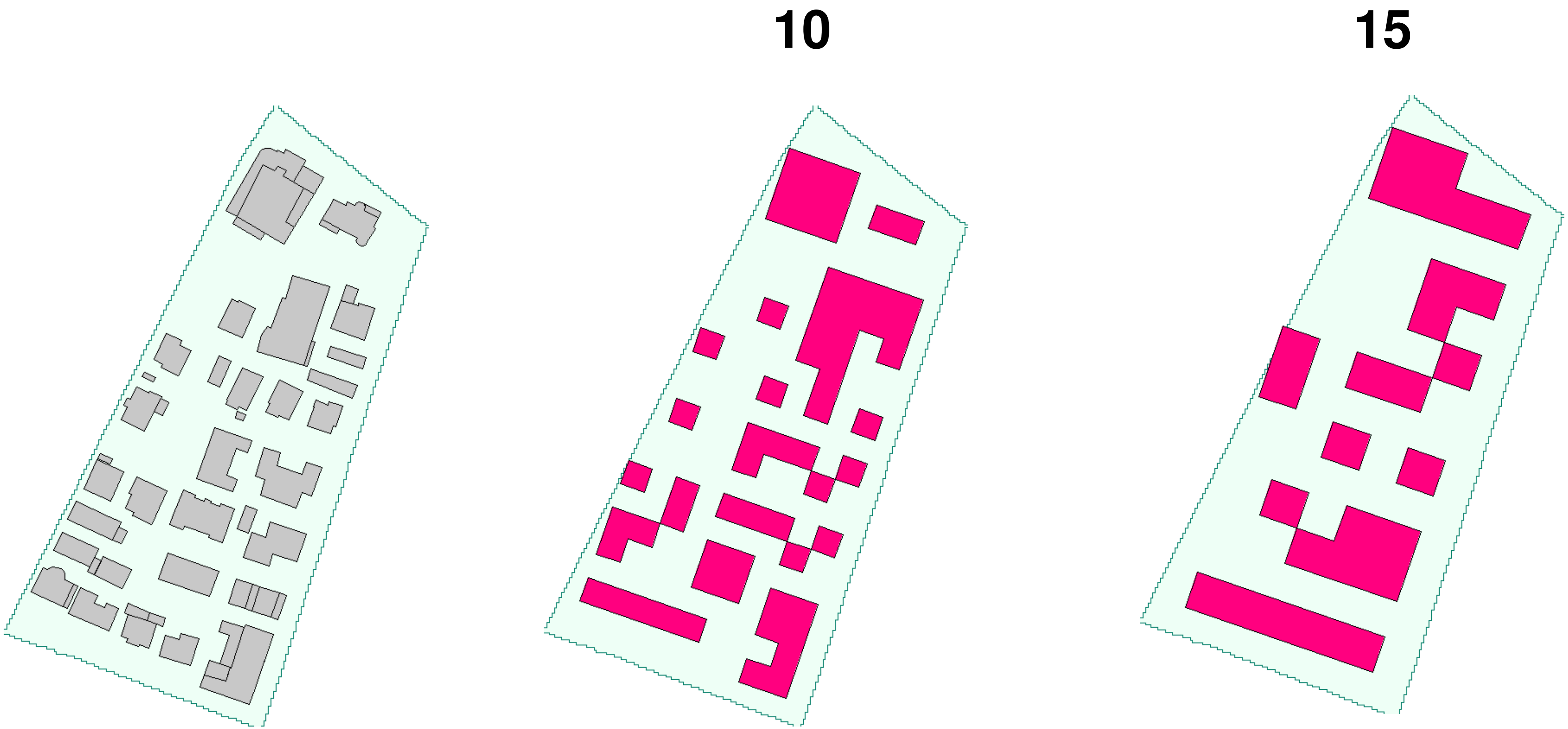


The quarters map with buildings



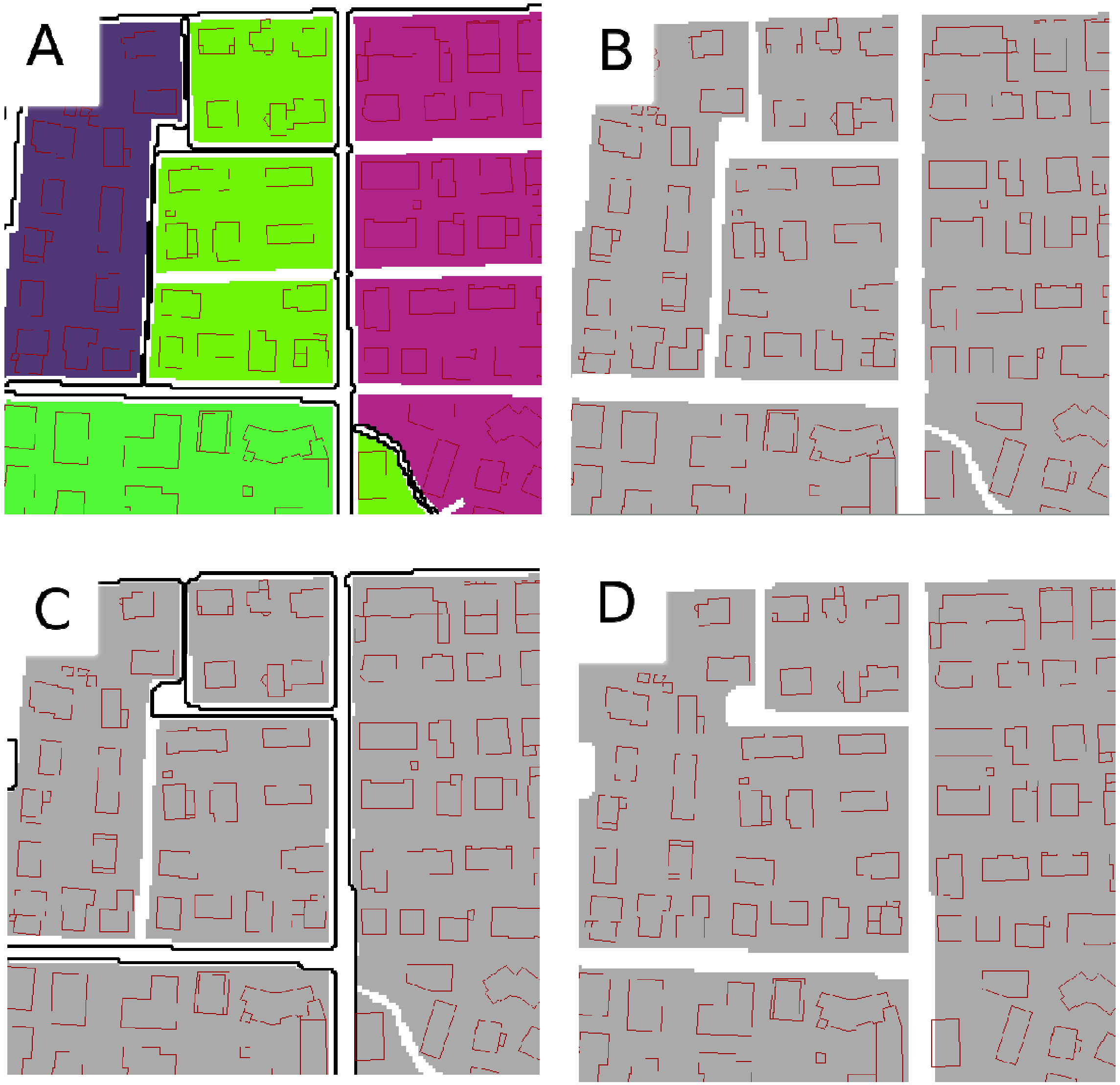
The generalized building height is a weighted average of the relevant buildings

The Level of Generalization (meters)



Stage 2. Calculation of quarters' hierarchy.

Buffering Process



A: Background Color by Original Classified Quarters (Black Polylines are Outlines of Buffers by Classes of Quarters; Width is Equal to Twice the Base Width);

B: Withdrawal of Buffers;

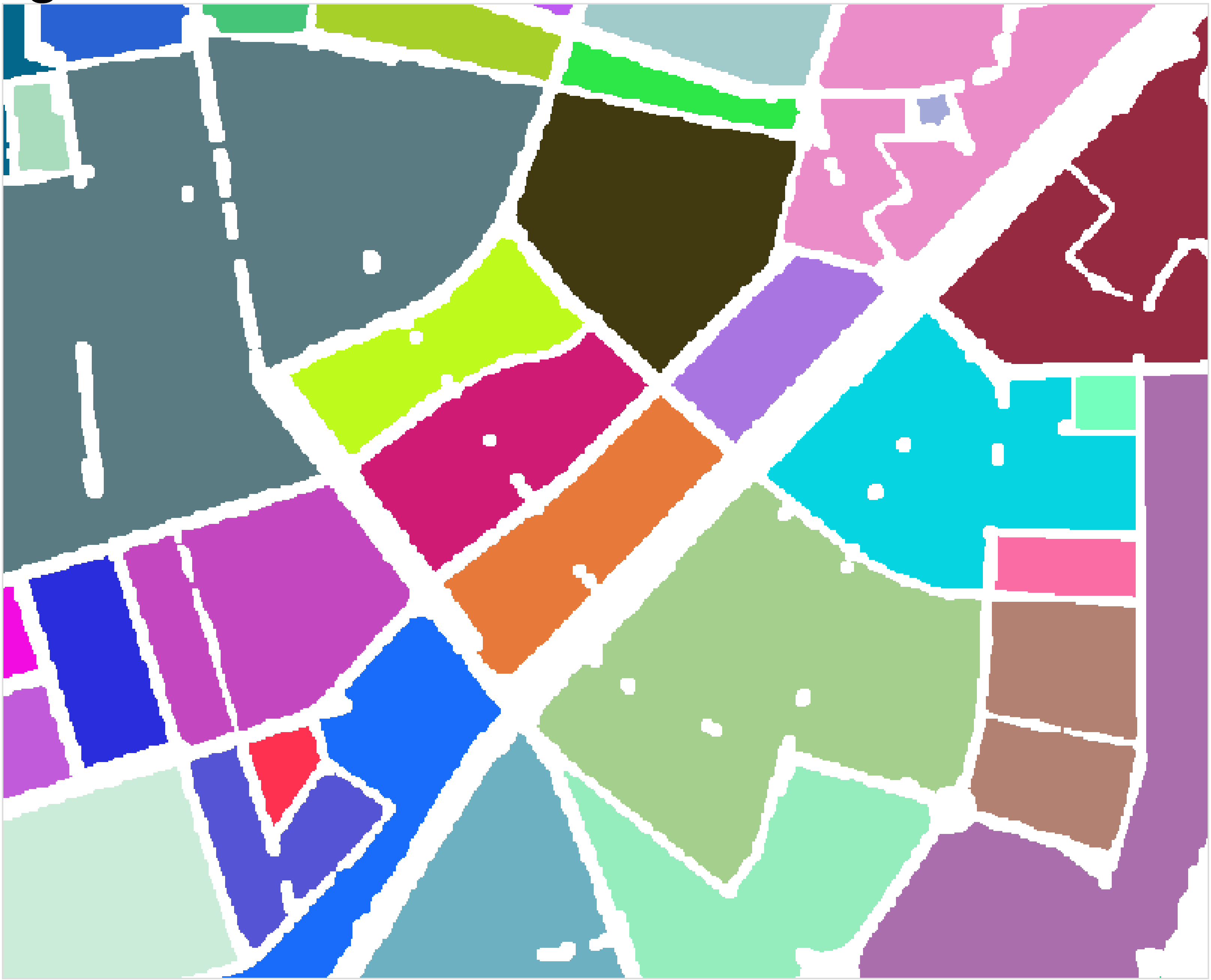
C: Adding Base Buffer Width to the Polygons;

D: Withdrawal of Buffers – Resulting as the Final Buffering.

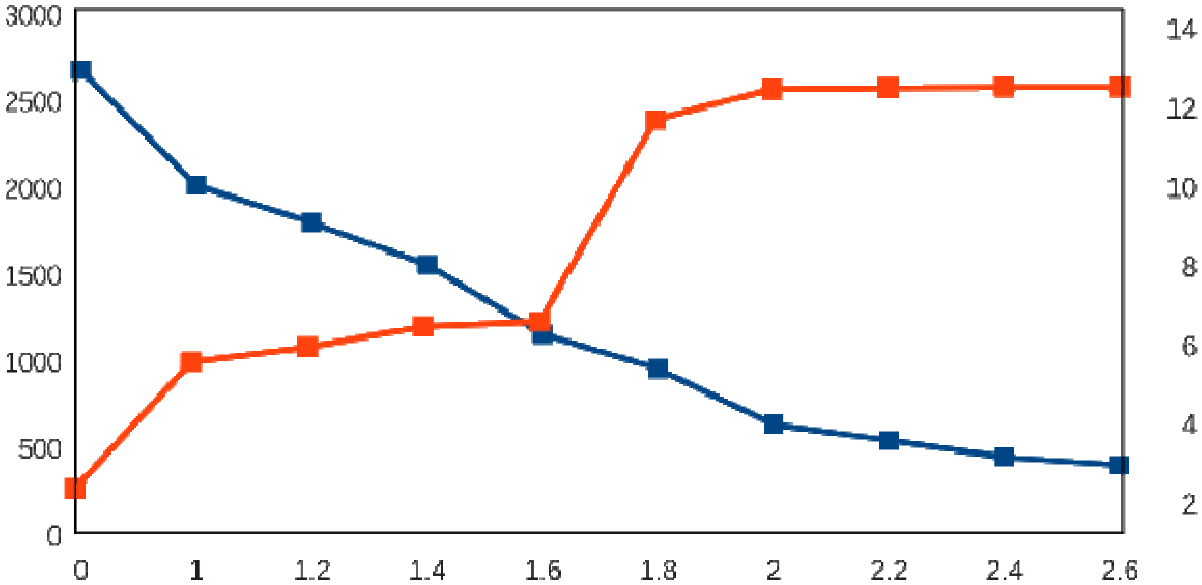
Buffering. Origianal quarters.

Buffering. 1.4 m.

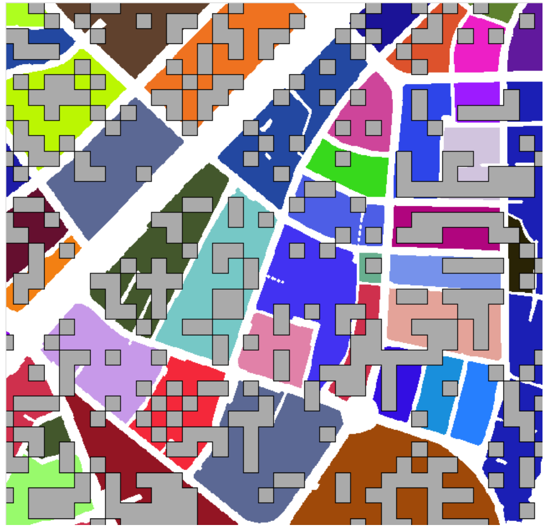
Buffering. 1.8 m.

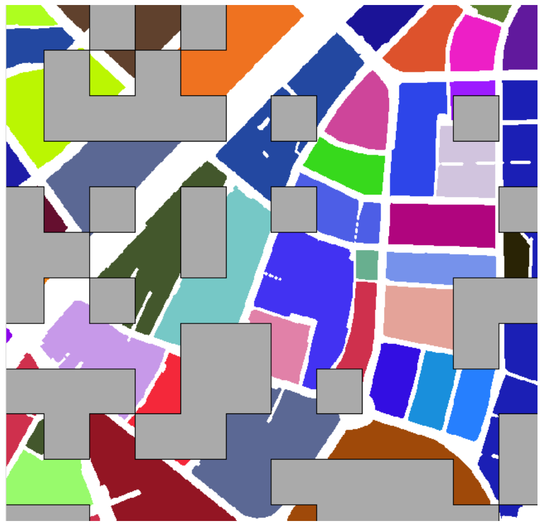


Defining correspondence between degrees of generalization of quarters and buildings.



Graph of Number of Quarters (blue Line, left Y-axis); and the Size of Maximal Quarter (red line, right Y-axis in million sq. meters); X-axis – Base Buffer Width (in meters).



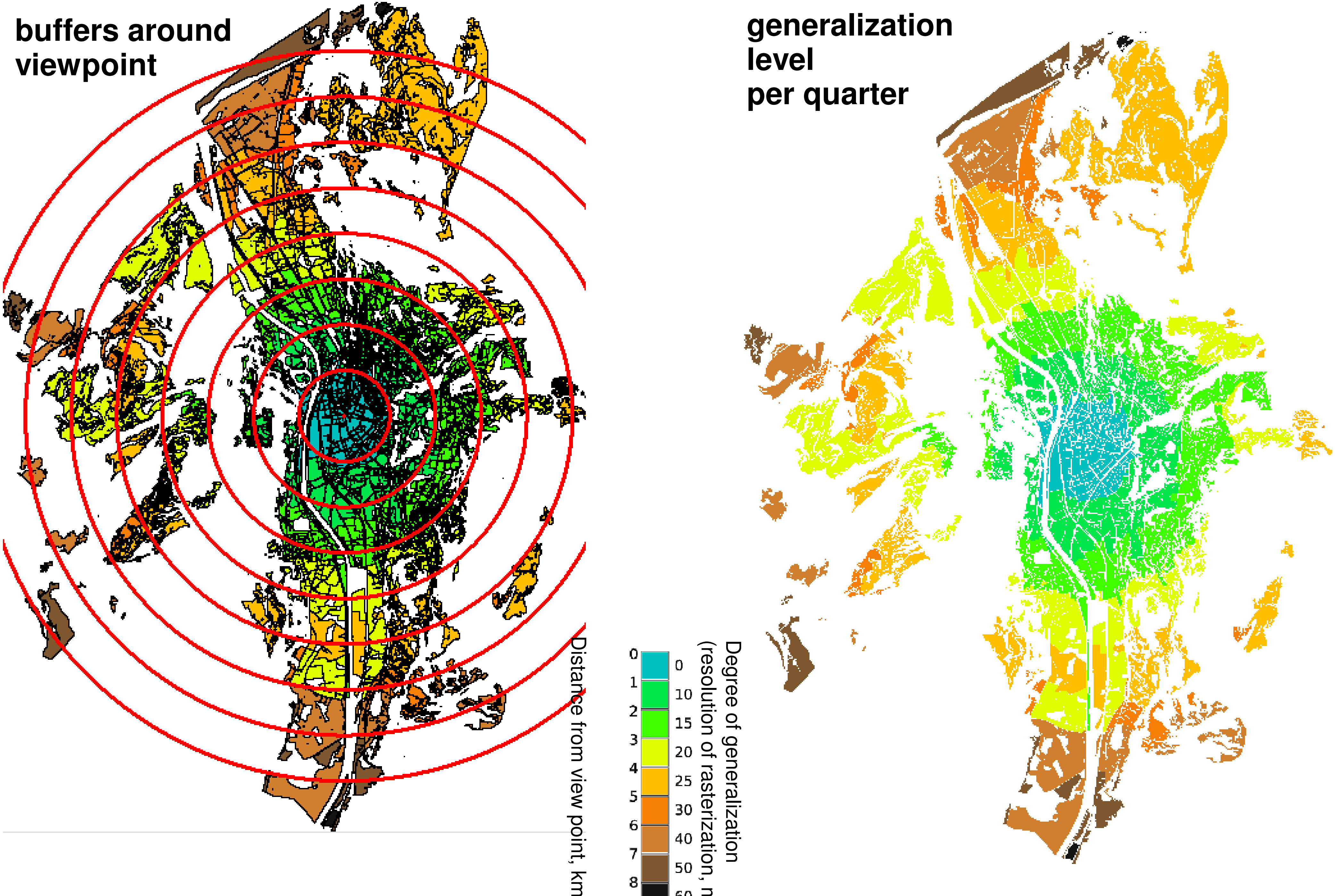


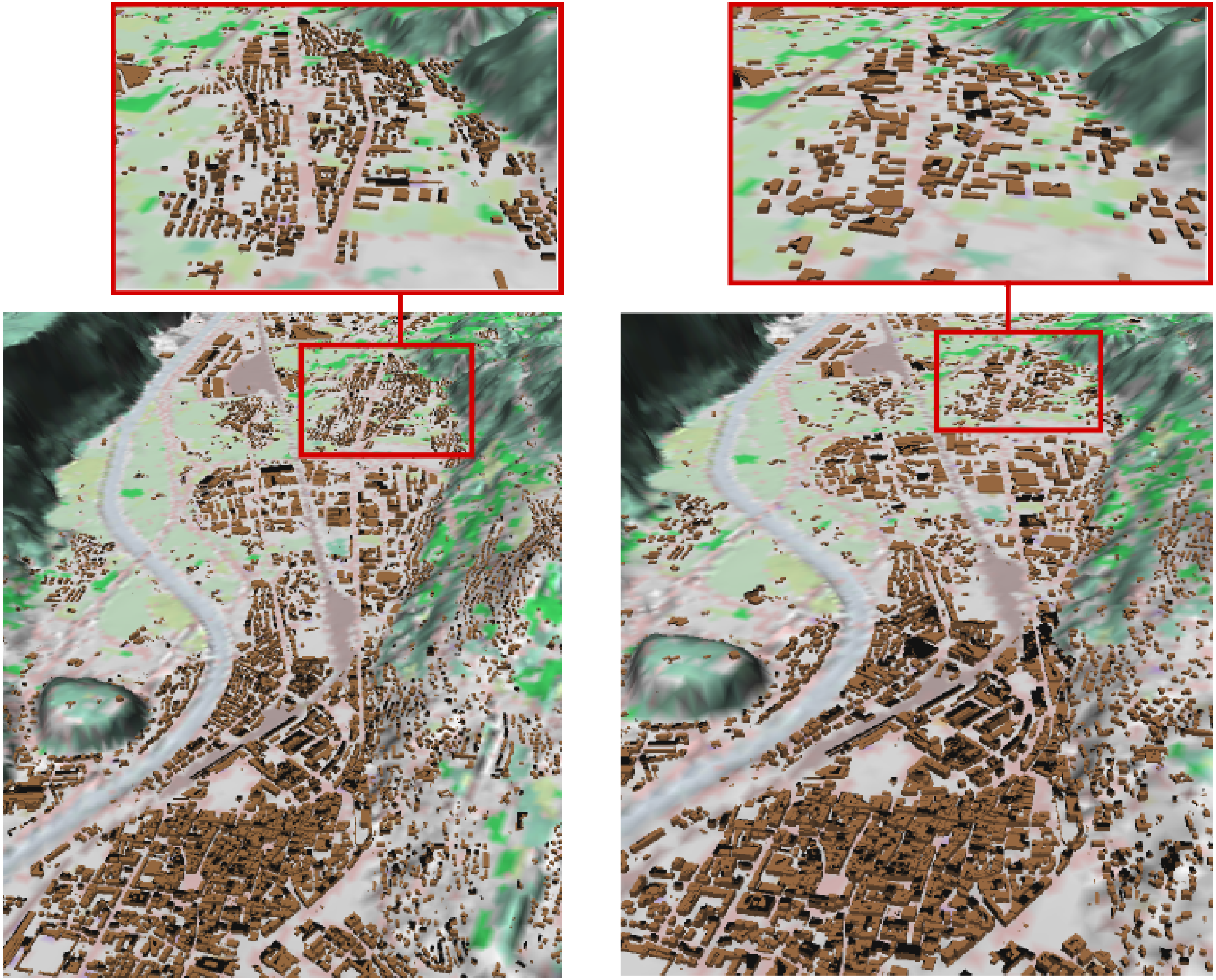
Quarters and Sizes of Buildings Generalization: Appropriate (upper) and Too Large (lower).

Base buffer widths and appropriate resolutions of generalization of buildings.

Base buffer width (in meters) used to generate quarters' map (number of level in hierarchical tree)	Resolutions of generalization, (in meters)
original buildings (0)	original buildings
original buildings (0)	10
original buildings (0)	15
1.0 (1)	20
1.0 (1)	25
1.2 (2)	30
1.4 (3)	40
1.6 (4)	50
1.8 (5)	60

Different levels of generalization (according to distances from view point)





Stage 3. Evaluation of the quality of generalization and 3D scene compilation using information theory and entropy.

1) Information content of map calculated by Coordinate Digit Density (CDD) function:

$$P(d_n) = \frac{1}{Sn} \quad (1); \quad D_n = O(d_n) - P(d_n) \quad (2);$$

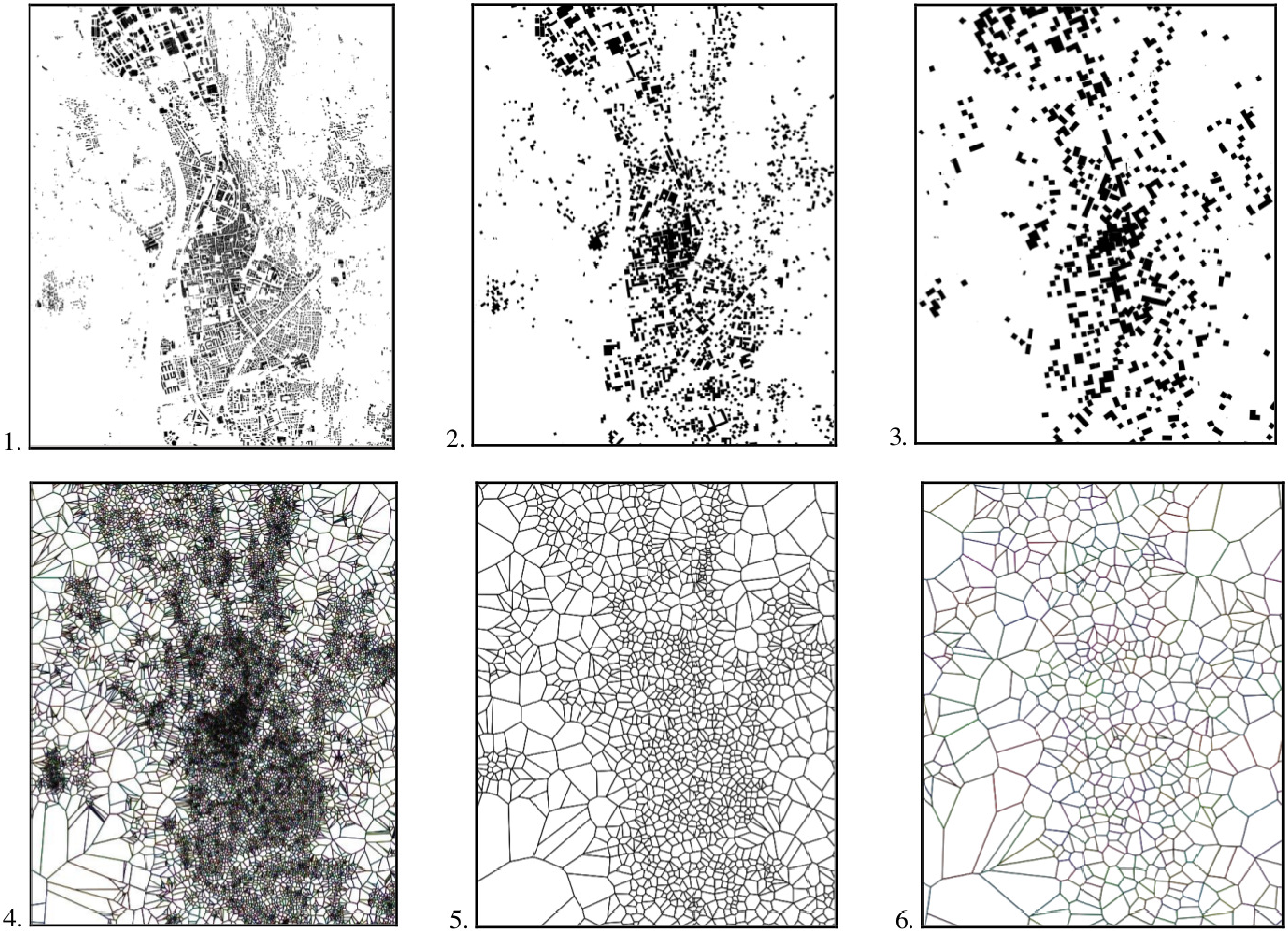
$$H(n) = \sum_{1}^{s} \left| D_n(s) \right| \quad (3); \quad I = \sum_{0}^{n} H(n) \quad (4);$$

2) Entropy of Voronoi regions:

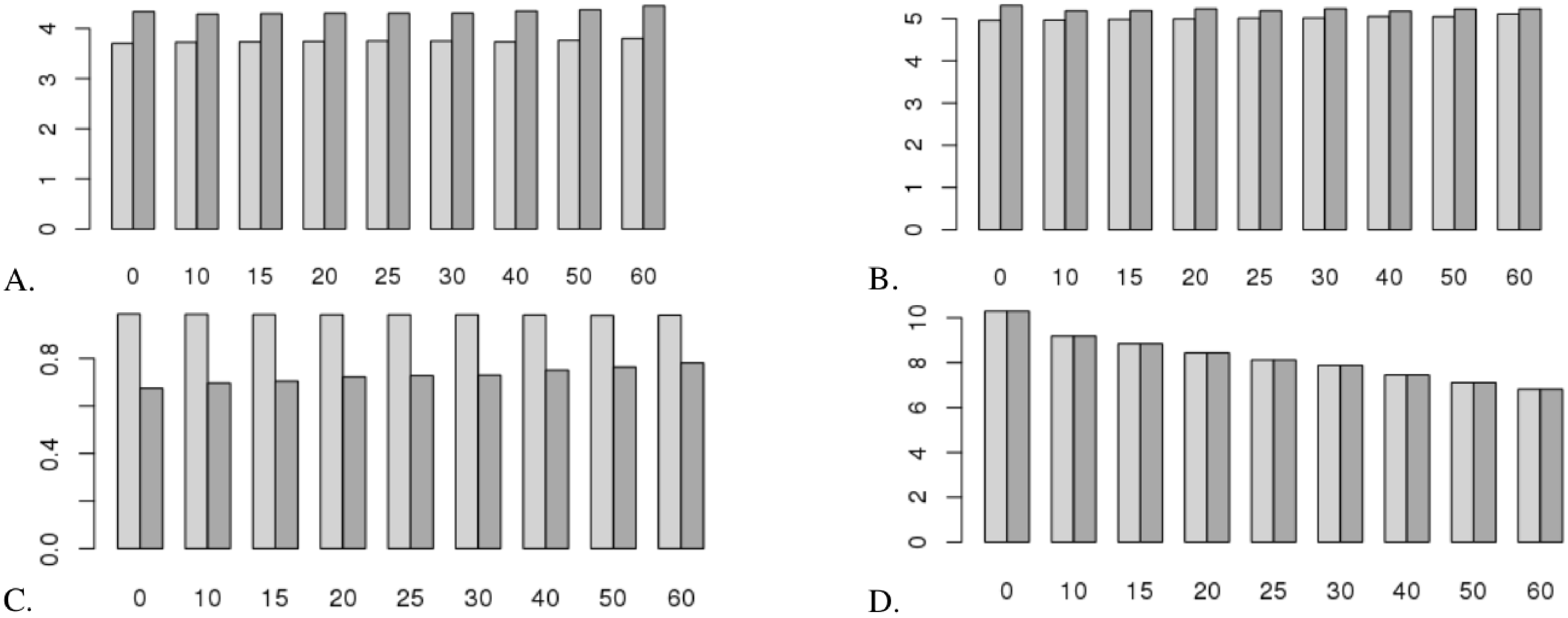
$$H = -\sum_{1}^{n} \frac{Si}{S} (\ln Si - \ln S) \quad (5); \quad H_N = \frac{H(M)}{\log_2 n} \quad (6);$$

3) Entropy of Voronoi neighbors:

$$H = \sum_{j=1}^{Mj} \frac{n_j}{N_j} \ln \left(\frac{n_j}{N_j} \right) \quad (7);$$

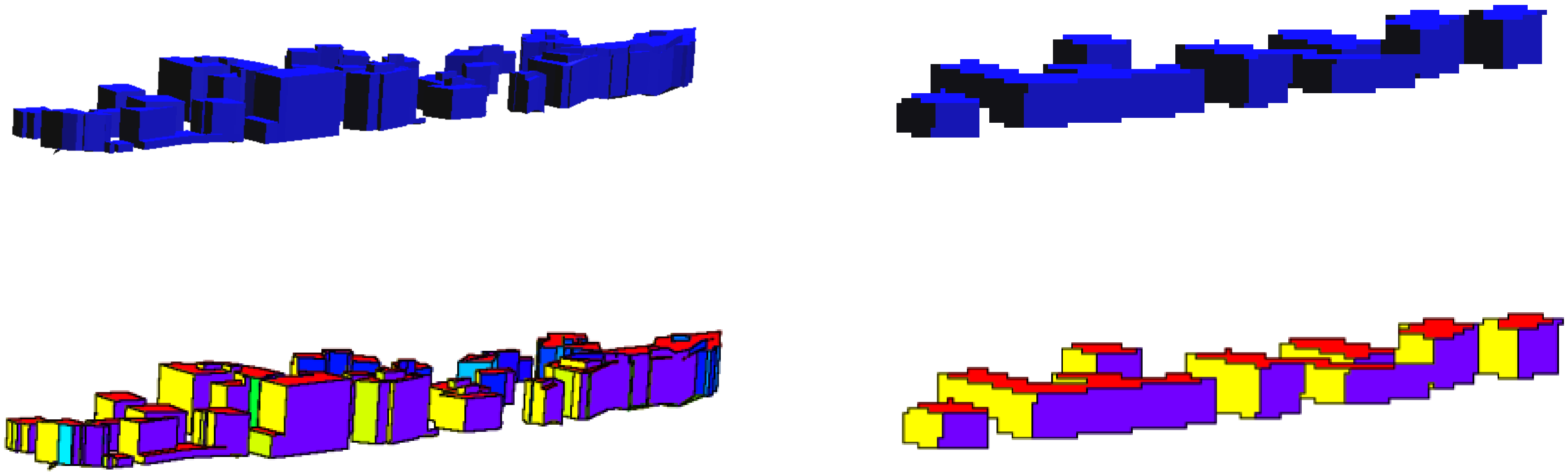

1.
2.
3.
4.
5.
6.

Information content (entropy) of buildings layers (dark gray bars) and random Voronoi maps (light gray bars). Vertical axis is entropy, horizontal degree of generalization (0-original buildings)

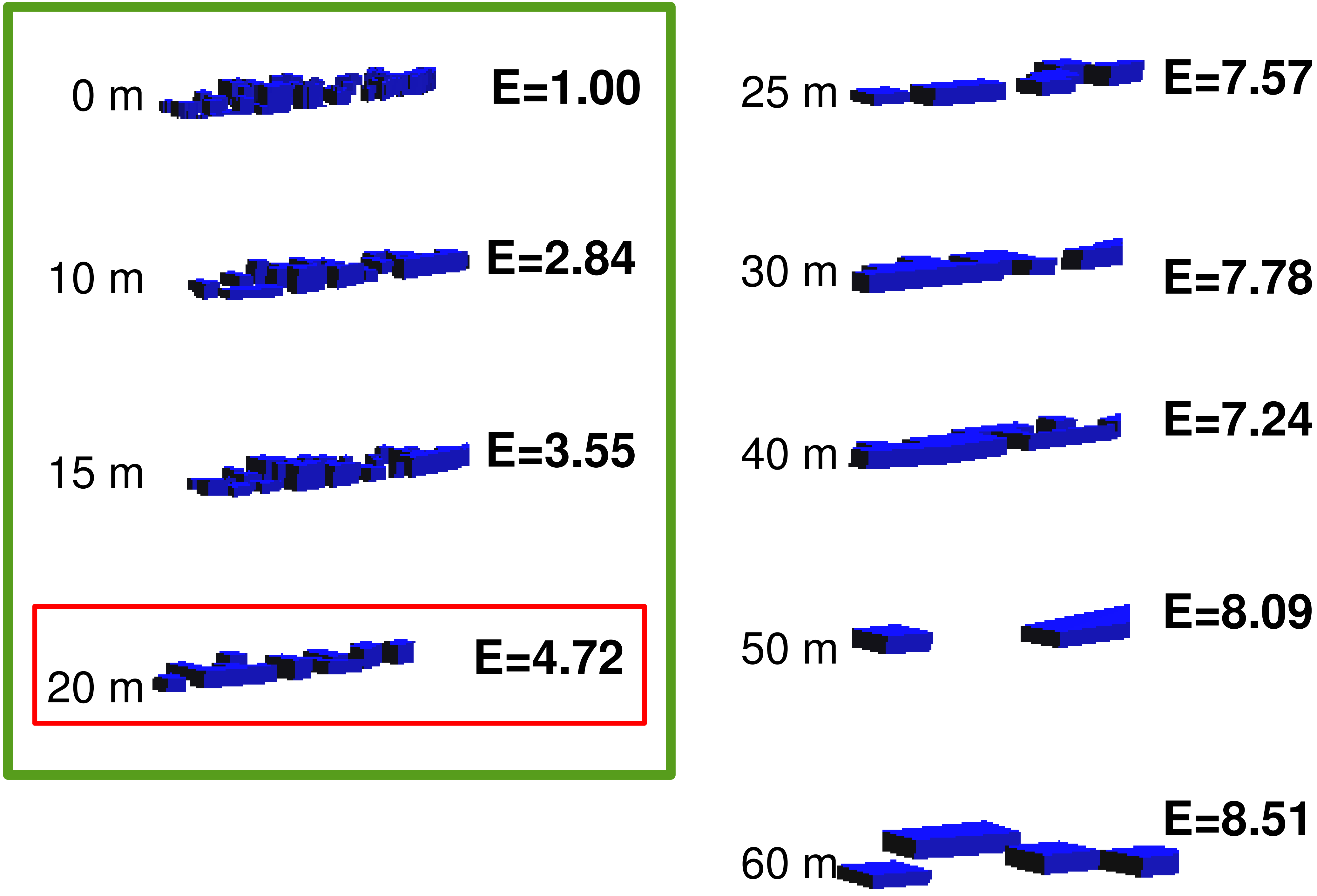


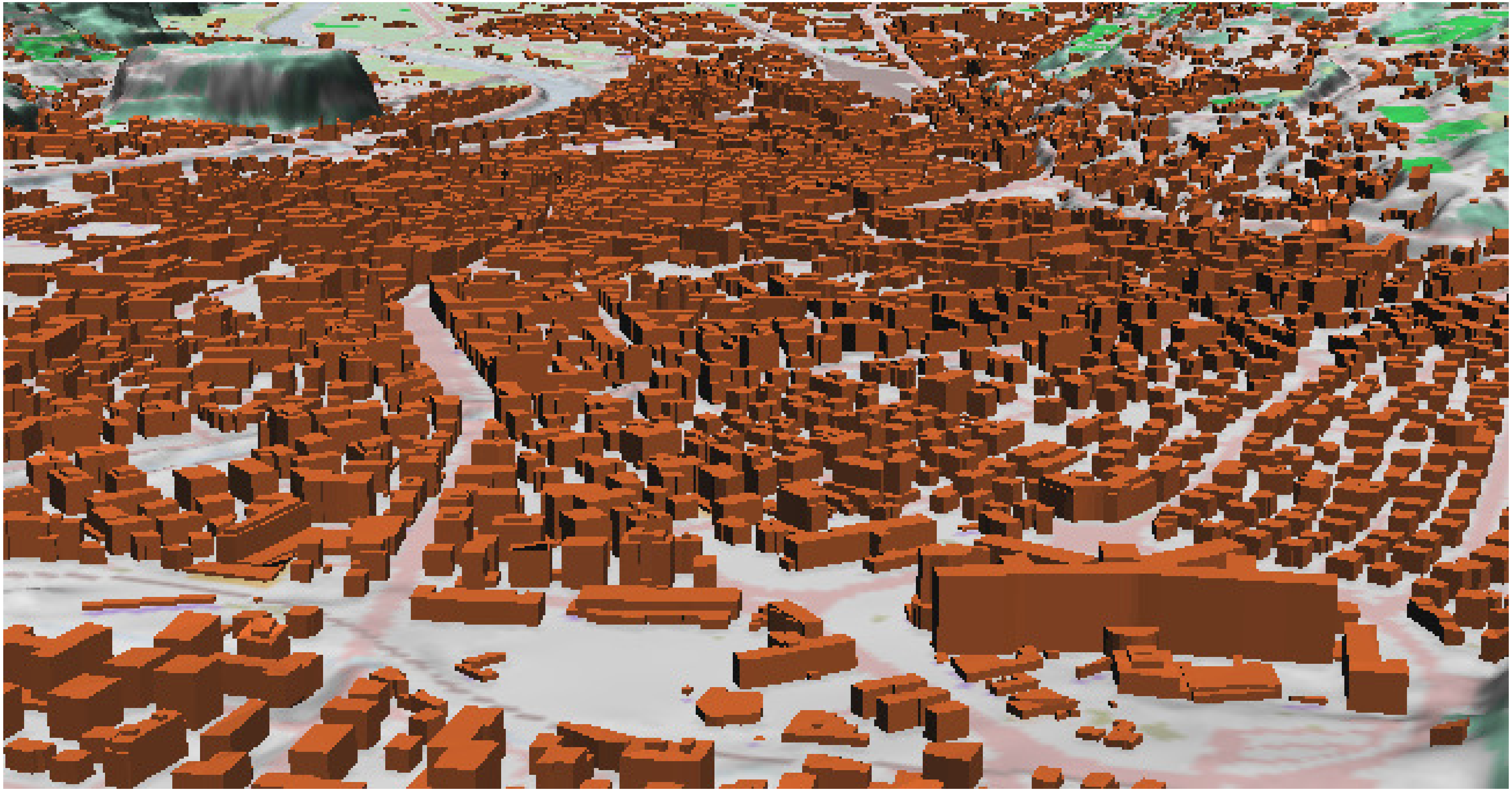
$$H = -\sum_{1}^{n} \frac{Si}{S} (\ln Si - \ln S)$$

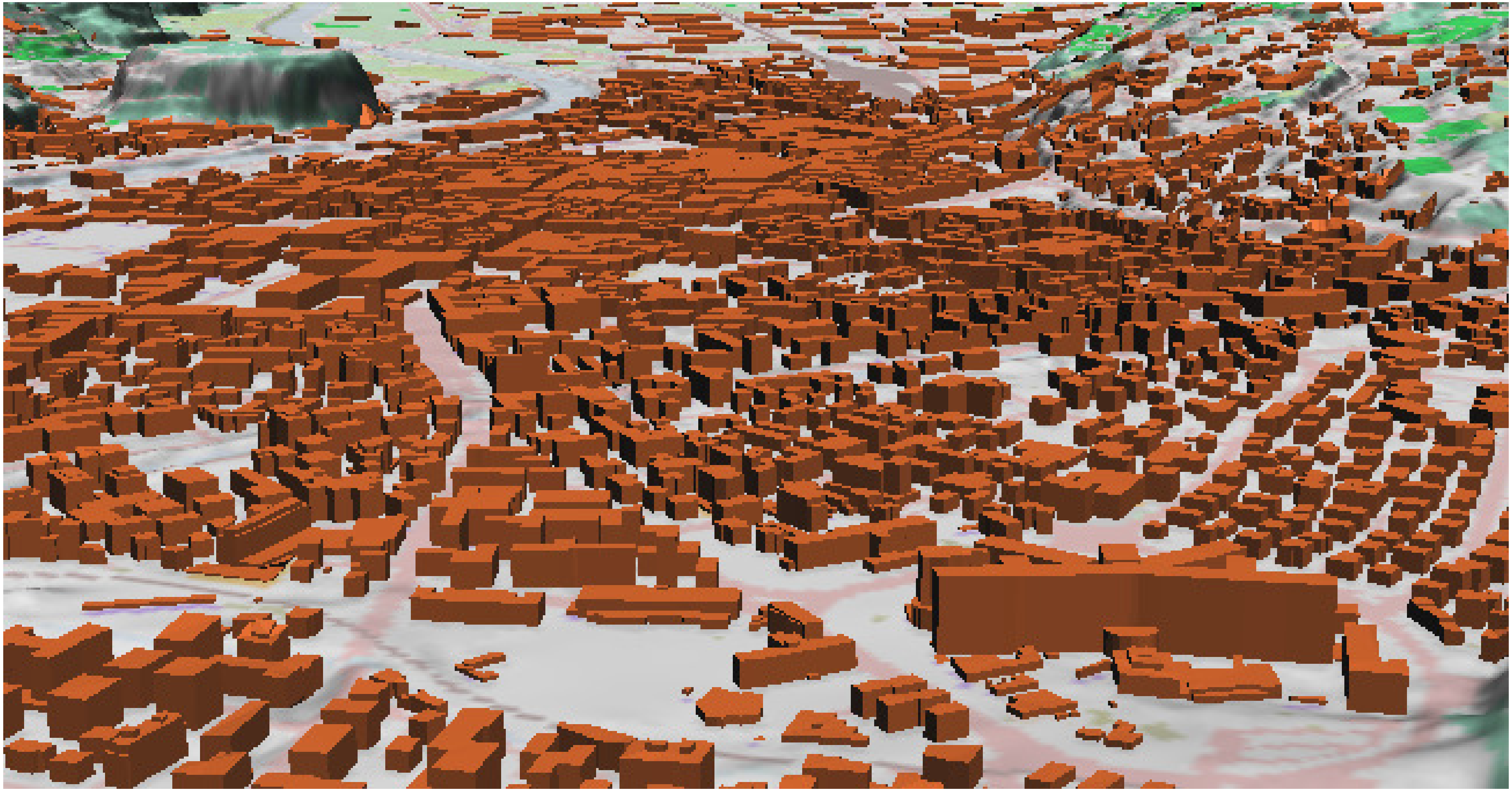
$$E = \left| \frac{Hg\_c - Horig\_c}{Hg\_0 - Horig\_0} \right|, \text{ until } E \leq 7$$



E = 4.72


0 m
E=1.00
10 m
E=2.84
15 m
E=3.55
20 m
E=4.72
25 m
E=7.57
30 m
E=7.78
40 m
E=7.24
50 m
E=8.09
60 m
E=8.51





The Reduction Level of the Problem

	Number of nodes	Number of polygons	Speed of 3D scene generating, seconds
Original building layer	114,197	12,527	10.2
Generalized building layer used for 3D	38,343	4,552	3.4

Next Phase:

To implement a parallel processing - aiming at a reducing level of the current results by a factor of 10-20

Conclusion

- ➔ It has been suggested a qualitatively new approach to generalization, which consists of taking into consideration relationships, influences and spatial relationships of objects in a real geographical environment.

- ➔ In performing this approach it will basically provide a cartographic, not just the mathematical, approach for generalization of a 3D urban environment.

- ➔ The contribution of this approach is that it will offer a comprehensive solution to the 3D cartographic generalization problem by enabling the generalization of 3D building models, which will allow a continuous and smoothed 3D representation of the urban environment.

Thank You for Listening

Acknowledgments:
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