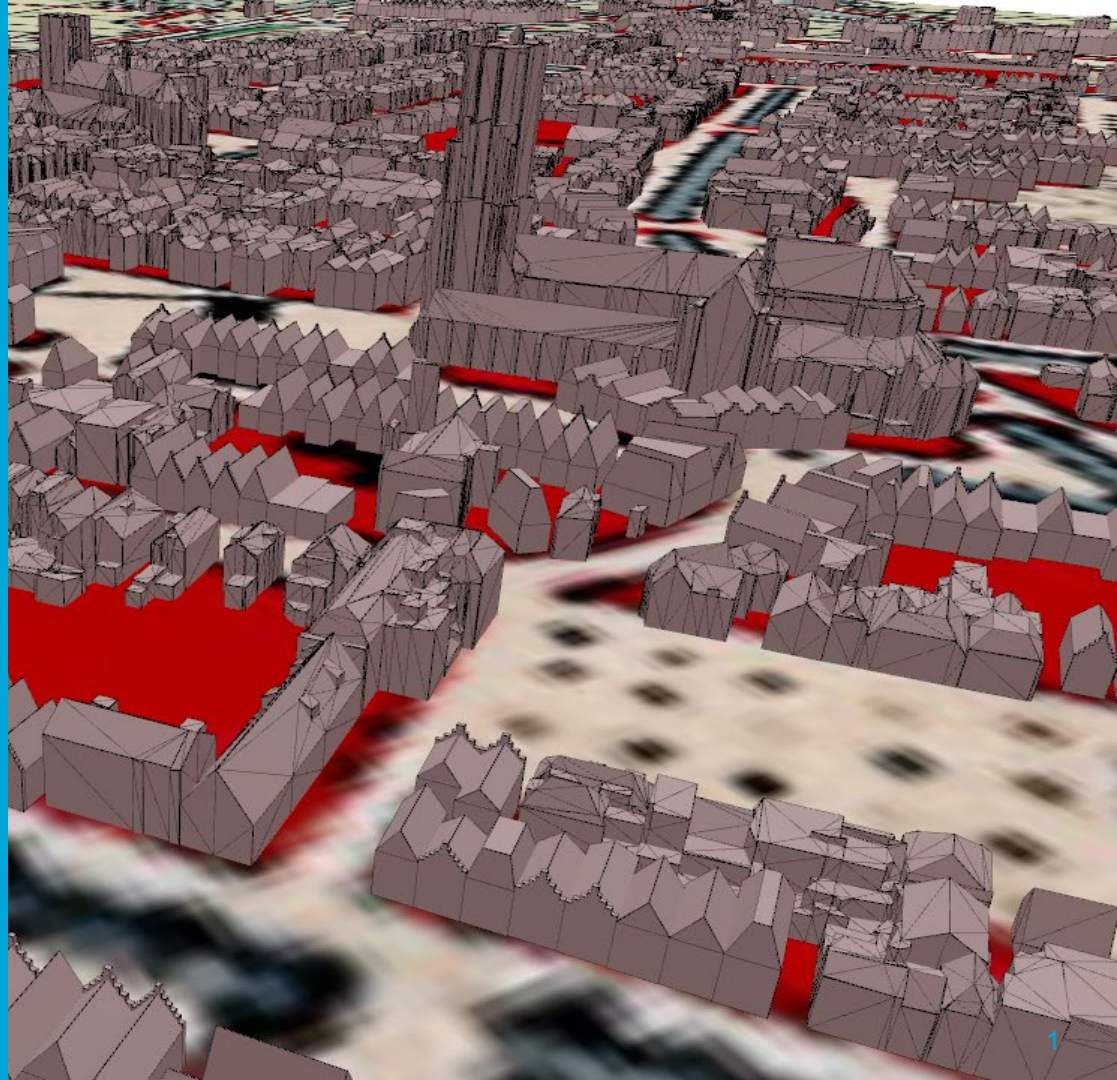


Automatic reconstruction of 3D city models from historical maps

Camille Morlighem
June 2021

1st supervisor: Dr. Hugo Ledoux

2nd supervisor: Anna Labetski



Content

- Introduction
- Related work
- Methodology
- Results and analysis
- Conclusion

Content

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- Related work
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- Conclusion

Motivation

Historical maps?

Invaluable source of information...

about the pre-satellites era...

in many domains....

John Snow, London 1854

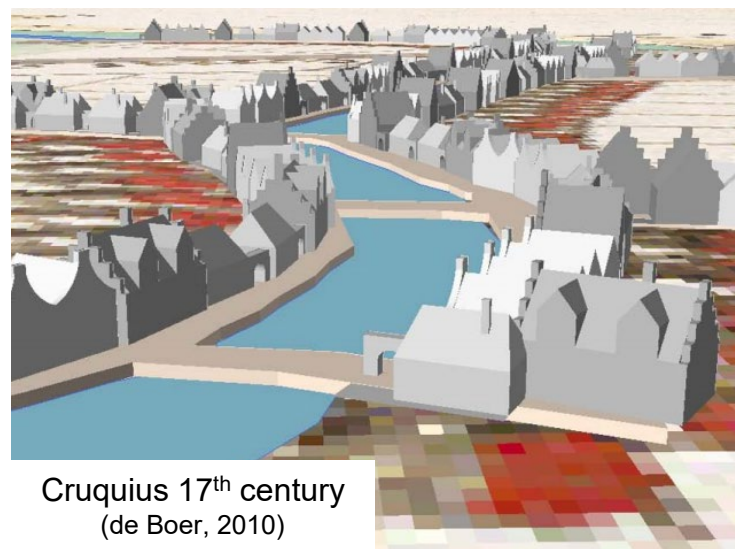


Motivation

Historical 3D city models?



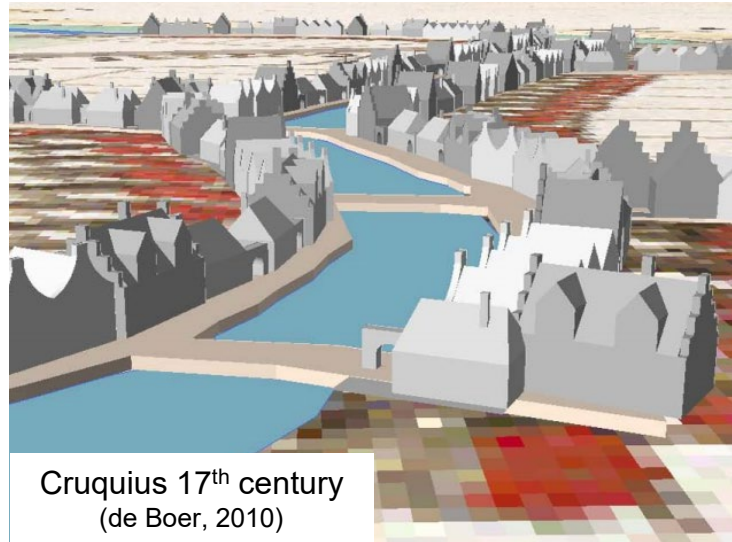
Highly detailed



Simple

vs.

Research question



Cruquius 17th century
(de Boer, 2010)

“To what extent can be automated the process of reconstructing simple 3D city models from historical maps?”

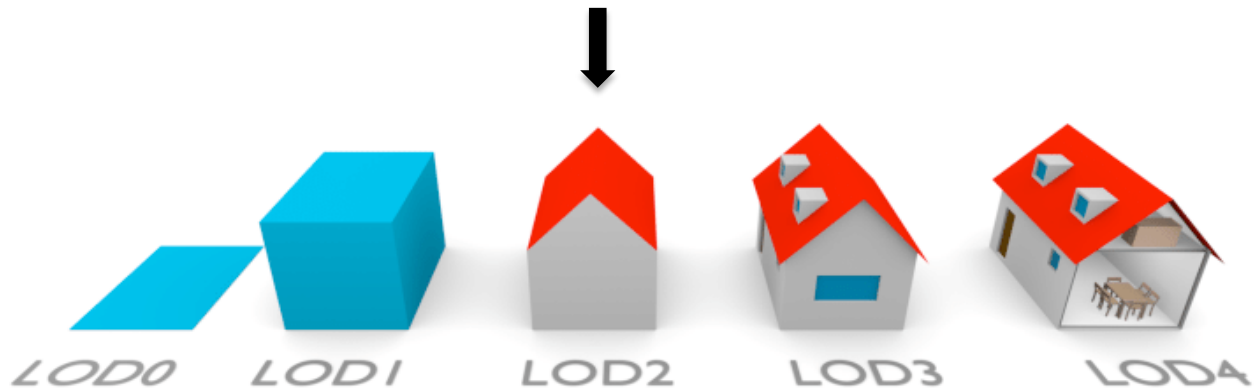
Objectives

1. Comparison of existing methods

Objectives

2. Automated methodology

- Models LoD2 buildings
- Maximises accuracy



Source: Biljecki et al. [2016]

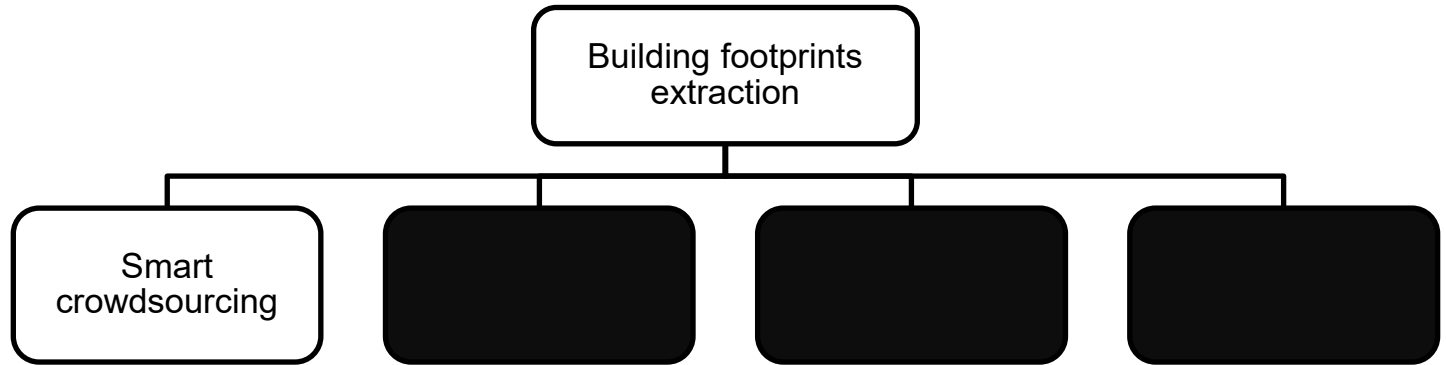
Content

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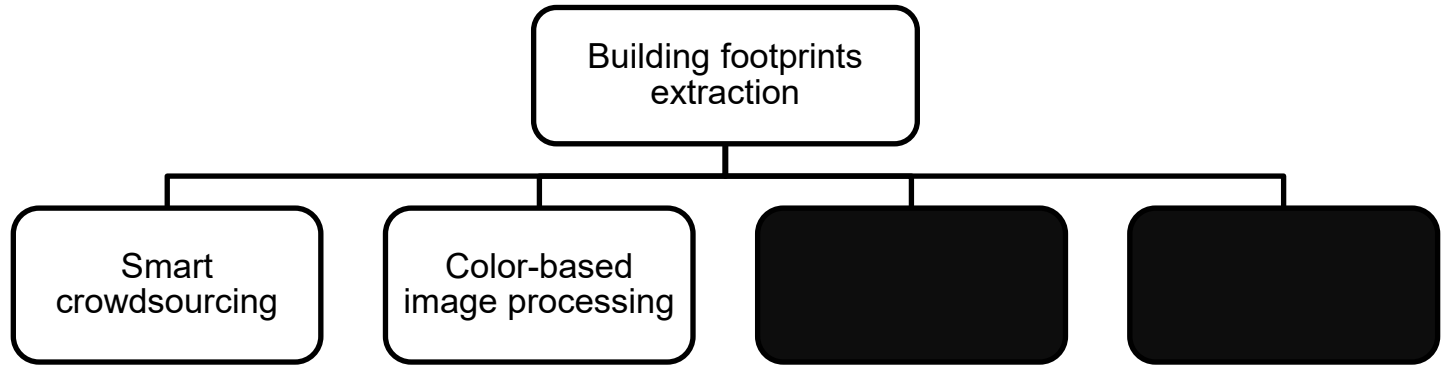
Related work

Building footprints
extraction

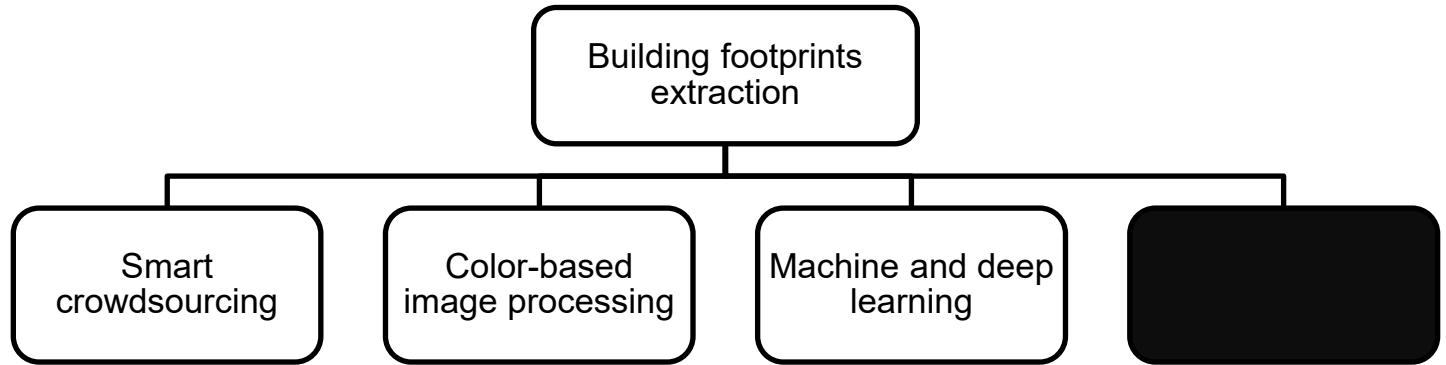
Related work



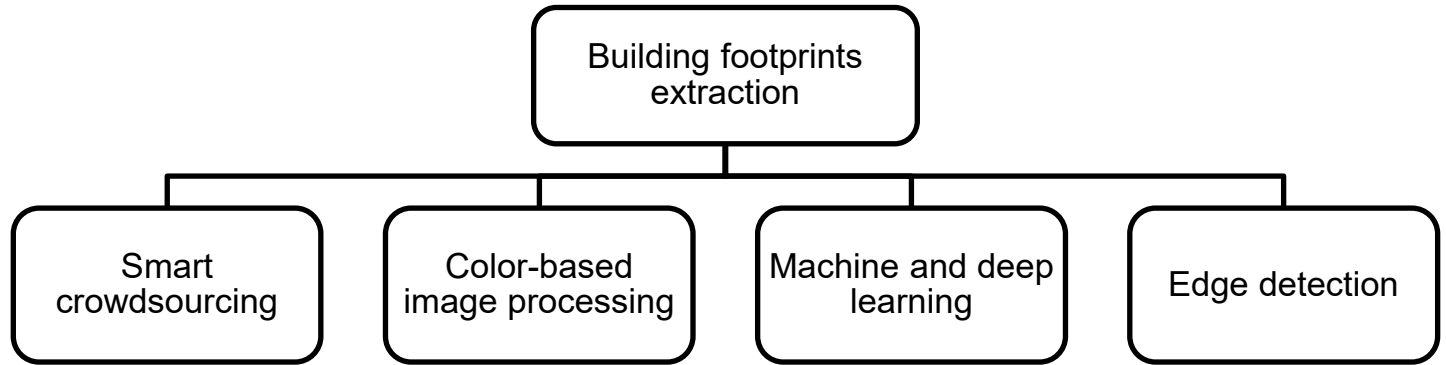
Related work



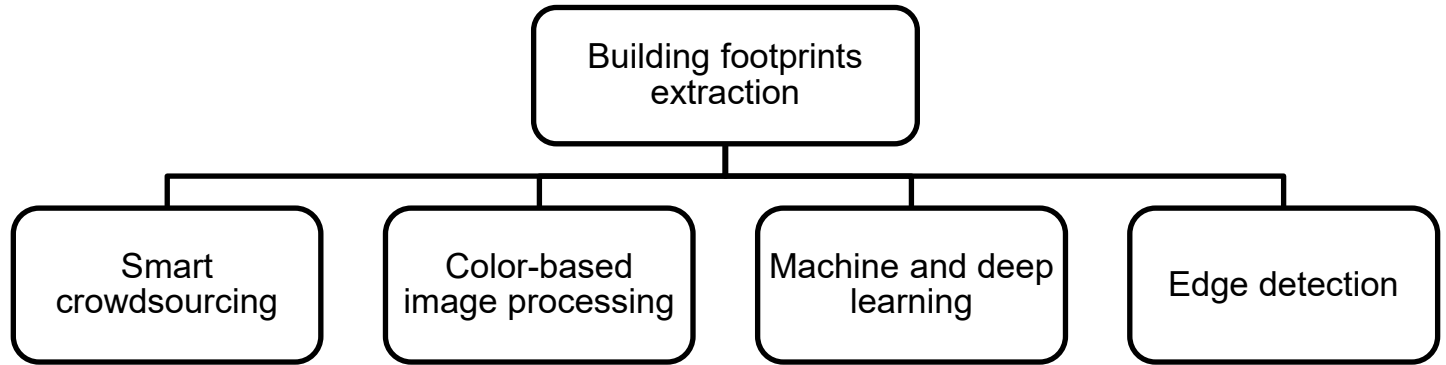
Related work



Related work

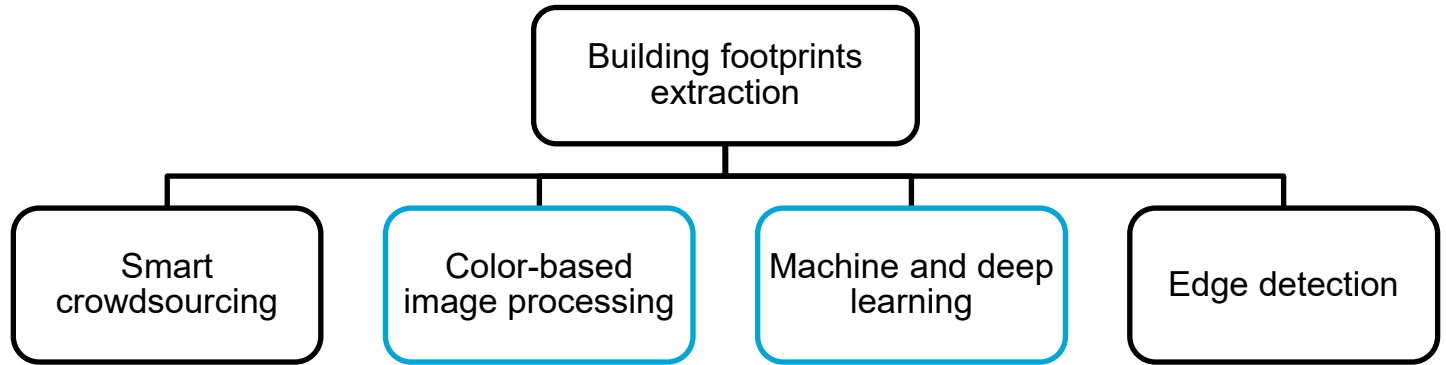


General observations



→ No perfect method

General observations



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Case studies

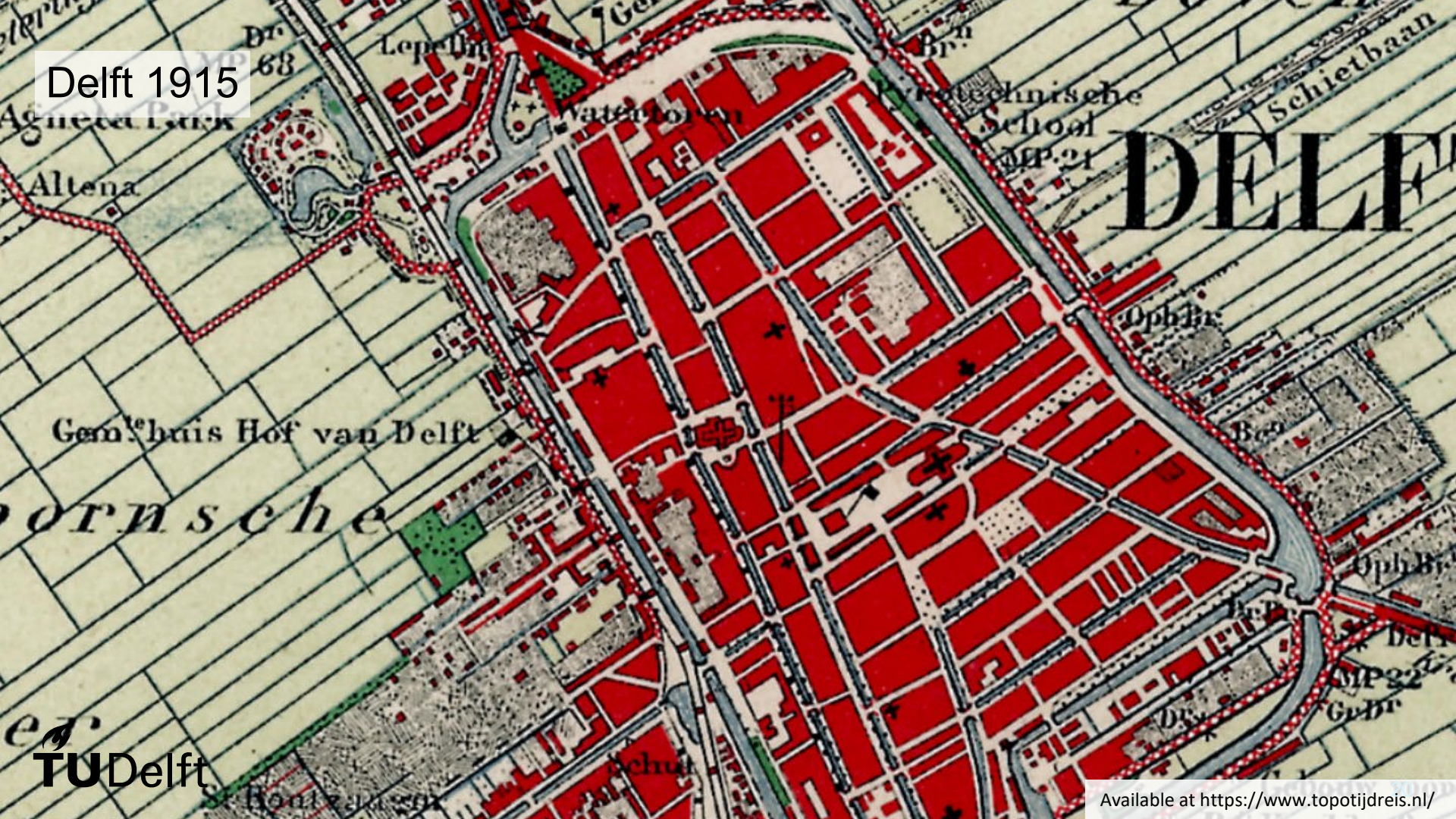
- Delft

Implement the methodology

- Brussels

Test the application of the methodology for other study areas

Delft 1915



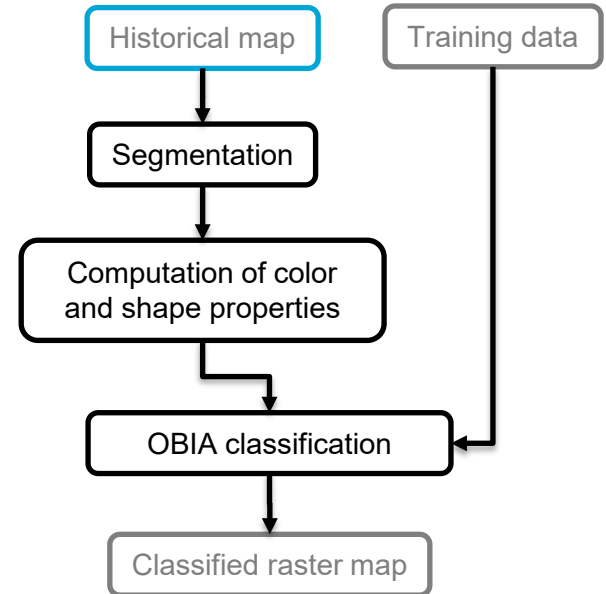
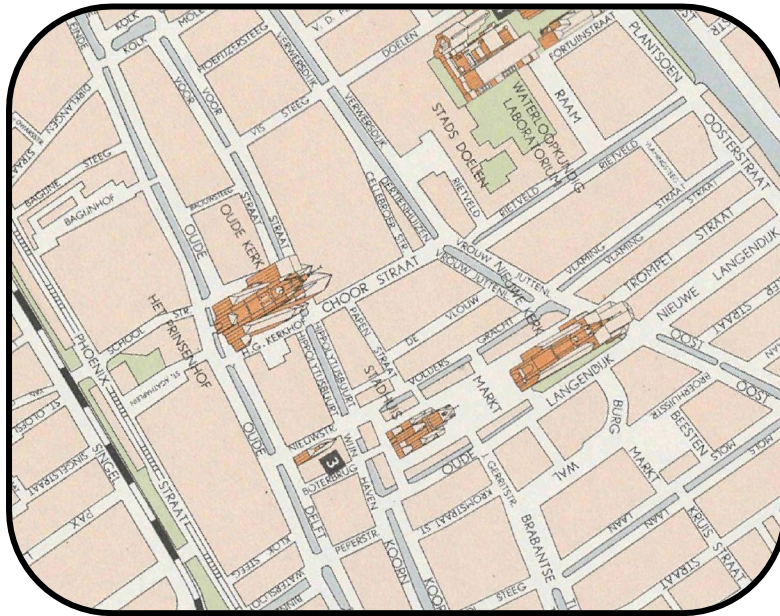
Delft 1961



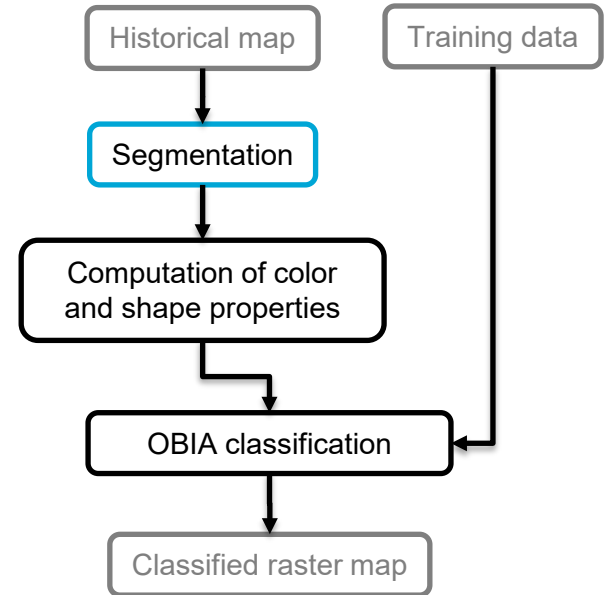
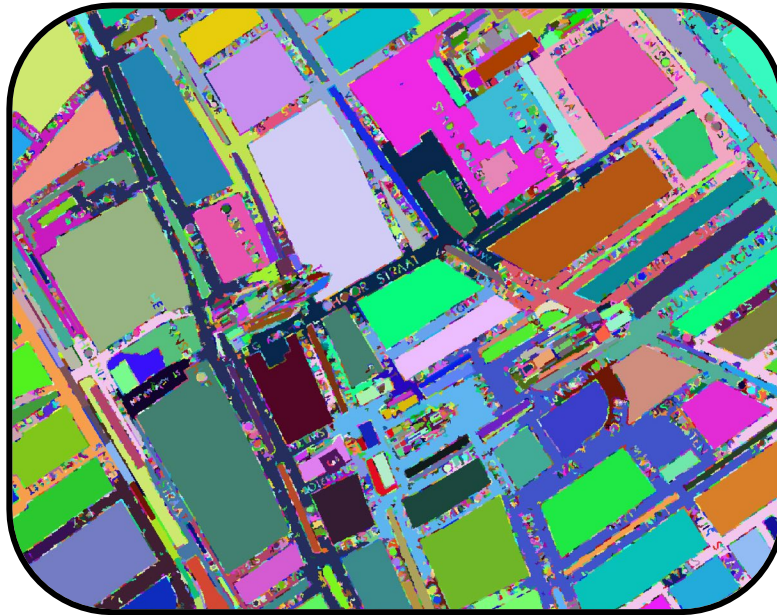
Brussels 1700



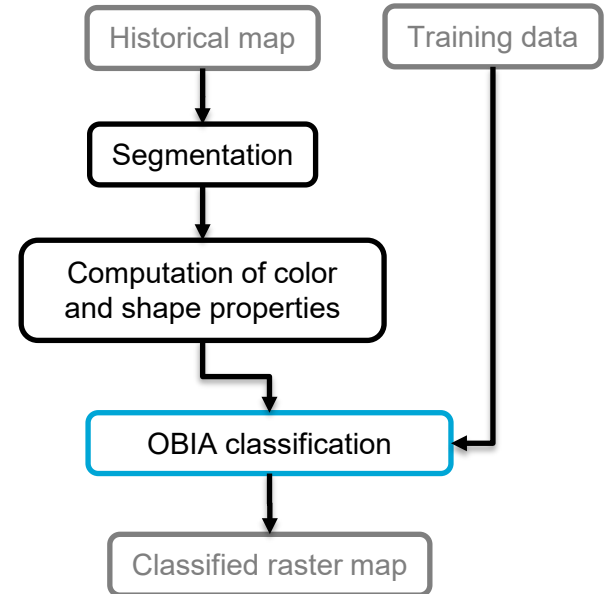
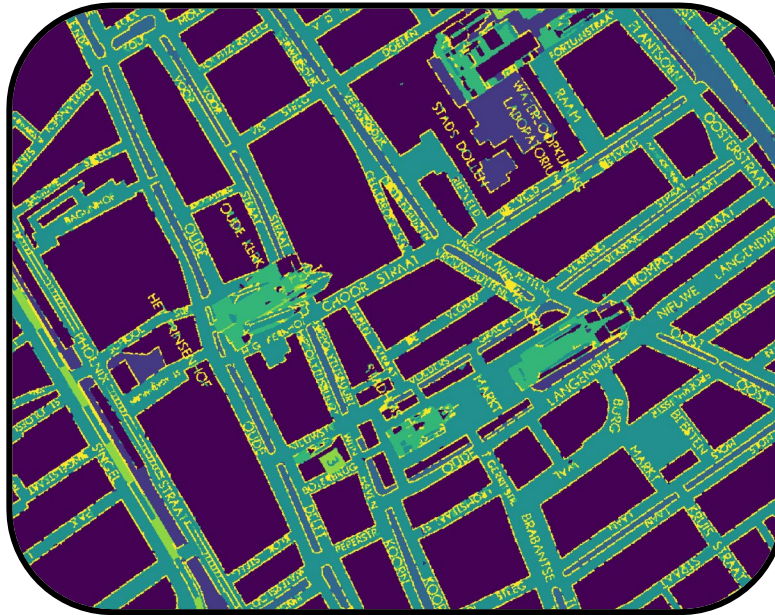
Building plots extraction



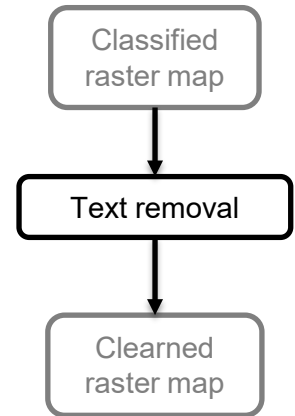
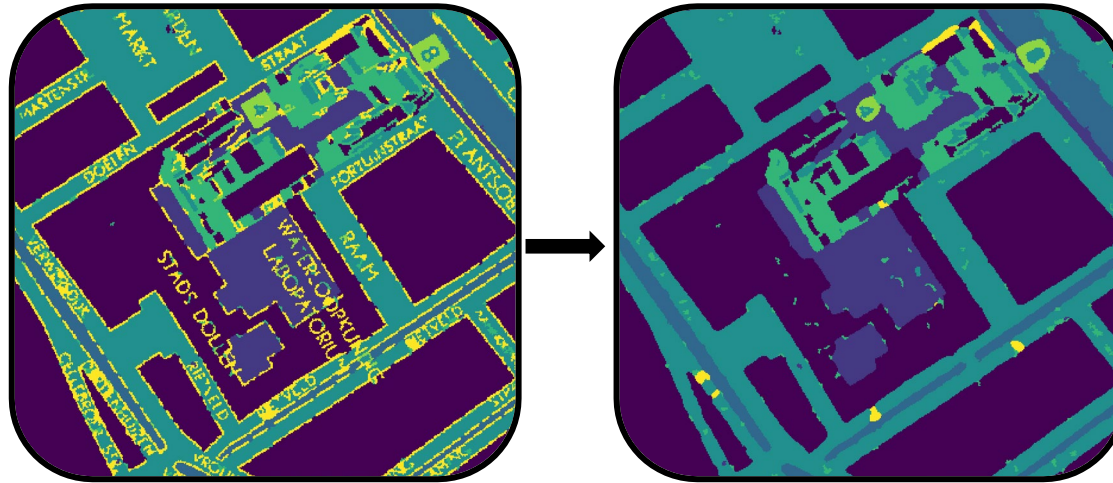
Building plots extraction



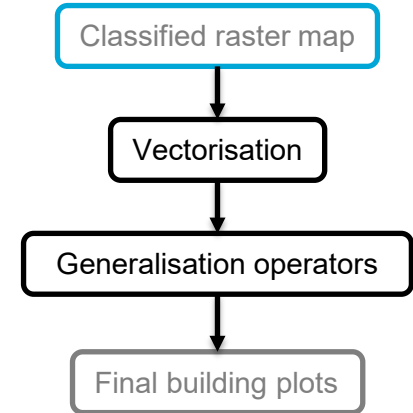
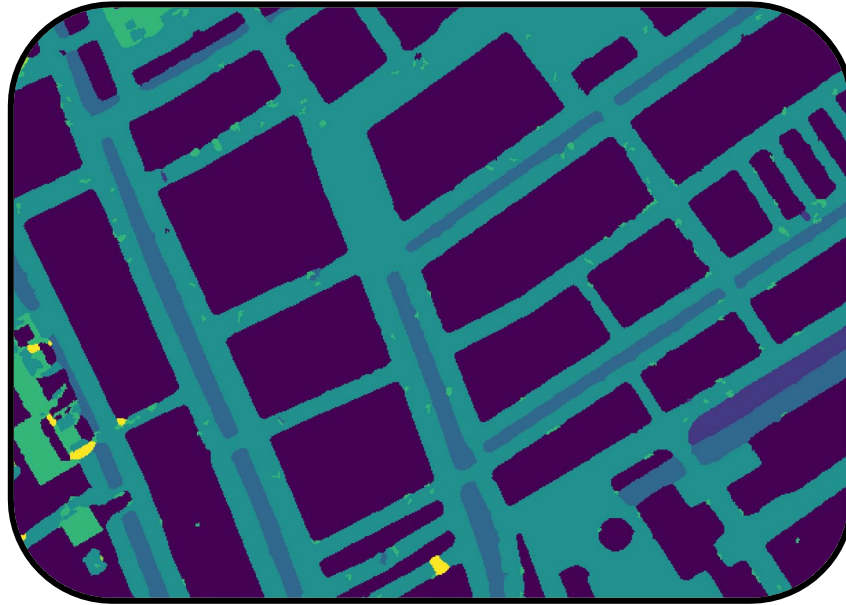
Building plots extraction



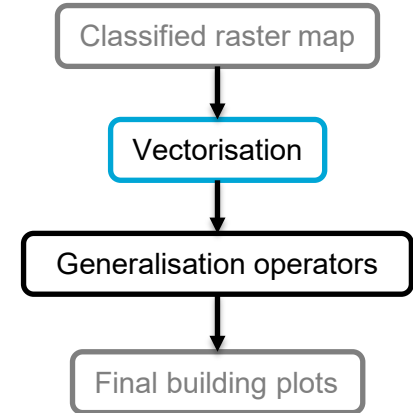
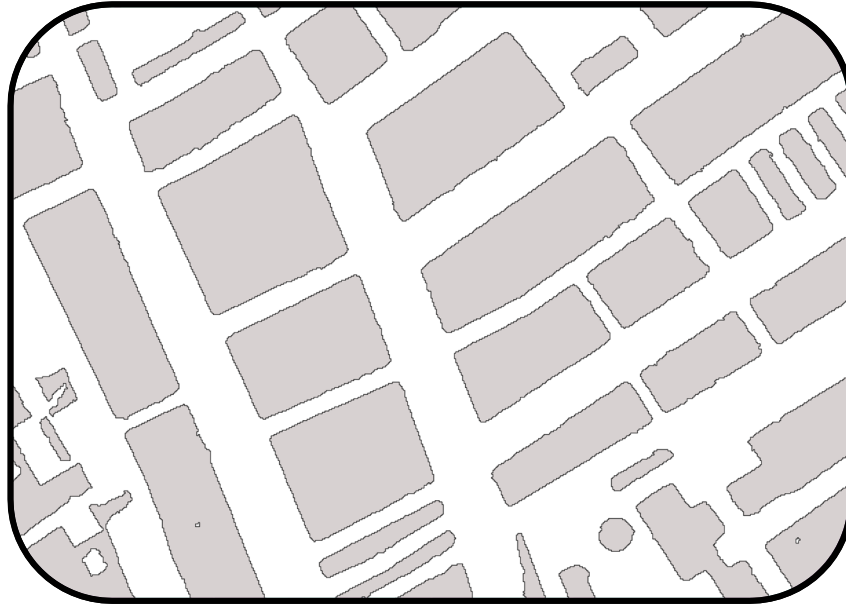
Building plots extraction



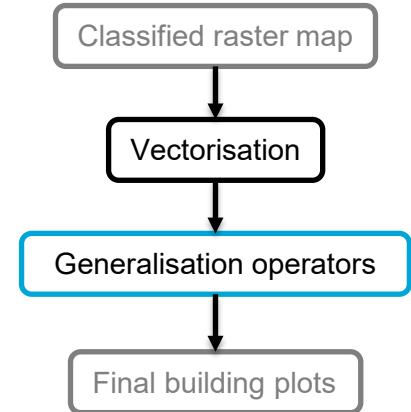
Building plots extraction



Building plots extraction

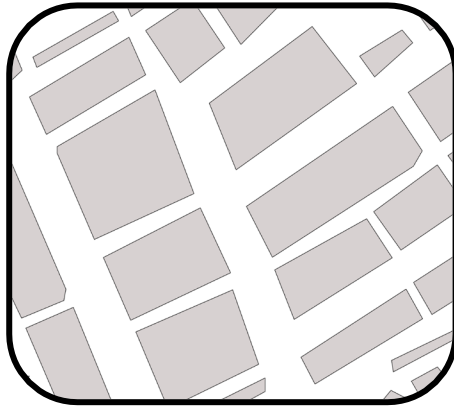


Building plots extraction



Reconstruction of individual footprints

1. Maps alignment



Historical building plots

+



Building footprints 2021

=



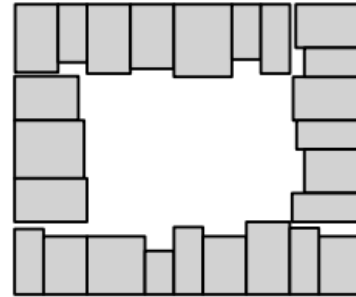
Aligned entities

Reconstruction of individual footprints

2. 2D procedural modelling



Building plot

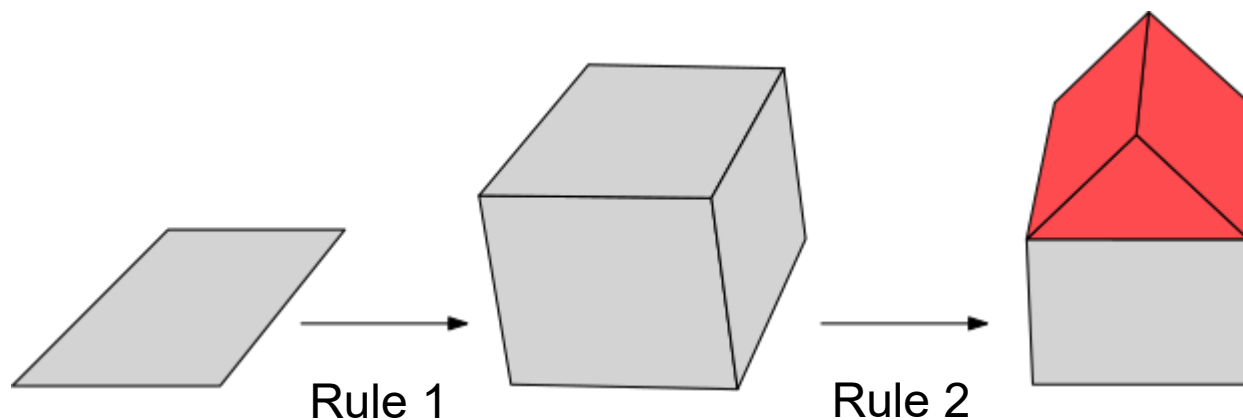


Building footprints

LoD2 buildings generation

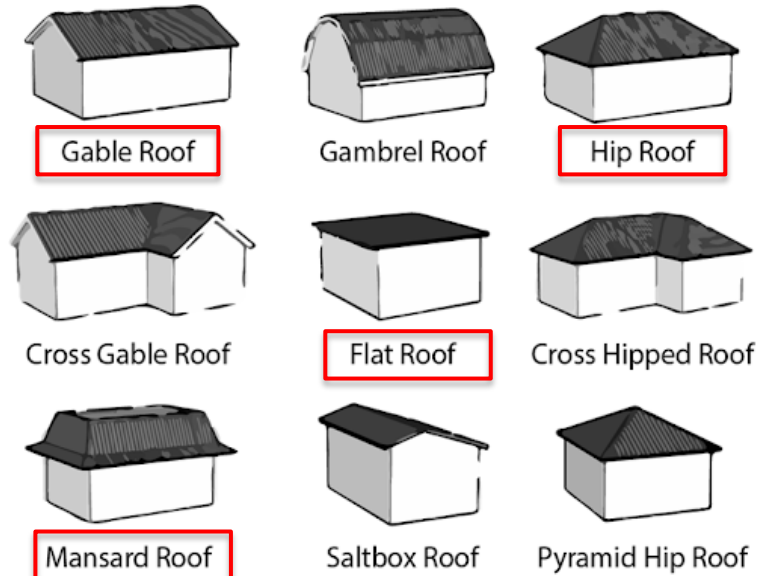
3D procedural modelling

Generate LoD2 buildings automatically from the building footprints using a set of rules



LoD2 buildings generation

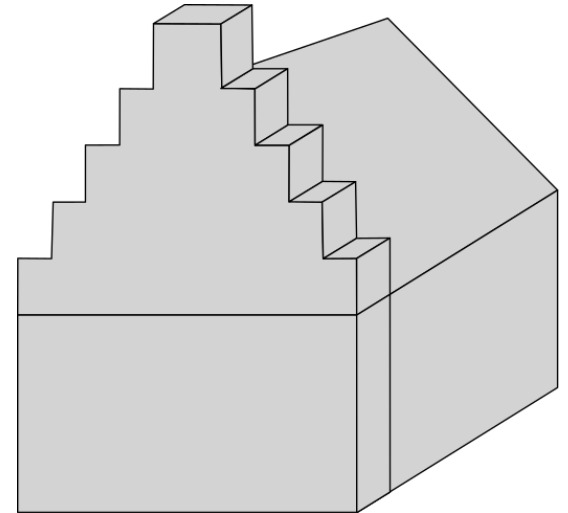
Blender addon



Source: Bondright Roofing Services [nd]

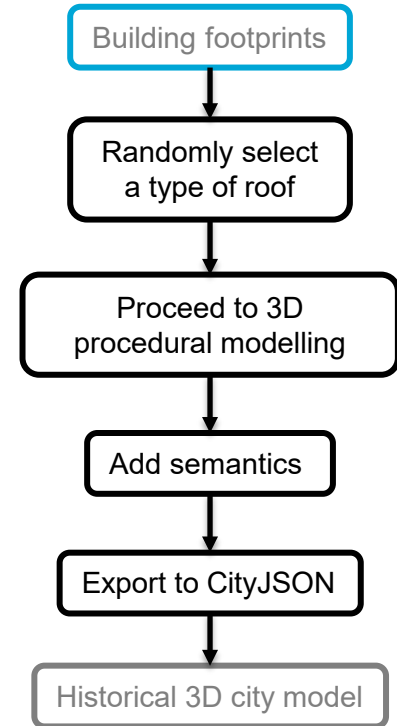
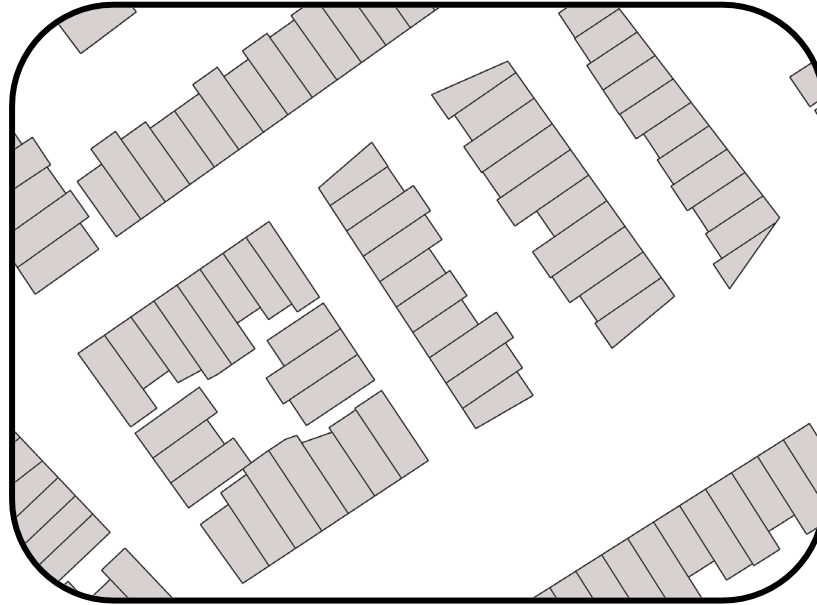
LoD2 buildings generation

Crow-stepped gable roofs

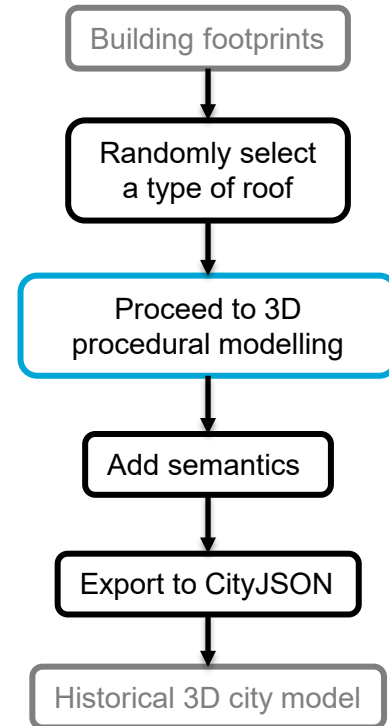
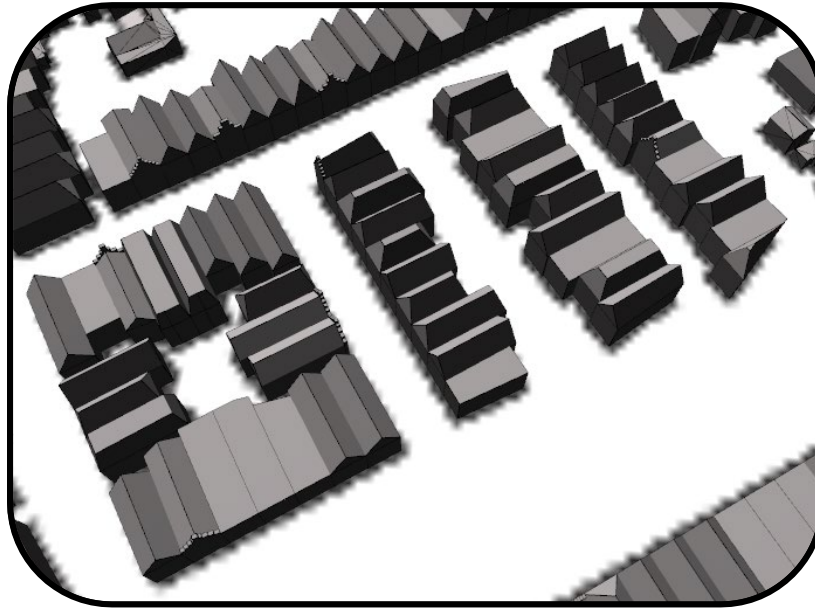


Source: Ryckaert [2012]

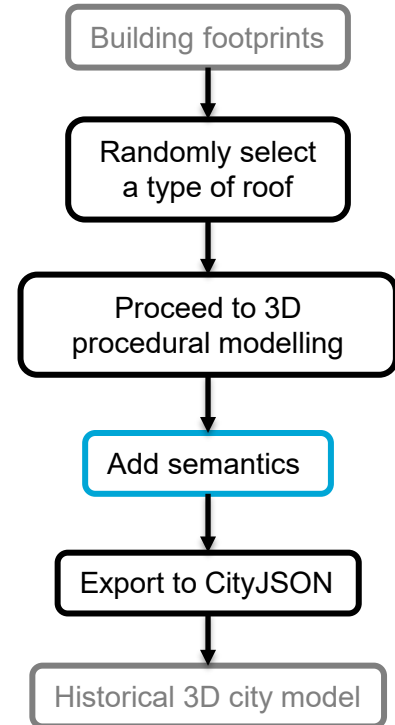
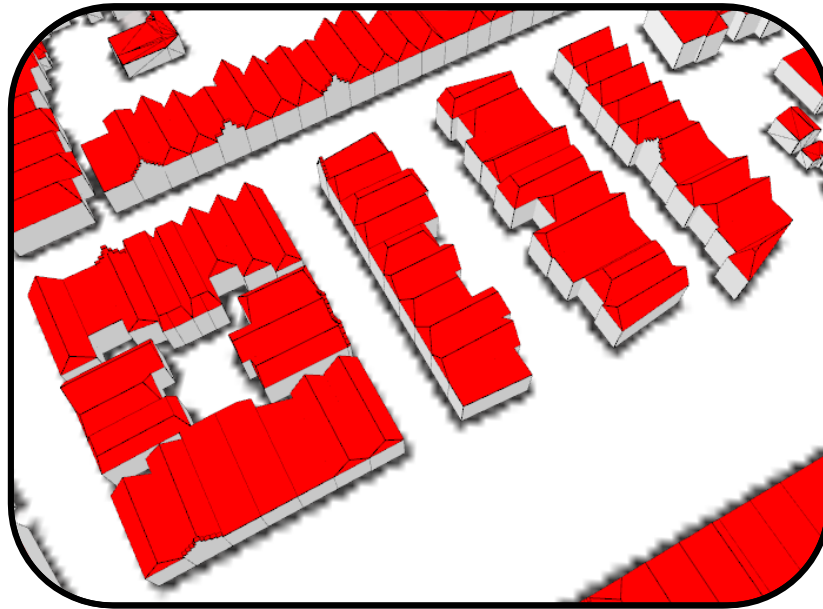
LoD2 buildings generation



LoD2 buildings generation



LoD2 buildings generation



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Building plots extraction

Performance assessment

- Recall

Percentage of building plots properly identified in the ground truth

- Precision

Percentage of features classified as building plots and that are indeed building plots in the ground truth

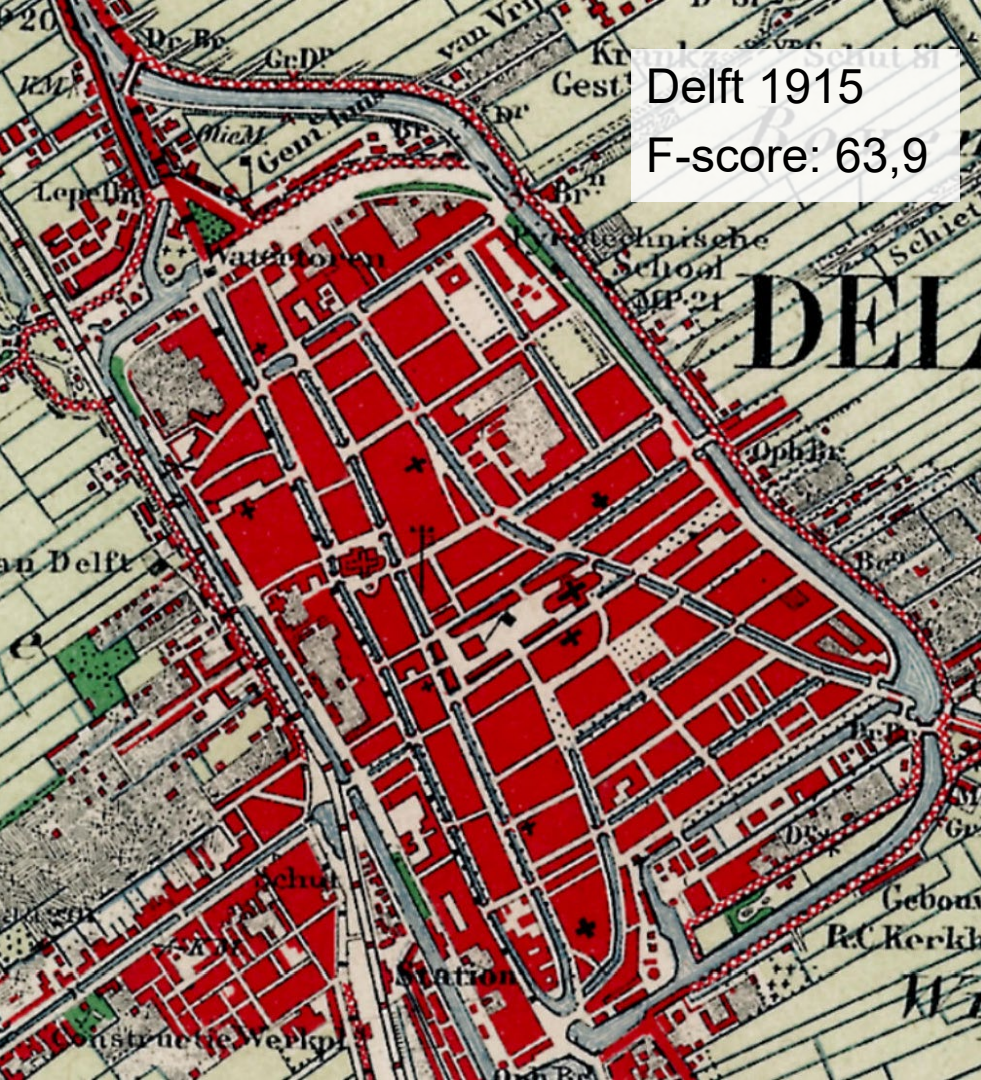
- F-score

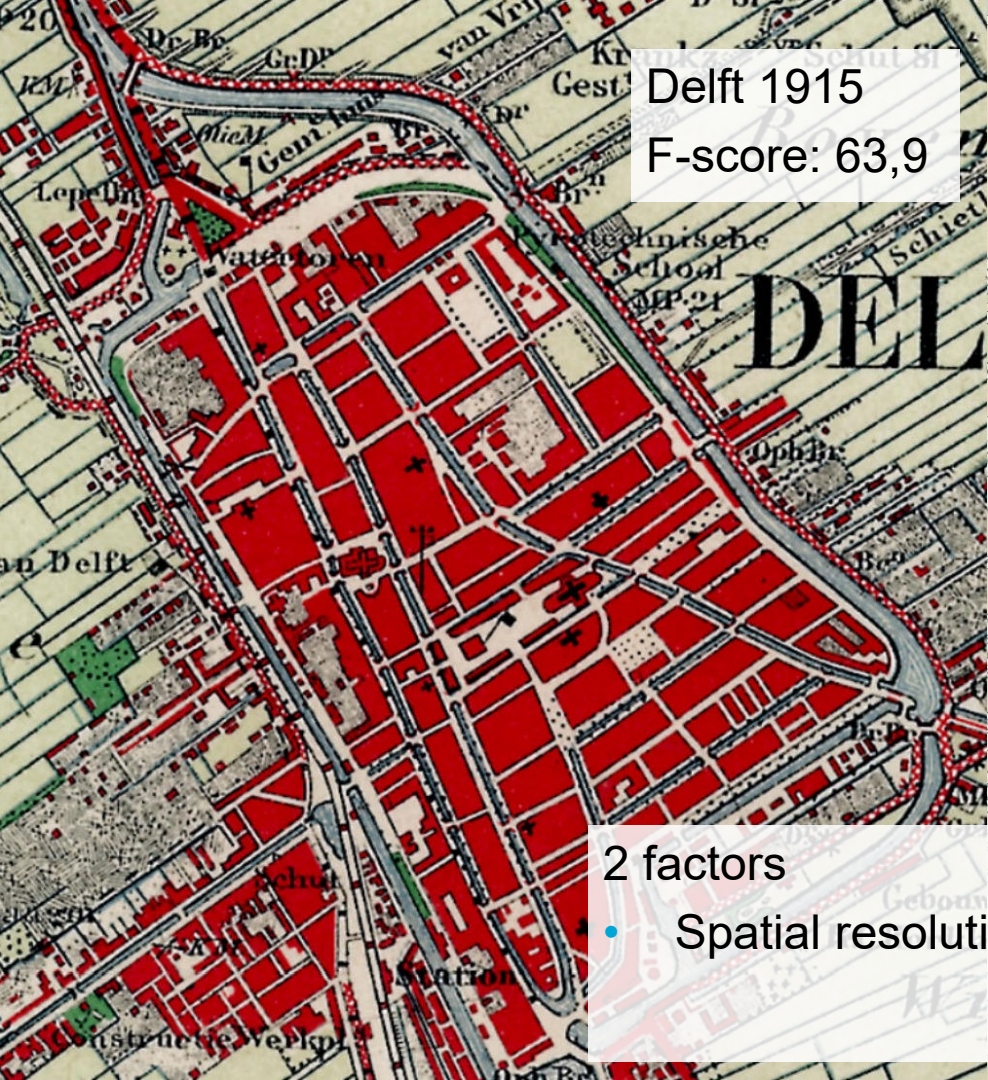
Function of the two metrics

Building plots extraction

Historical maps	Precision	Recall	F-score
Delft 1880	60.7	67.4	63.9
Delft 1915	92.7	56.0	69.9
Delft 1961	93.6	88.9	91.2
Delft 1982	95.4	90.5	92.9
Brussels 1700	78.7	89.5	83.7
Brussels 1890	89.7	84.6	87.0
Brussels 1924	92.7	85.3	88.9

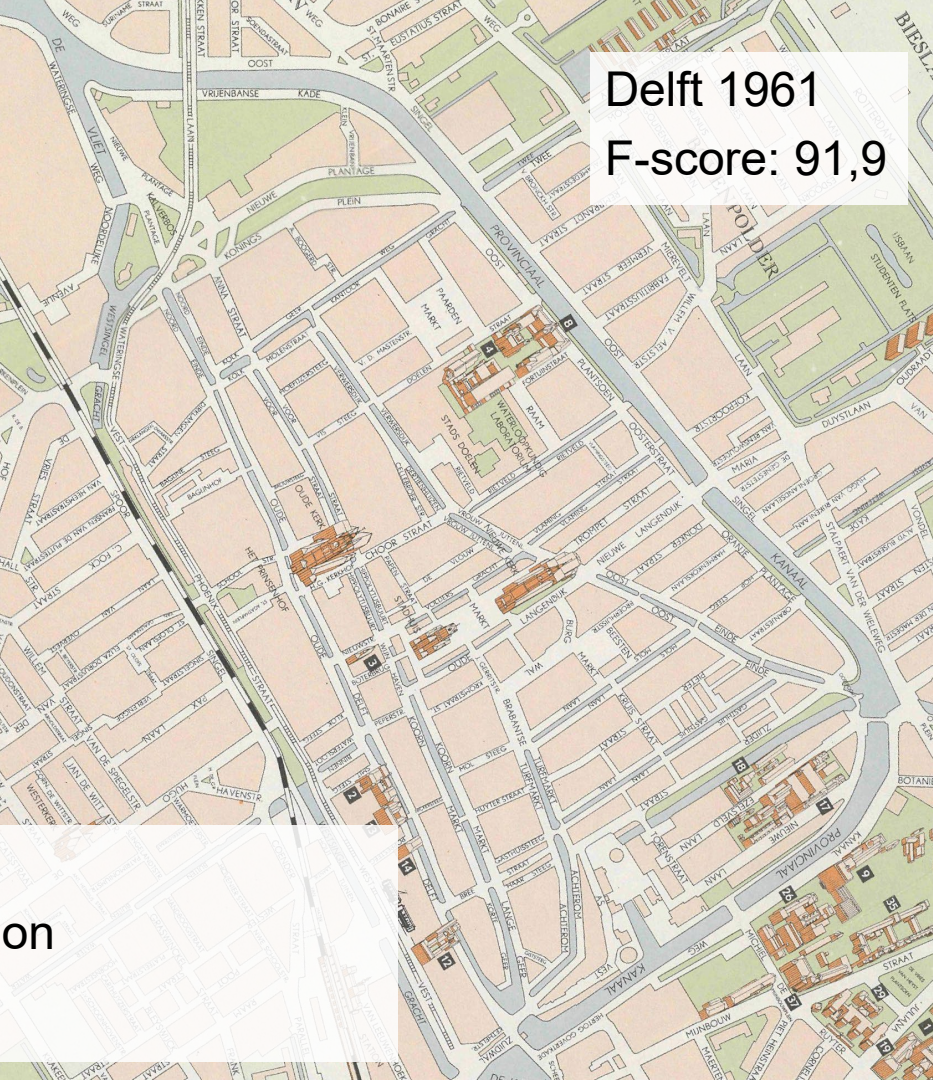
→ F-score > 83% for almost all maps



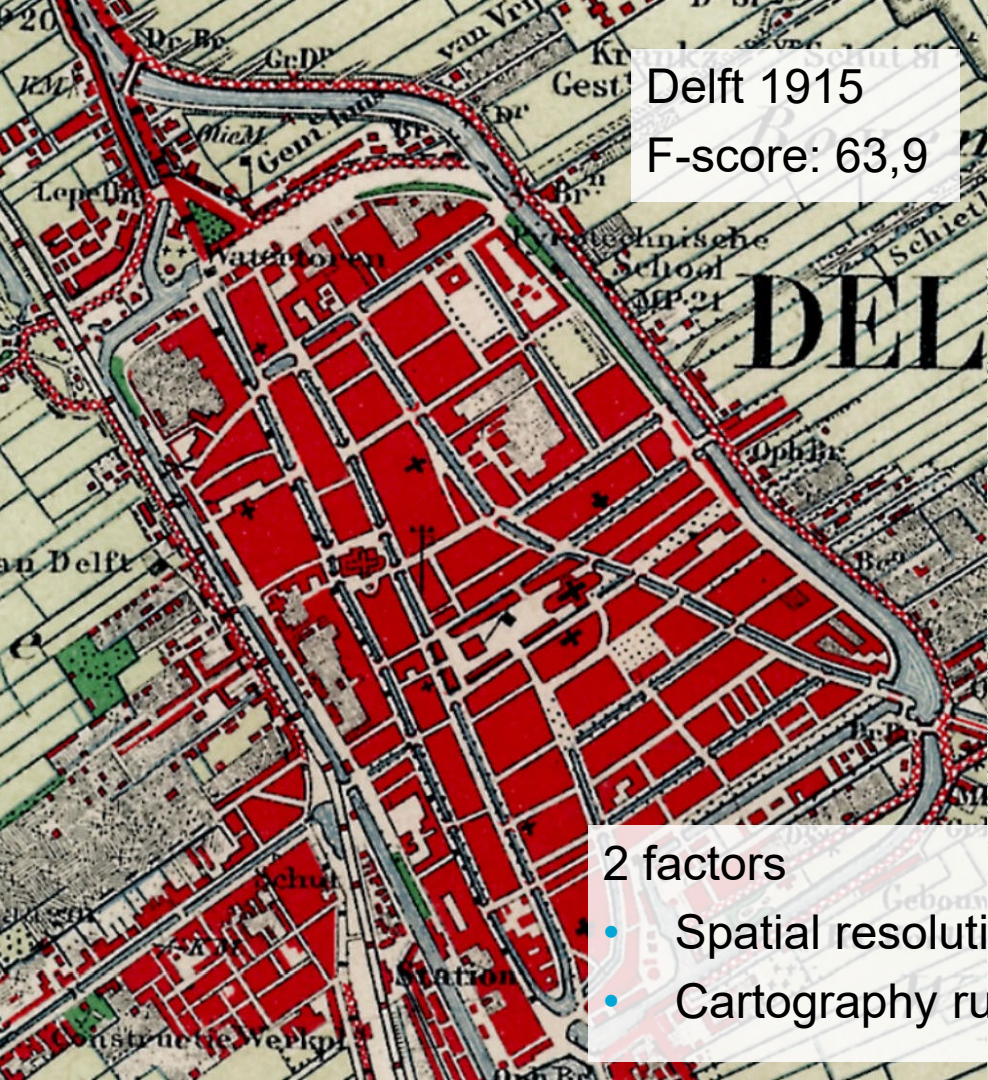


Delft 1915
F-score: 63,9

2 factors
• Spatial resolution

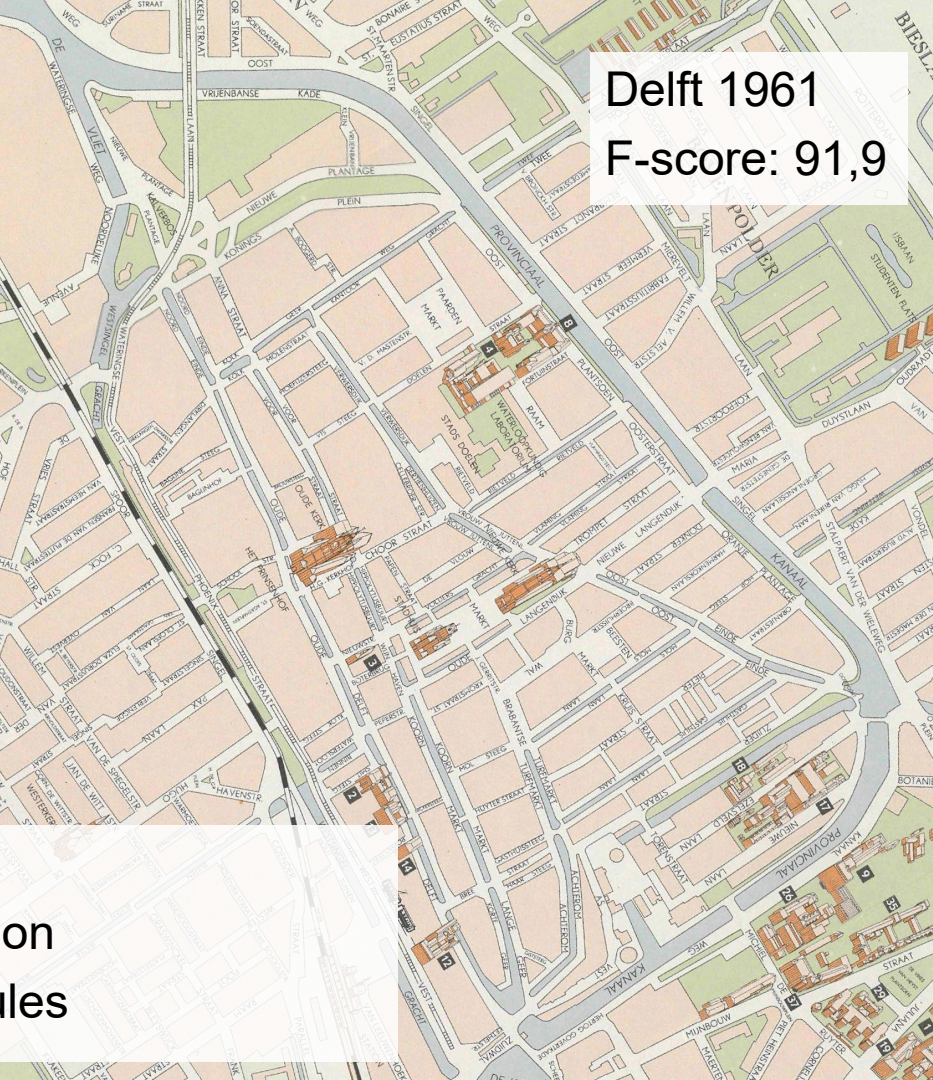


Delft 1961
F-score: 91,9



Delft 1915
F-score: 63,9

- 2 factors
- Spatial resolution
 - Cartography rules



Delft 1961
F-score: 91,9

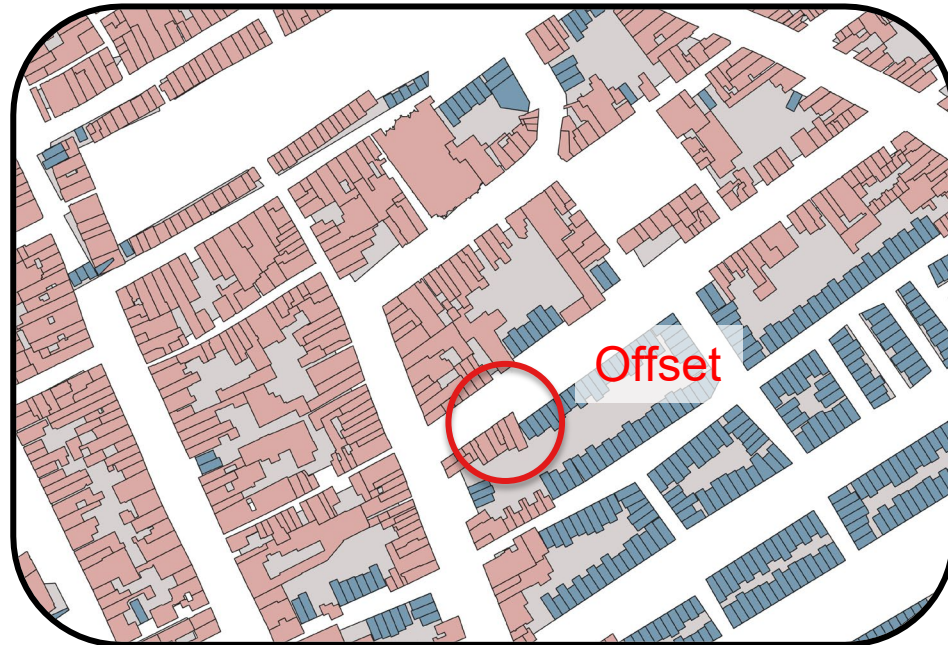
Reconstruction of individual footprints

Maps alignment + 2D procedural modelling



Reconstruction of individual footprints

Maps alignment + 2D procedural modelling



LoD2 buildings generation

1. Delft

Delft 1880



Delft 1880

Delft 1915



Delft 1880

Delft 1915

Delft 1961



Delft 1880

Delft 1915

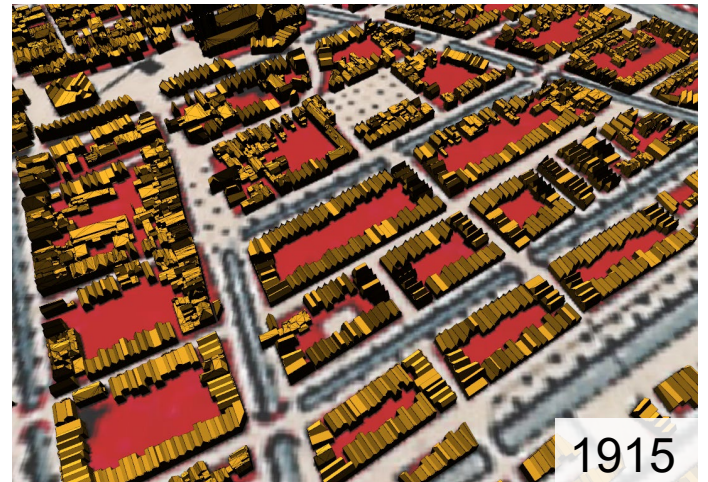
Delft 1961

Delft 1982





1880



1915



1961



1982

LoD2 buildings generation

2. Brussels



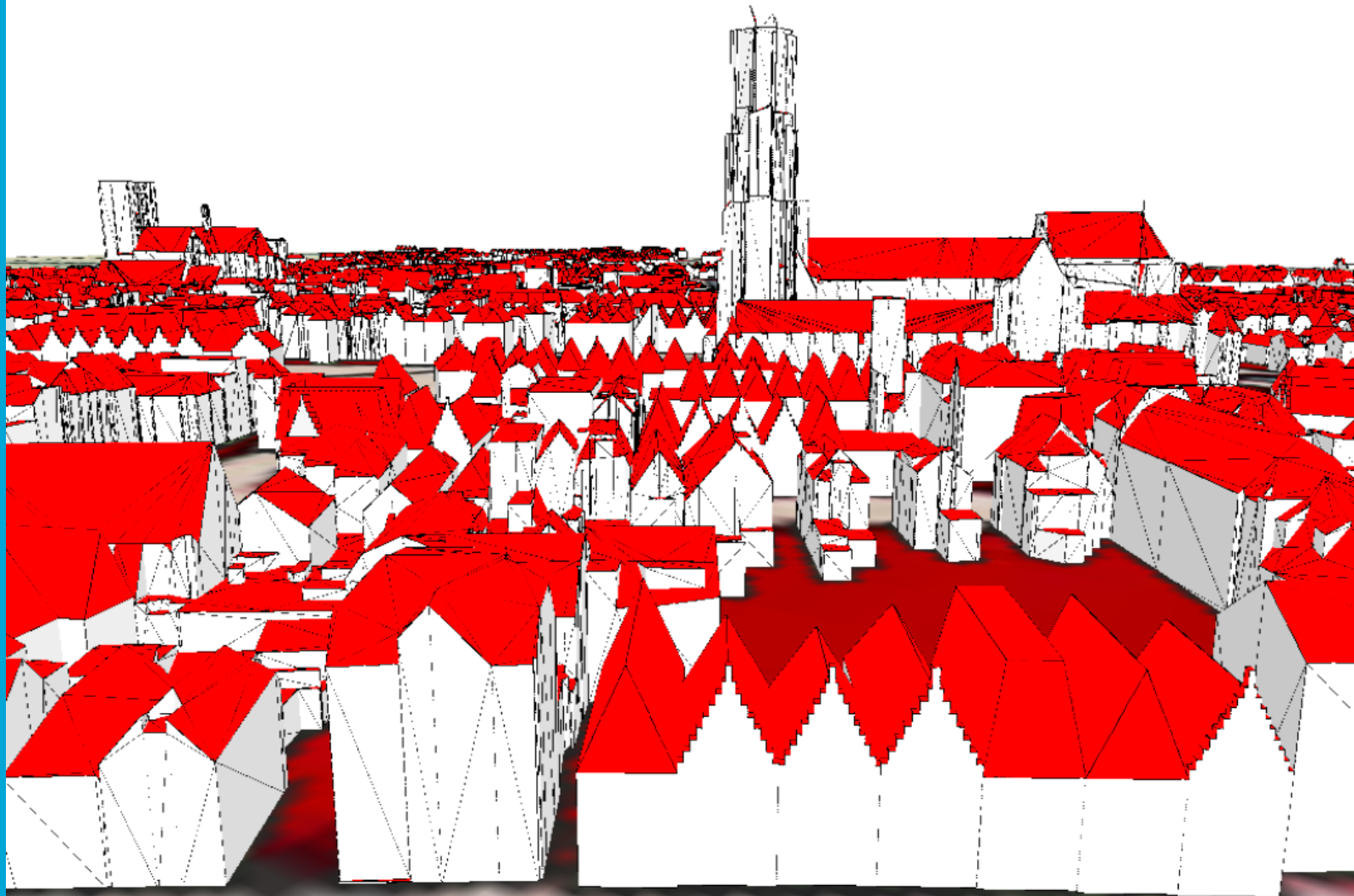
LoD2 buildings generation

Results assessment

- Visual assessment

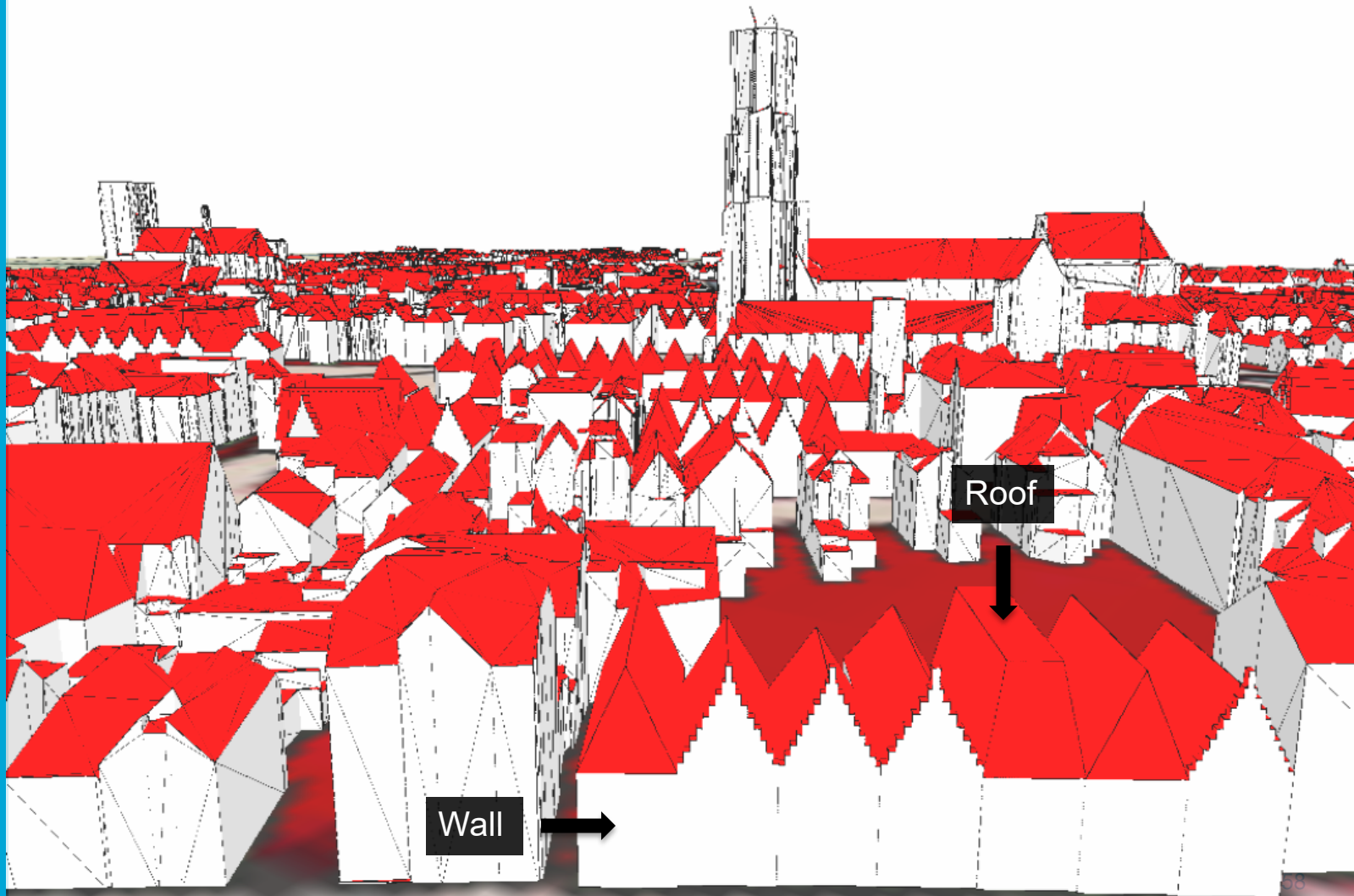
Are the buildings generated as expected?

Delft 1915



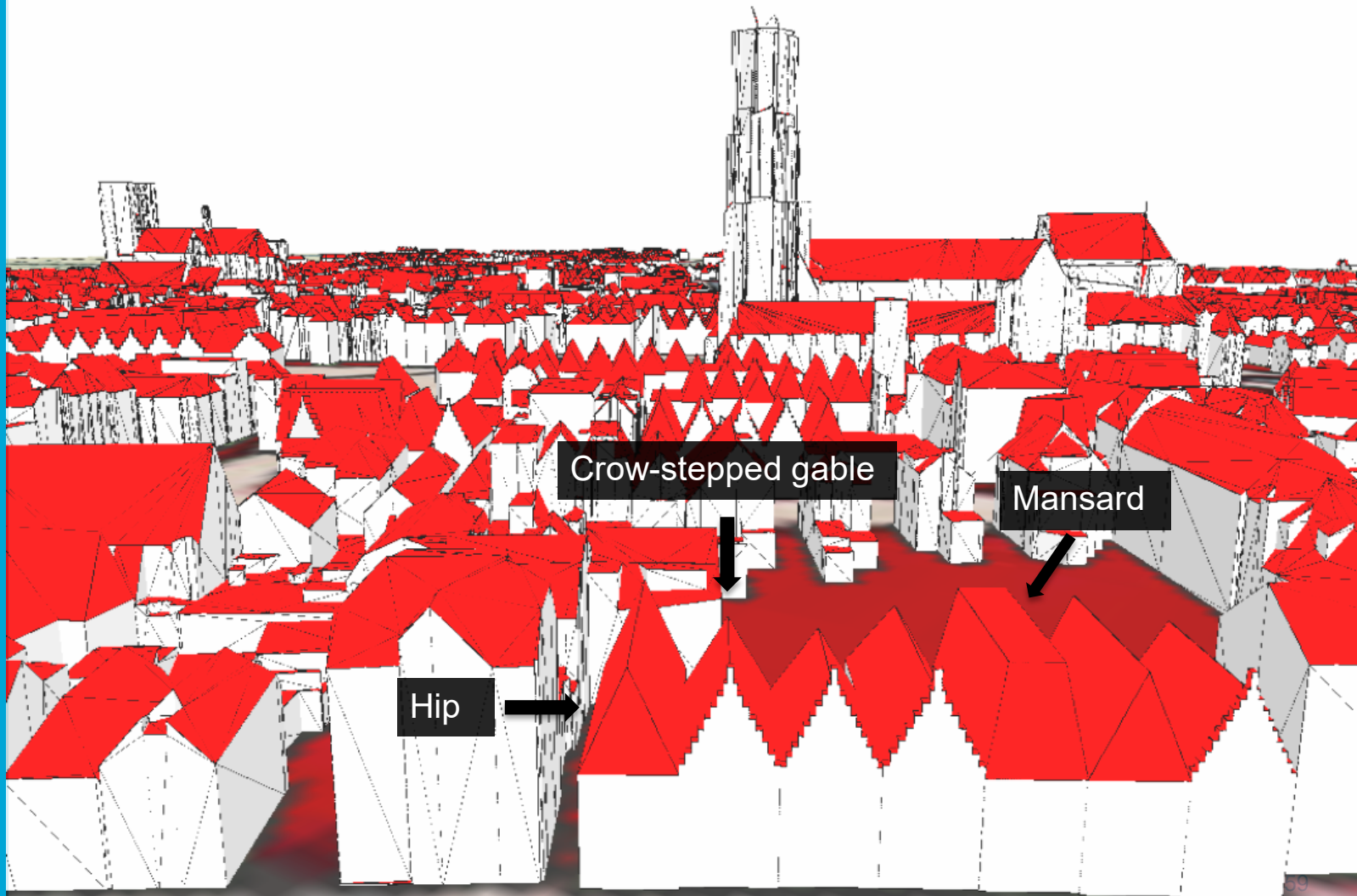
Delft 1915

Semantics



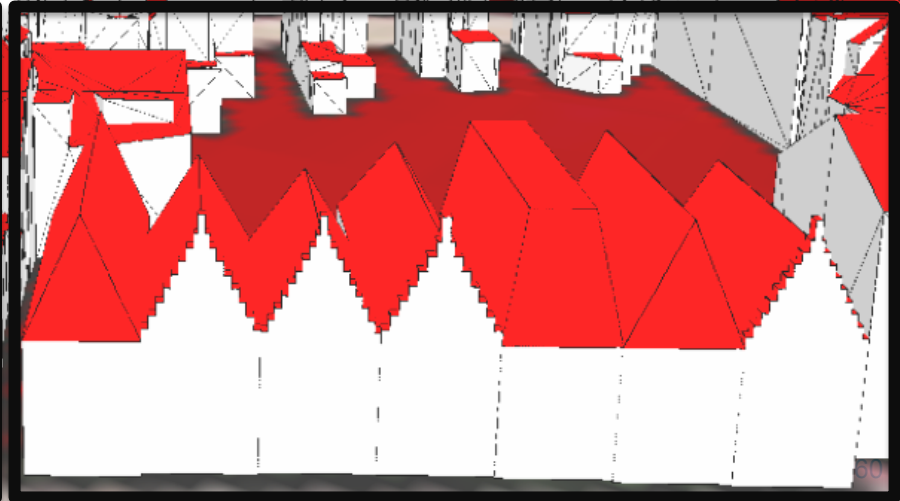
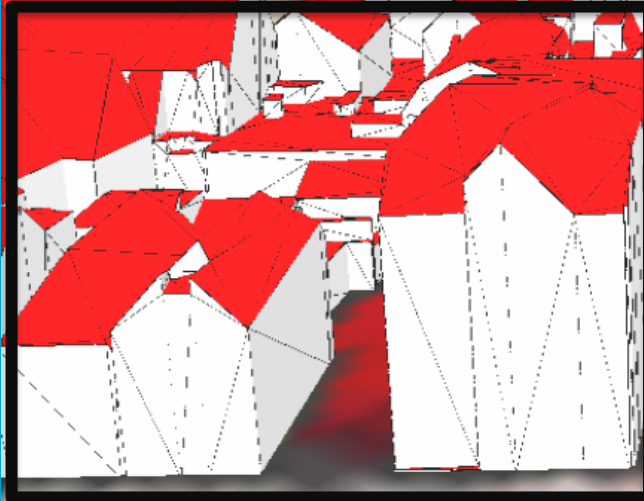
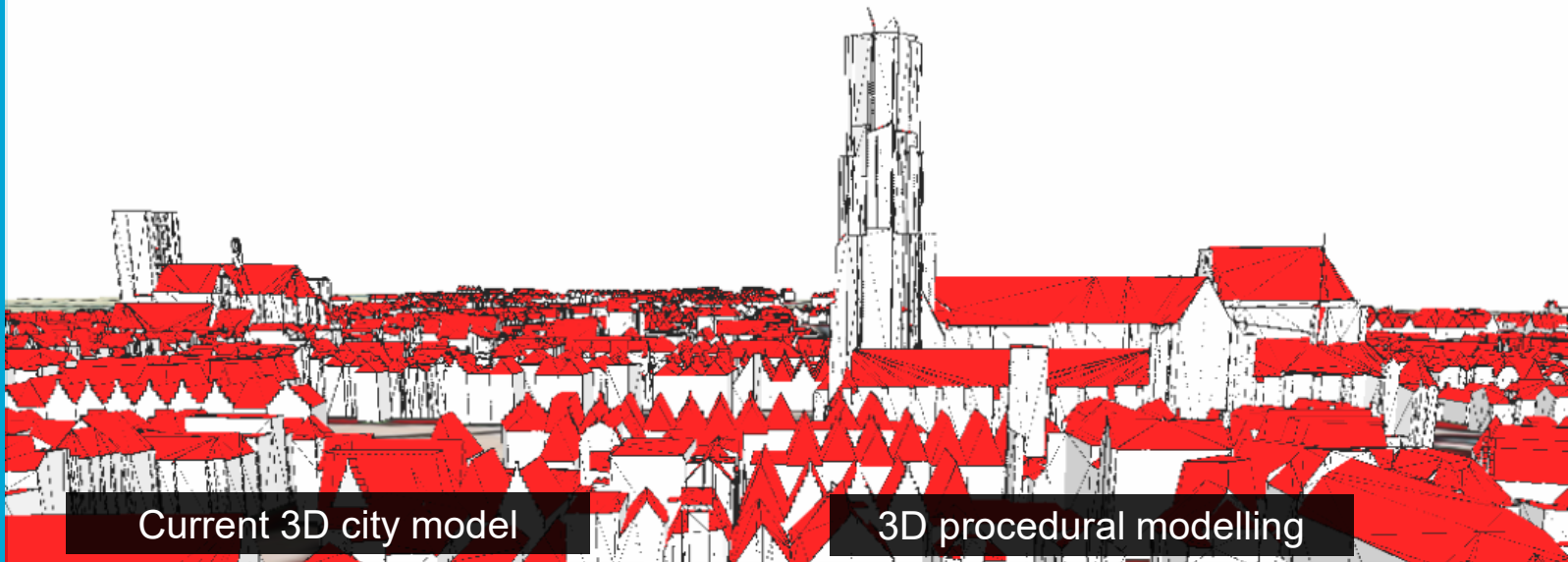
Delft 1915

Semantics
Roof types



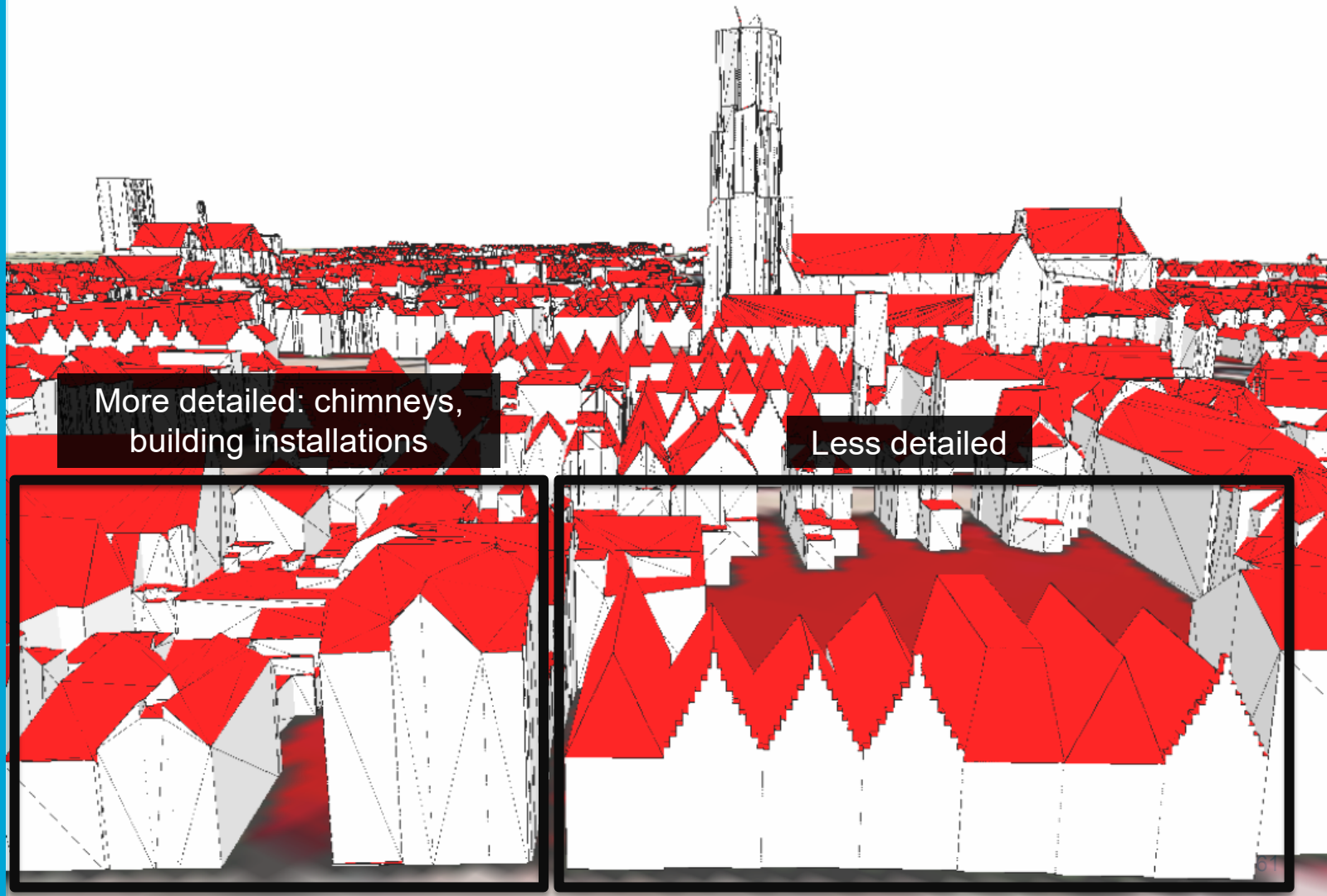
Delft 1915

Semantics
Roof types
Multi-LoD



Delft 1915

Semantics
Roof types
Multi-LoD



LoD2 buildings generation

Results assessment

- Validity assessment

Is the CityJson file valid ?

→ Yes !

Are the geometries valid according to standards?

→ > 99% for all historical 3D city models

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Research question

“To what extent can be automated the process of reconstructing simple 3D city models from historical maps?”

- Limited user interventions
 - Provide input datasets
 - Create training data
 - Pass some user-defined parameters
- Methodology flexible
- Large processing time

Discussion

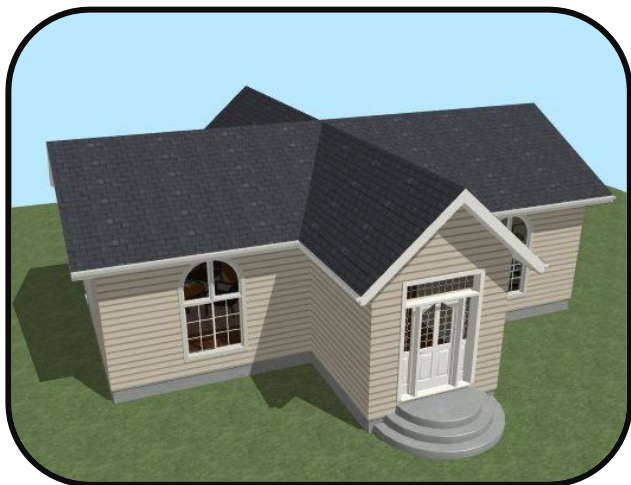
- Application to other study areas?

Discussion

- Application to other study areas?
- Use cases for such historical 3D city models?
 - Preservation of the cultural heritage
 - Pragmatic applications
 - New applications not investigated yet

Future work

- Addition of procedural modelling rules
- Use of additional historical sources
- 3D reconstruction of other features



Source: Home Designer® Software [2019]



Source: Jones [nd]

Thank you !

References

Biljecki, F., Ledoux, H., and Stoter, J. (2016c). An improved LOD specification for 3D building models. *Computers, Environment and Urban Systems*, 59:25–37

de Boer, A. (2010). Processing old maps and drawings to create virtual historic landscapes
Bondright Roofing Services (n.d.). BONDRIGHT ROOFING GUIDE TO RESIDENTIAL ROOFING TYPES. <http://bondrightroofing.co.uk/bondright-roofing-guide-to-residential-roofingtypes.php>

Home Designer® Software (2019). Creating a Cross Gable Roof. <https://www.homedesignersoftware.com/support/article/KB-01043/creating-a-cross-gableroof.html>

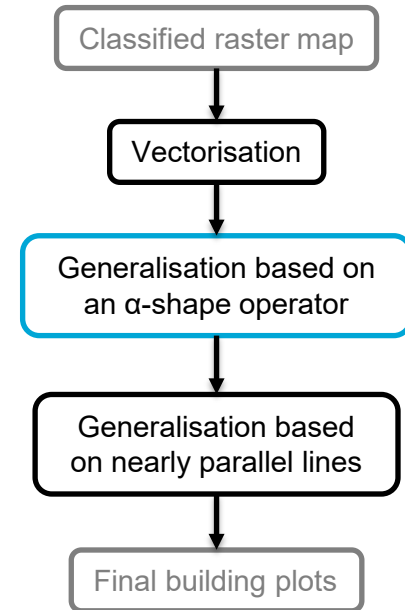
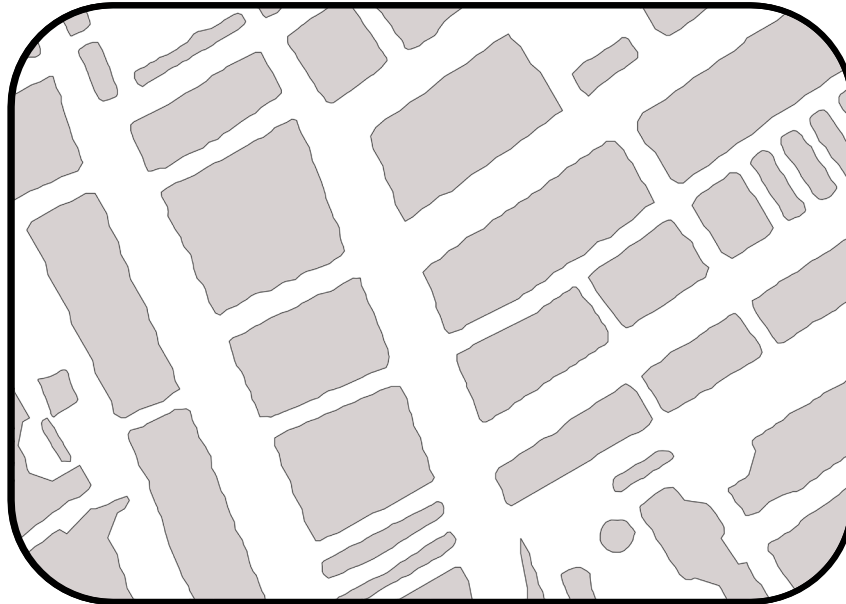
Jones, S. (n.d.). Leaning Houses in Amsterdam. <https://thetravelbunny.com/canal-leaninghouses-amsterdam/>

McLeod, K. S. (2000). Our sense of Snow: the myth of John Snow in medical geography. *Social Science Medicine*, 50(7):923 – 935

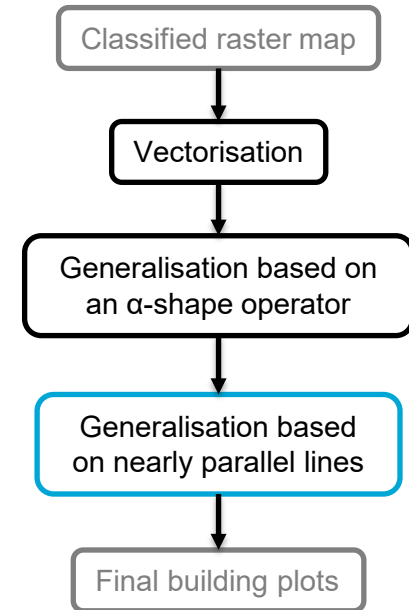
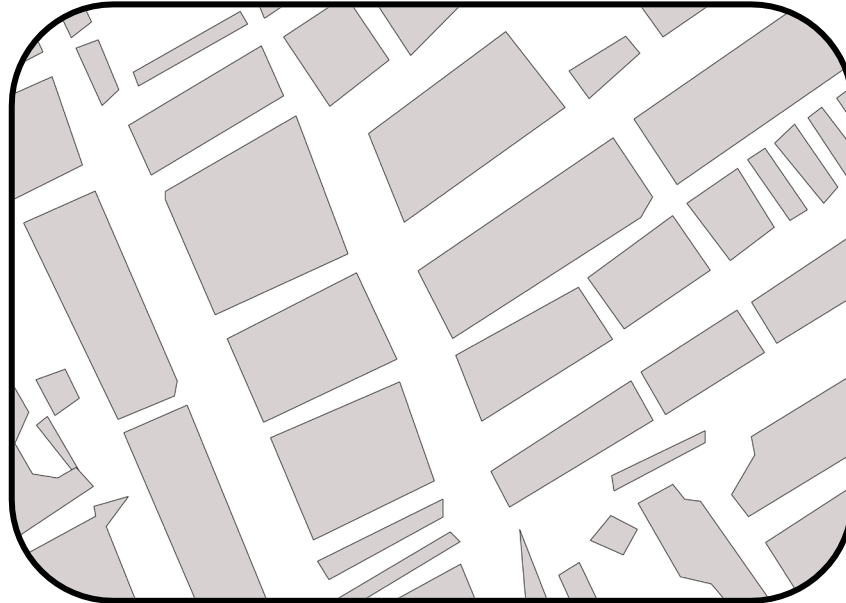
Ryckaert, M. (2012). Bruges (Belgium): houses at the Potterierei. https://commons.wikimedia.org/wiki/File:Brugge_Houses_Potterierei_R02.jpg

Extra slides

Building plots extraction

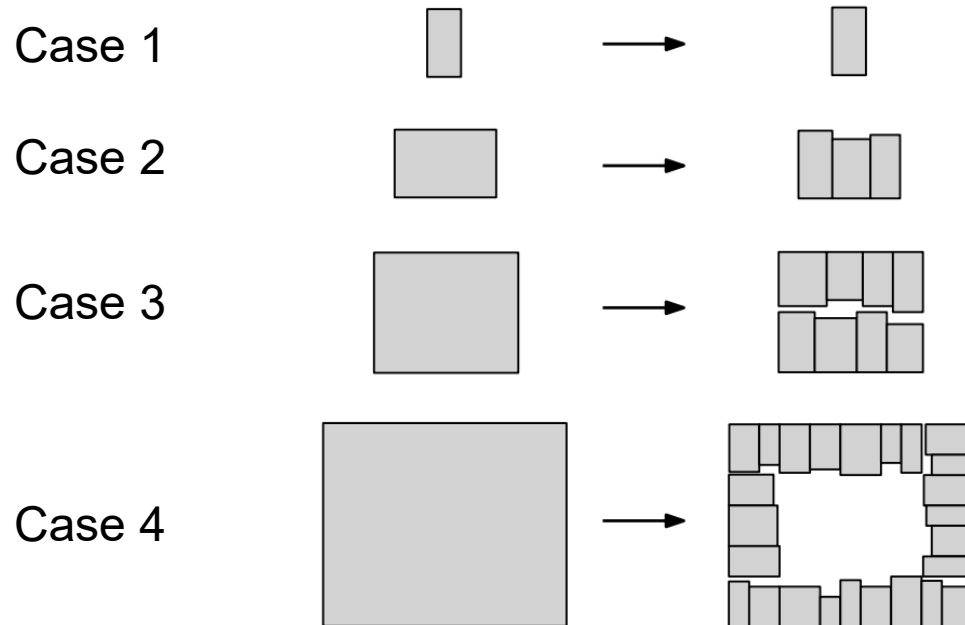


Building plots extraction



Reconstruction of individual footprints

2D procedural modelling



LoD2 buildings generation

Assign building reference heights

- Ground height

Use current elevation dataset (point cloud)

- Roof height

Use height attribute of the aligned building footprints

Contributions

- Literature review about historical 3D city modelling
- Comparisons of different methods
- Automated subdivision of building plots into footprints
- Blender addon for 3D procedural modelling enriched
- Automated reconstruction of historical 3D city models