

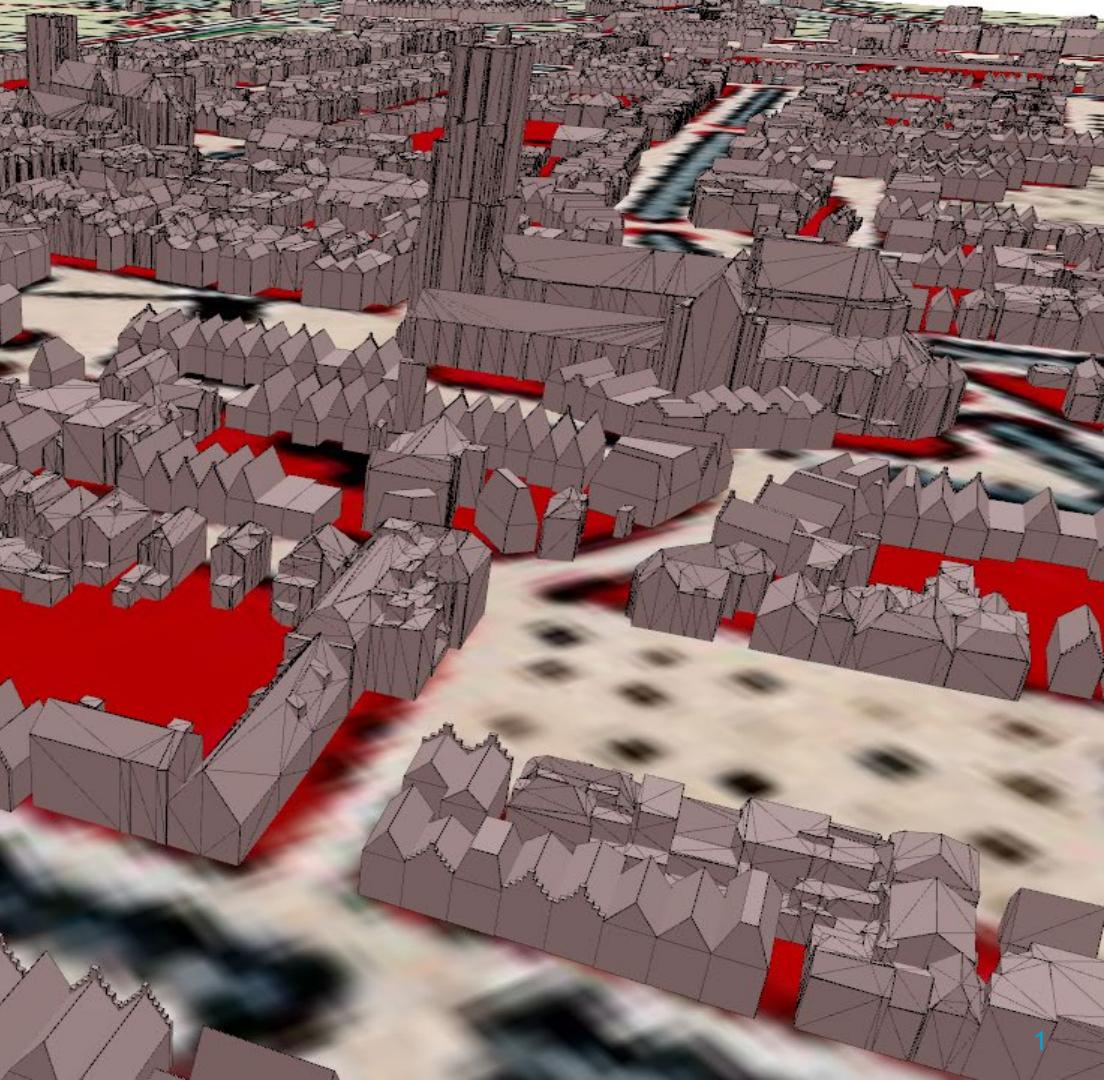
# Automatic reconstruction of 3D city models from historical maps

Camille Morlighem

June 2021

**1<sup>st</sup> supervisor:** Dr. Hugo Ledoux

**2<sup>nd</sup> supervisor:** Anna Labetski



# Content

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

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# Motivation

Historical maps?

Invaluable source of information...

about the pre-satellites era...

in many domains....

# John Snow, London 1854



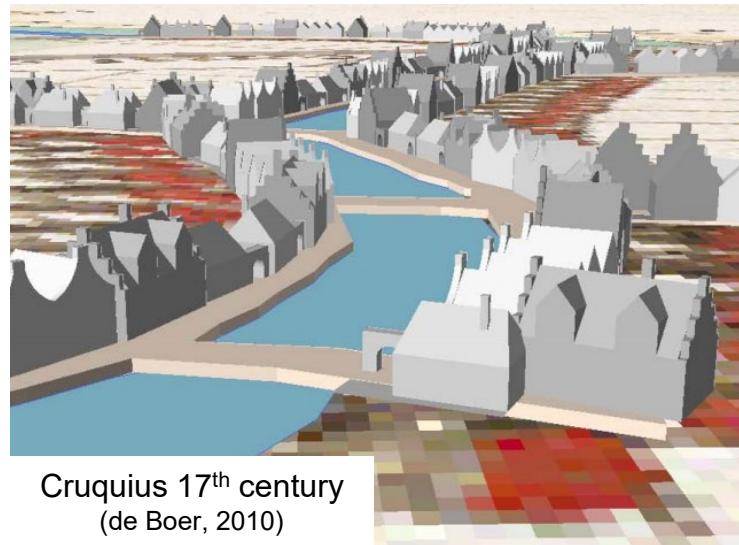
# Motivation

Historical 3D city models?



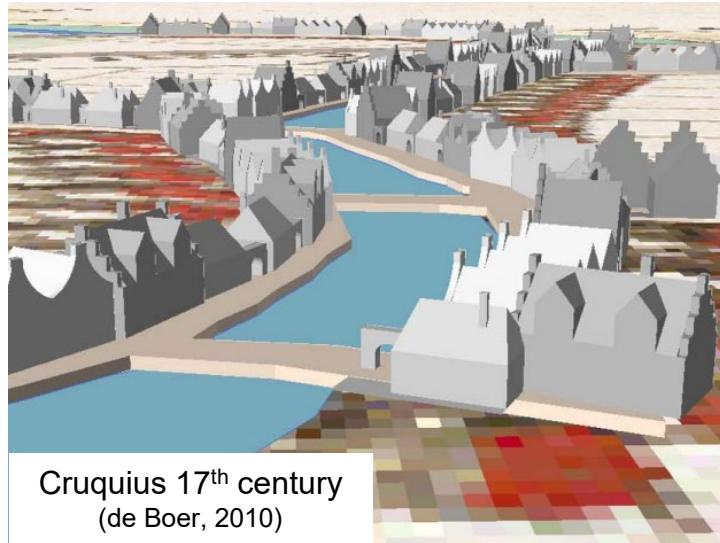
Highly detailed

vs.



Simple

# Research question



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

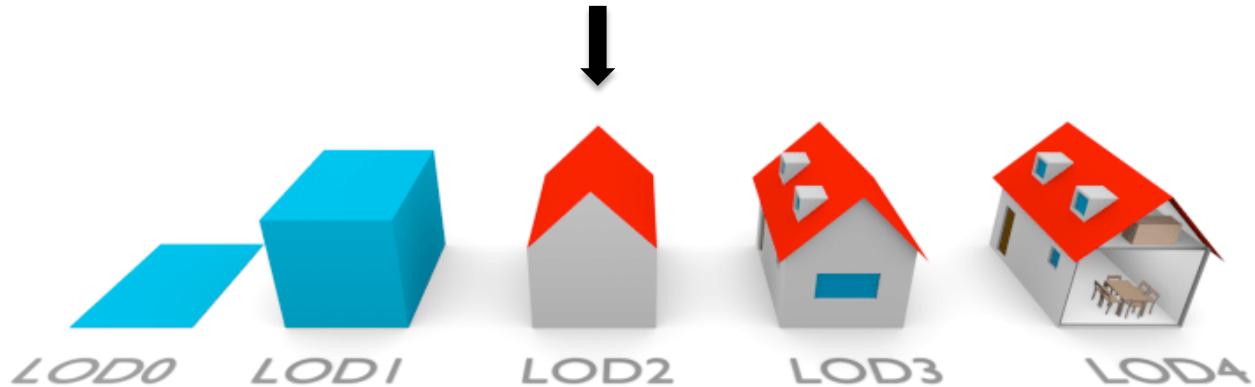
# Objectives

1. Comparison of existing methods

# Objectives

## 2. Automated methodology

- Models LoD2 buildings
- Maximises accuracy



Source: Biljecki et al. [2016]

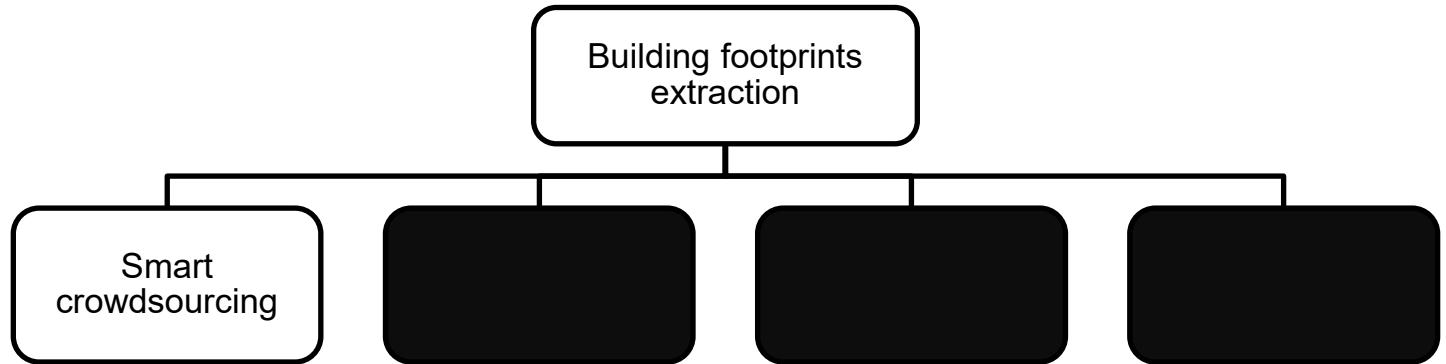
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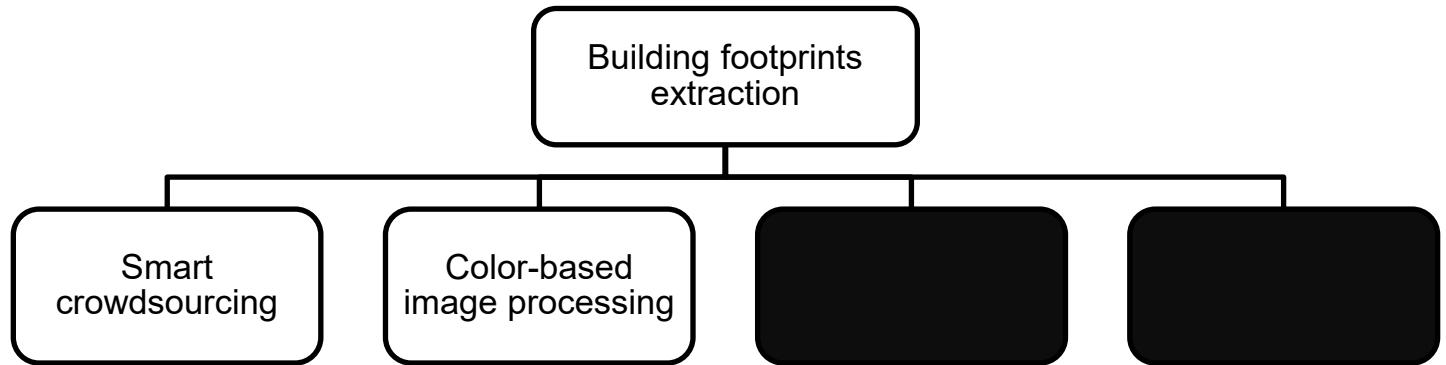
# Related work

Building footprints  
extraction

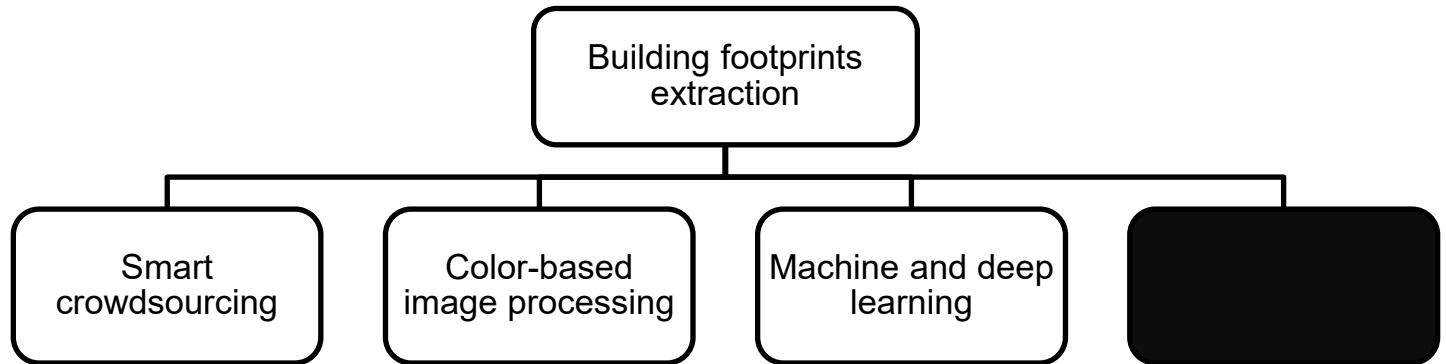
# Related work



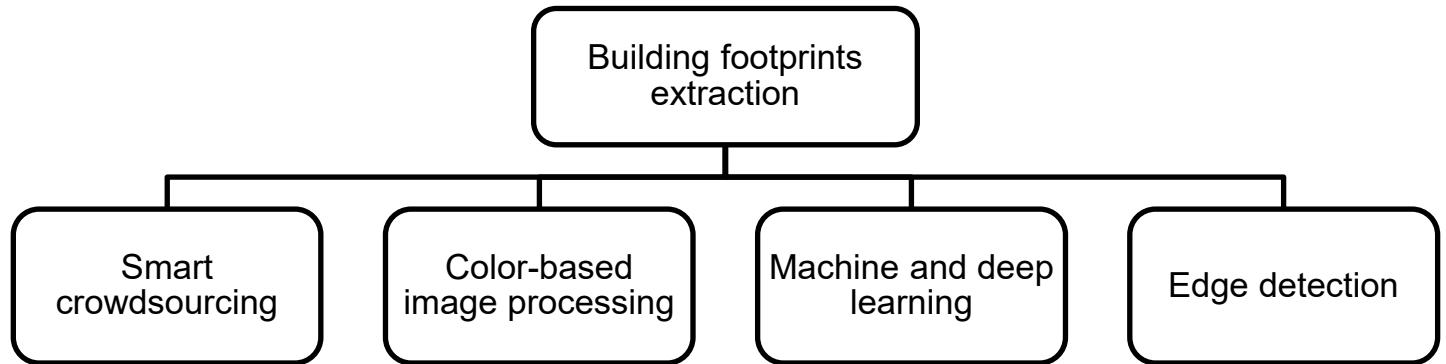
# Related work



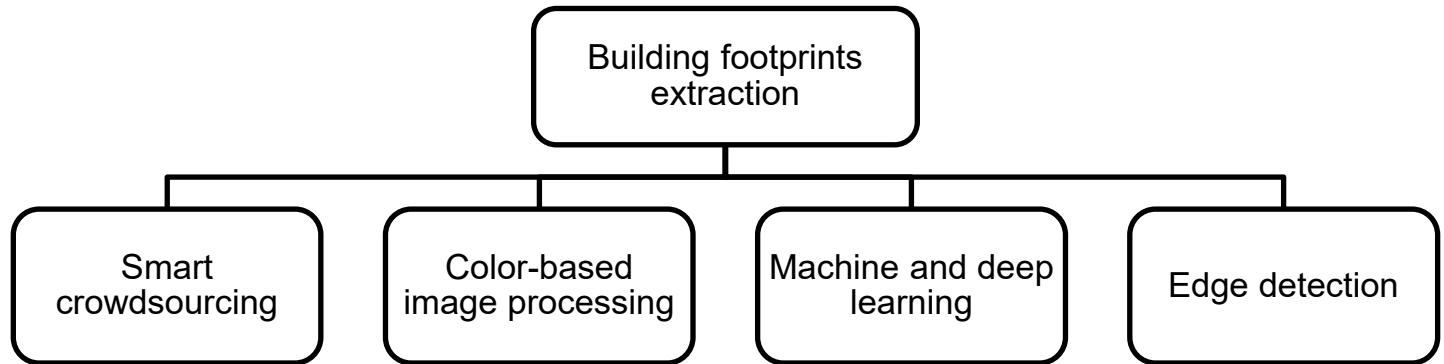
# Related work



# Related work

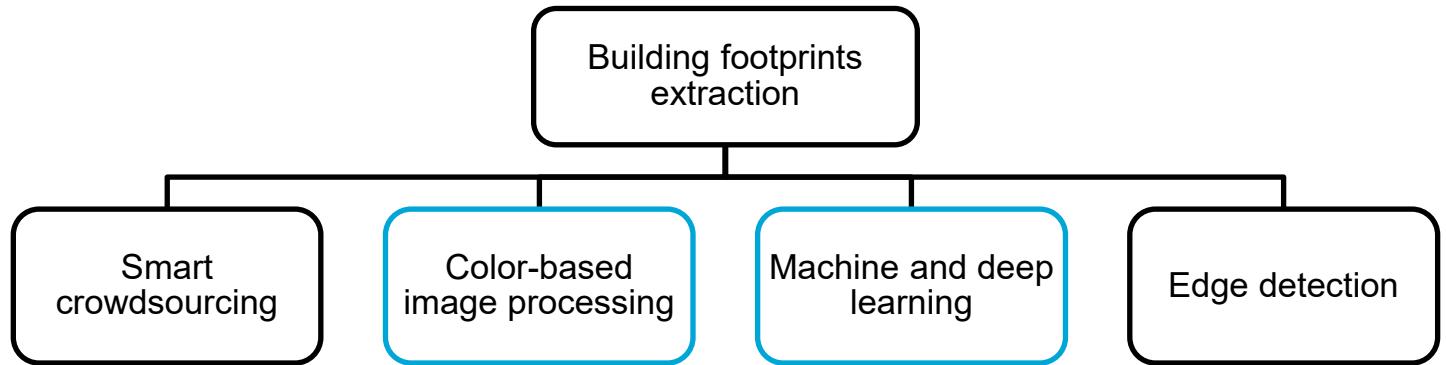


# General observations



→ No perfect method

# General observations



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# Case studies

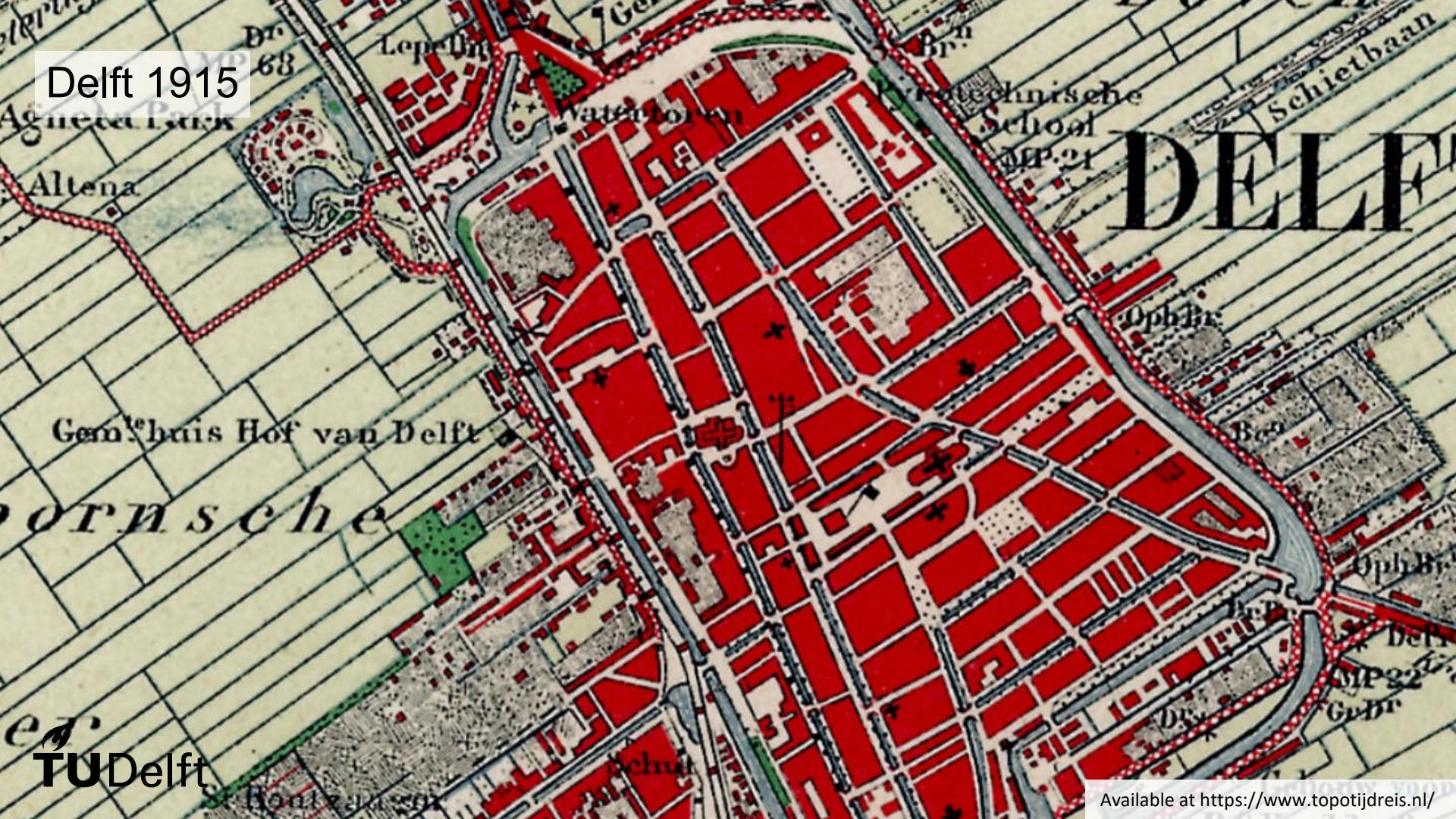
- Delft

Implement the methodology

- Brussels

Test the application of the methodology for other study areas

Delft 1915

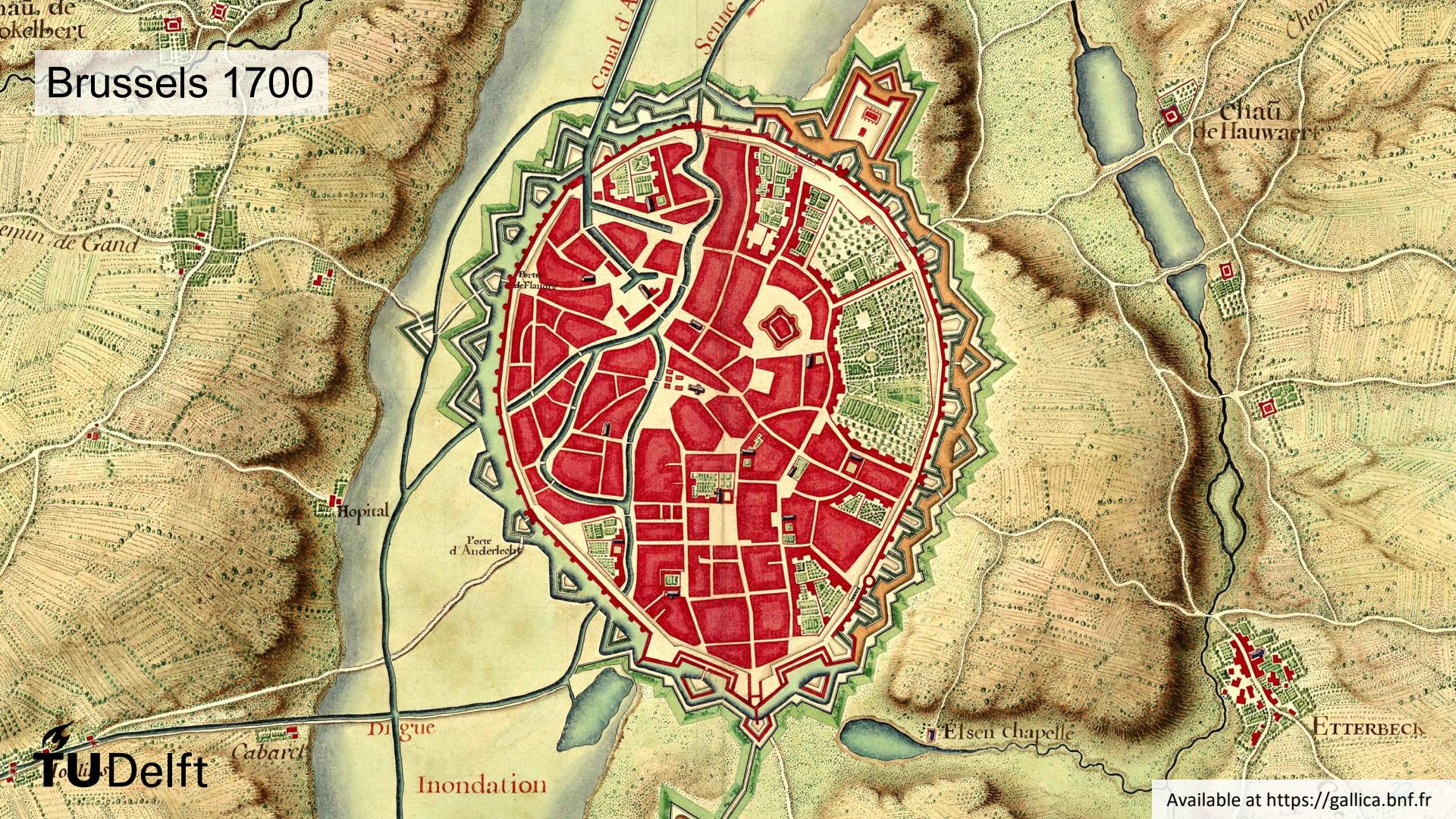


# Delft 1961



nau, de  
okelbert

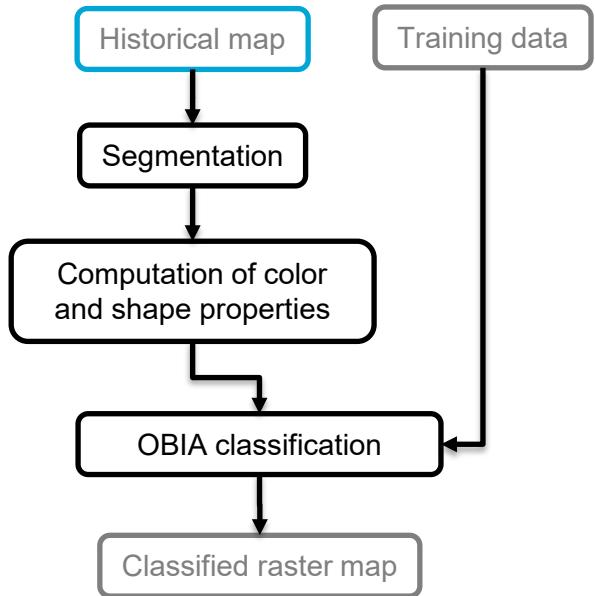
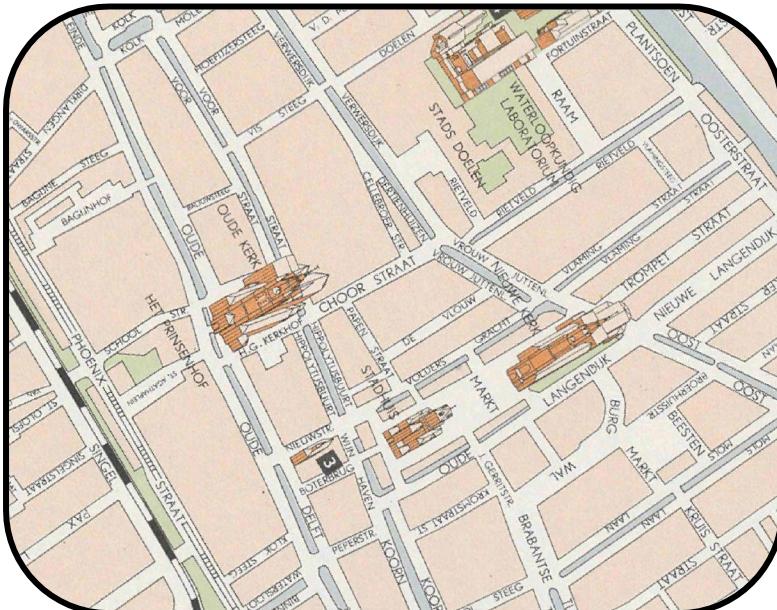
# Brussels 1700



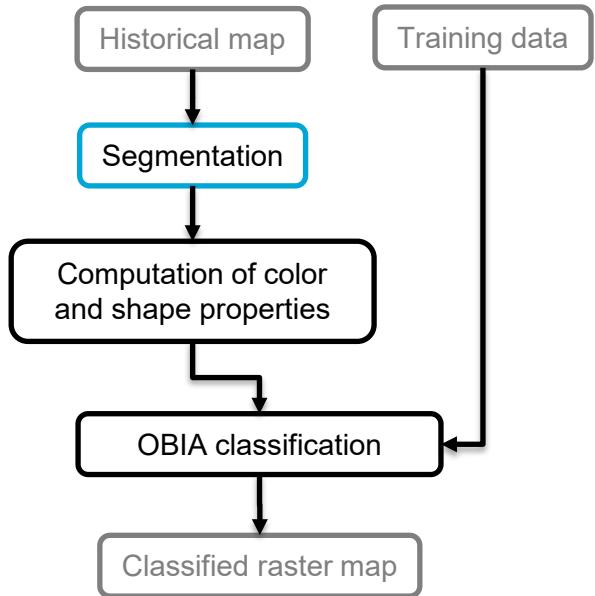
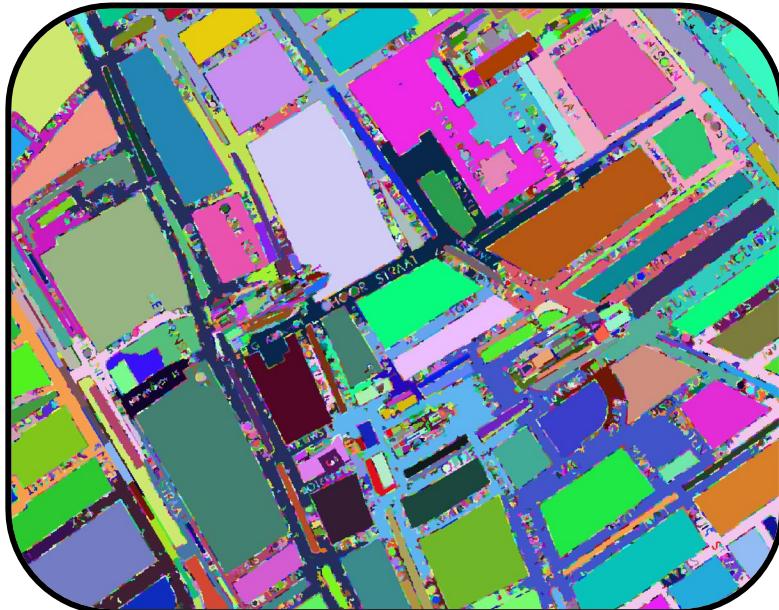
# Brussels 1890



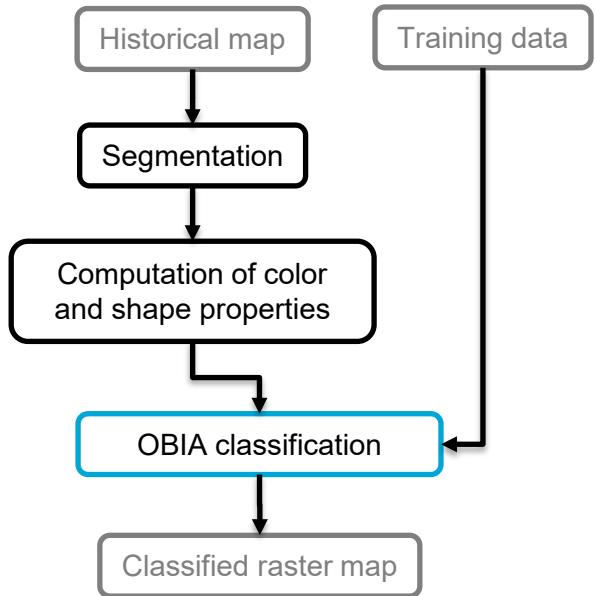
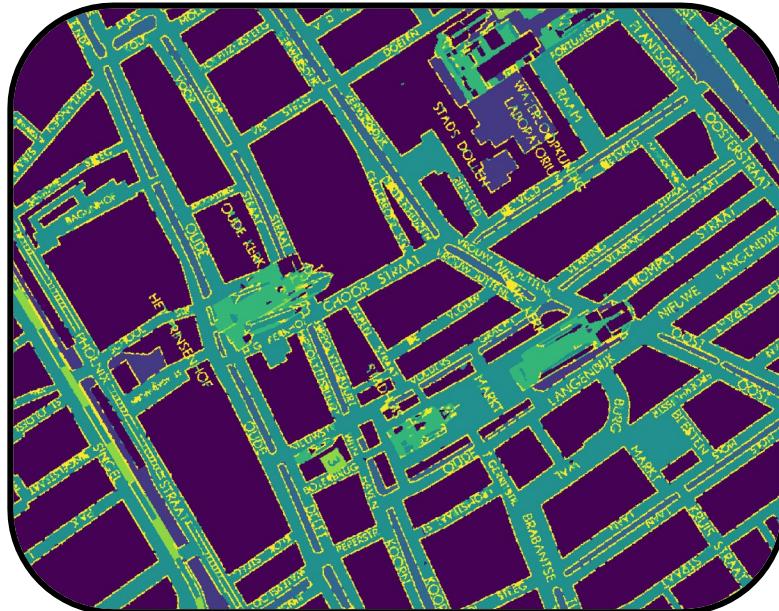
# Building plots extraction



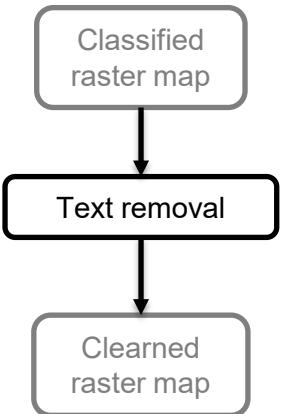
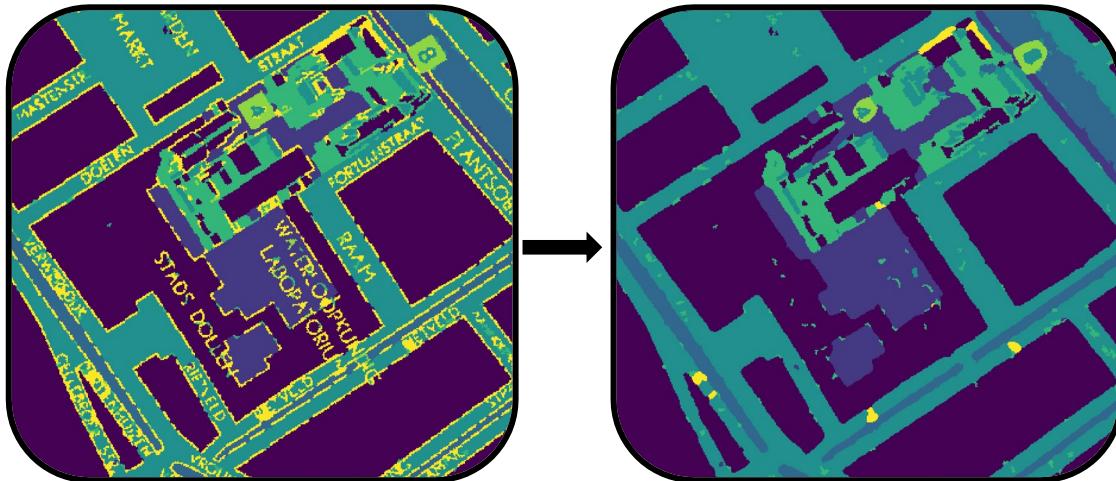
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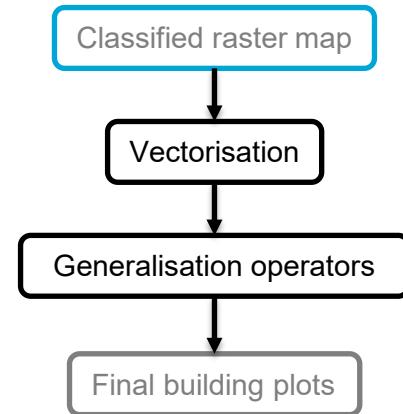
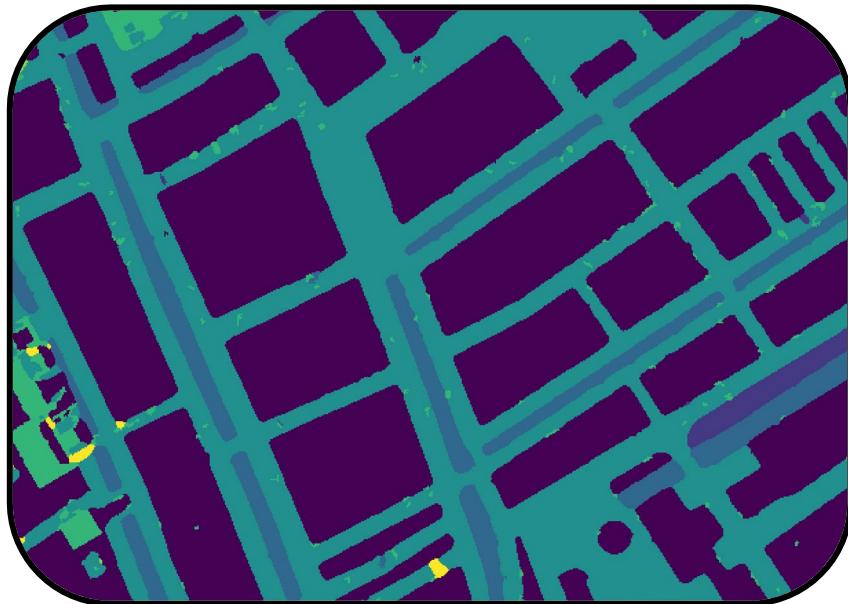
# Building plots extraction



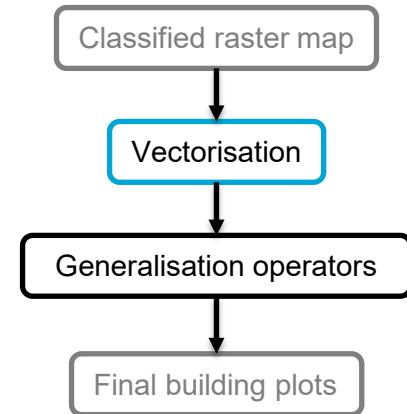
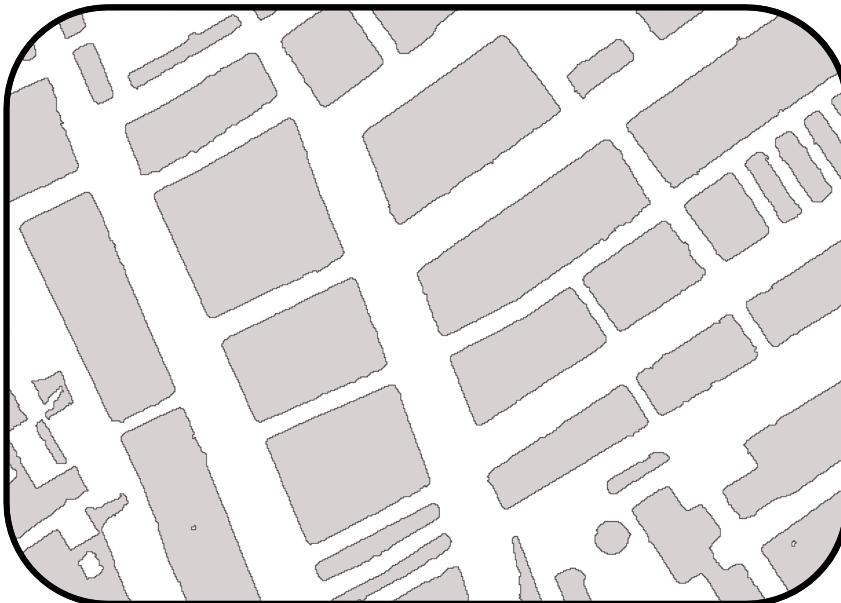
# Building plots extraction



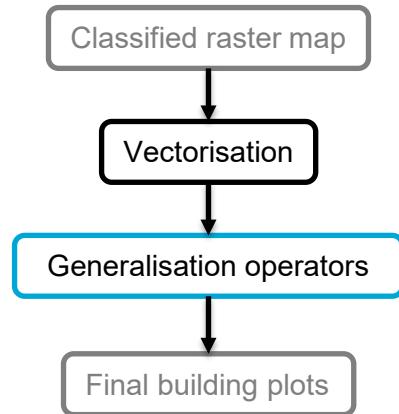
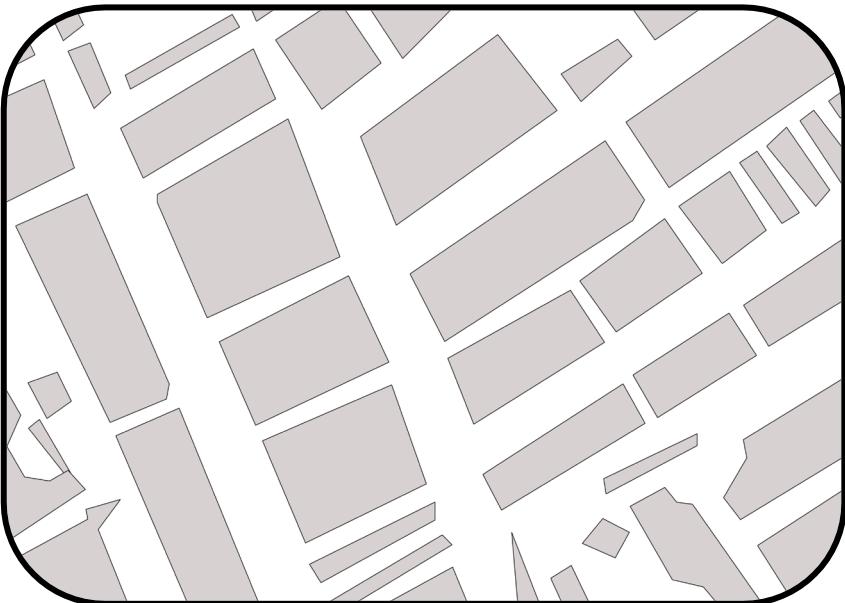
# Building plots extraction



# Building plots extraction

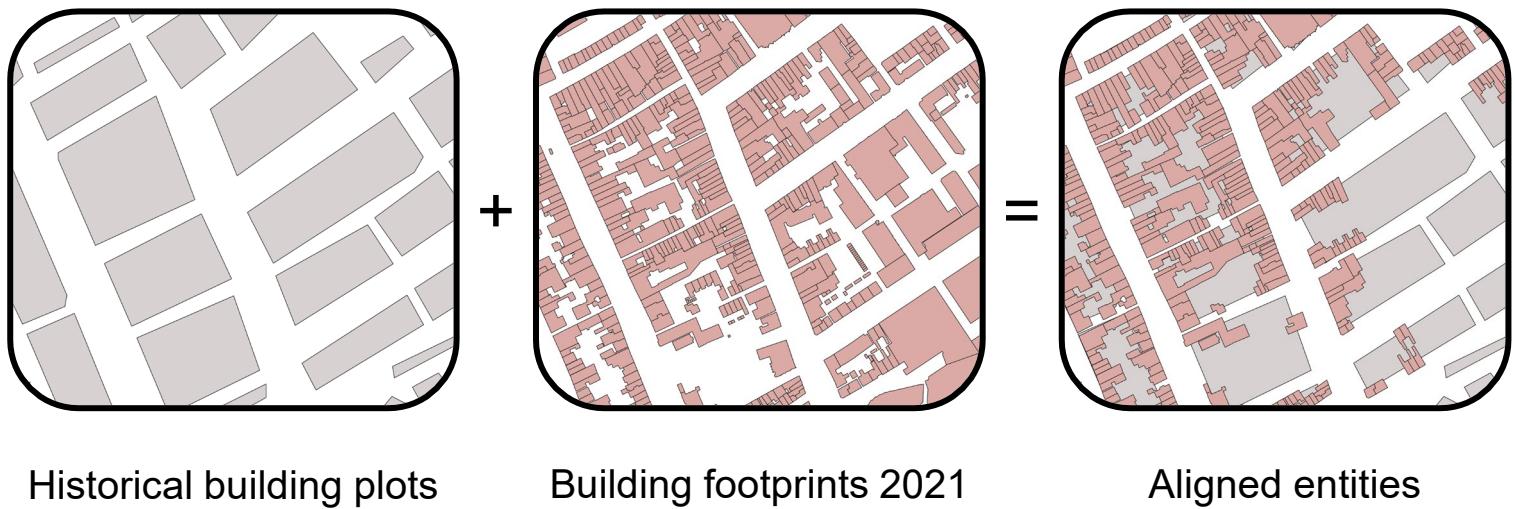


# Building plots extraction



# Reconstruction of individual footprints

## 1. Maps alignment



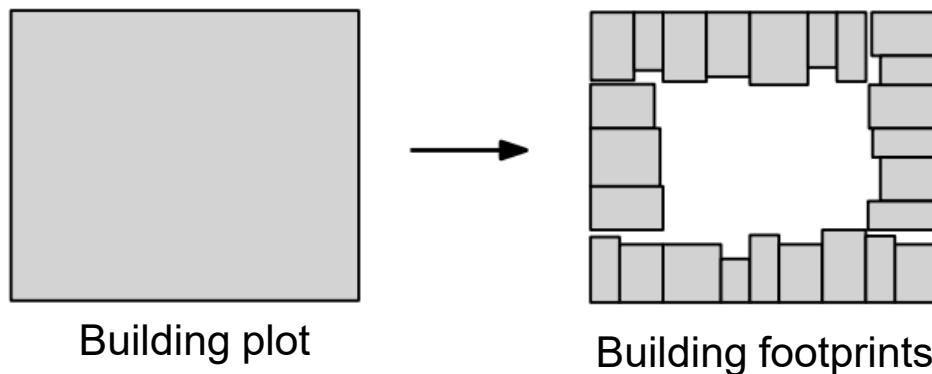
Historical building plots

Building footprints 2021

Aligned entities

# Reconstruction of individual footprints

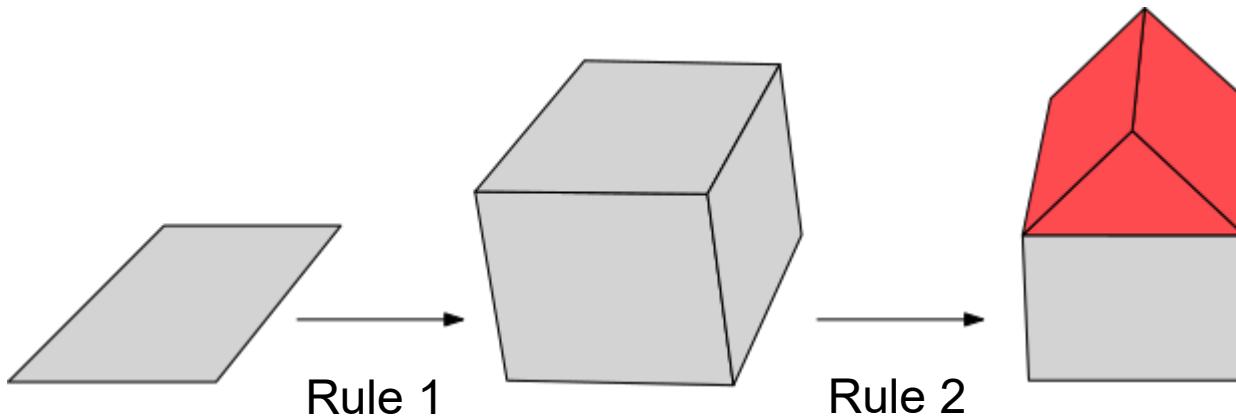
## 2. 2D procedural modelling



# LoD2 buildings generation

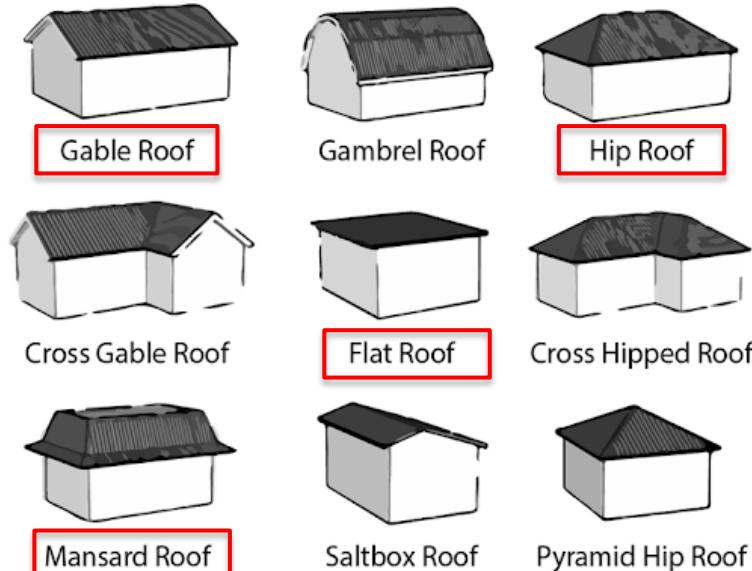
## 3D procedural modelling

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



# LoD2 buildings generation

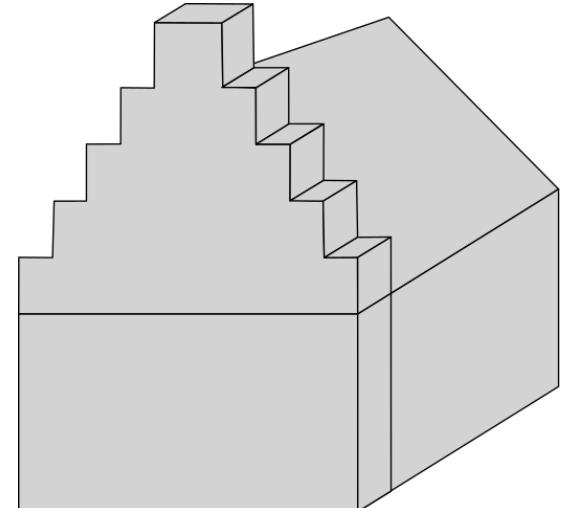
Blender addon



Source: Bondright Roofing Services [nd]

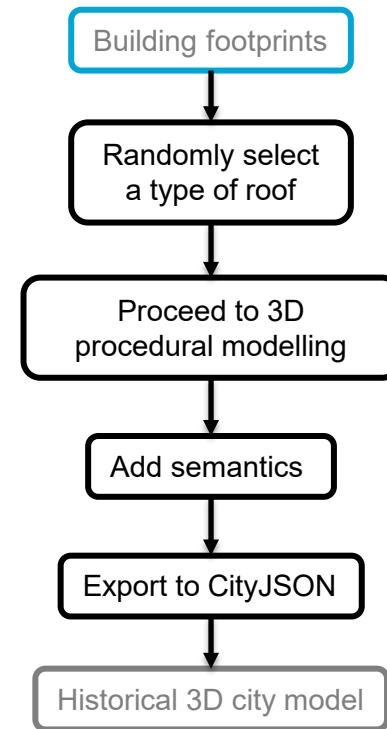
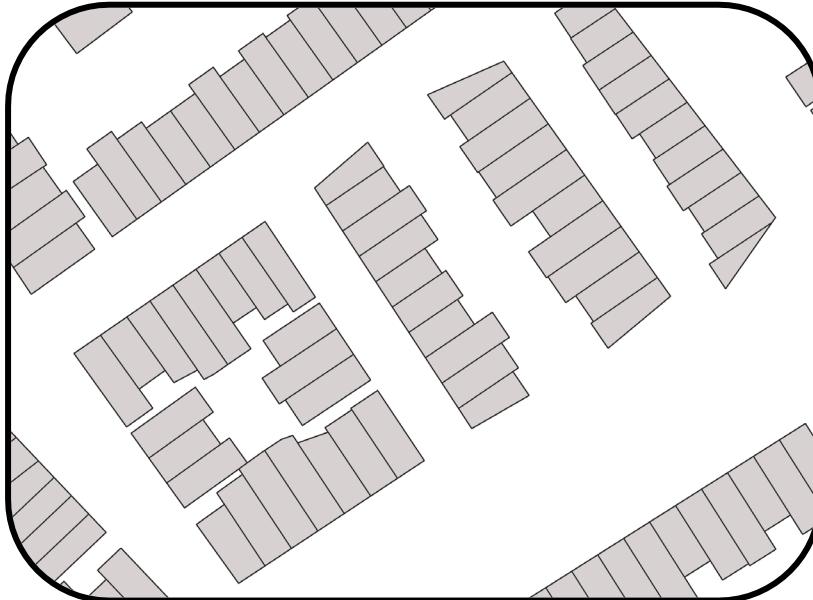
# LoD2 buildings generation

Crow-stepped gable roofs

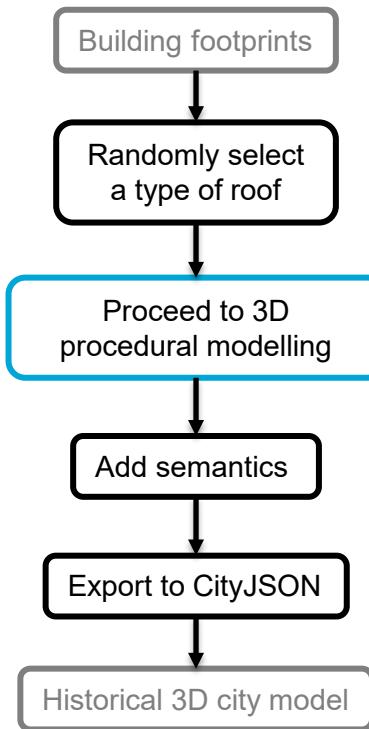
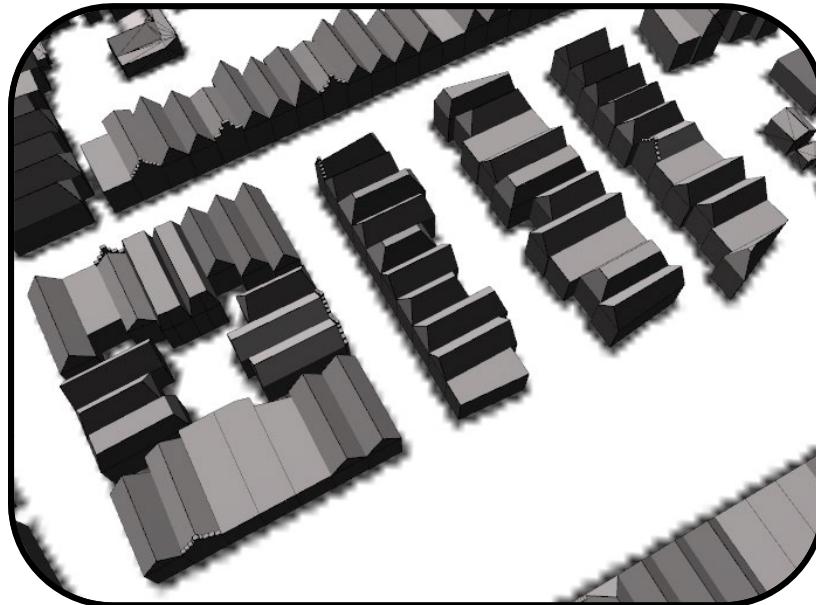


Source: Ryckaert [2012]

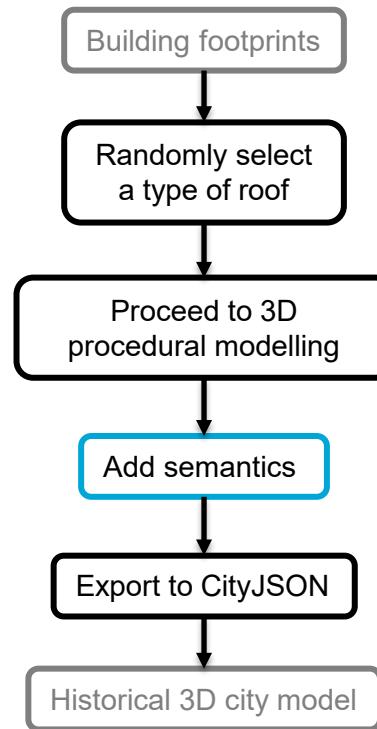
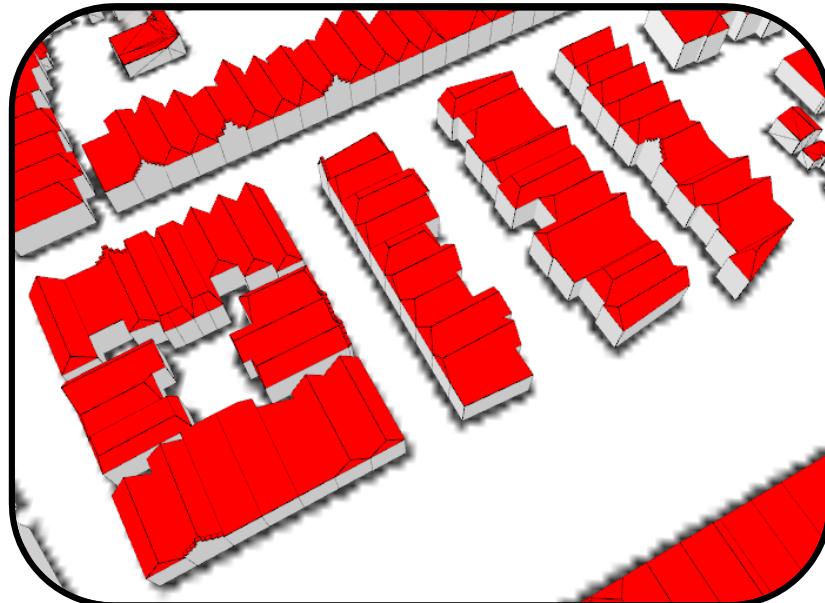
# LoD2 buildings generation



# 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

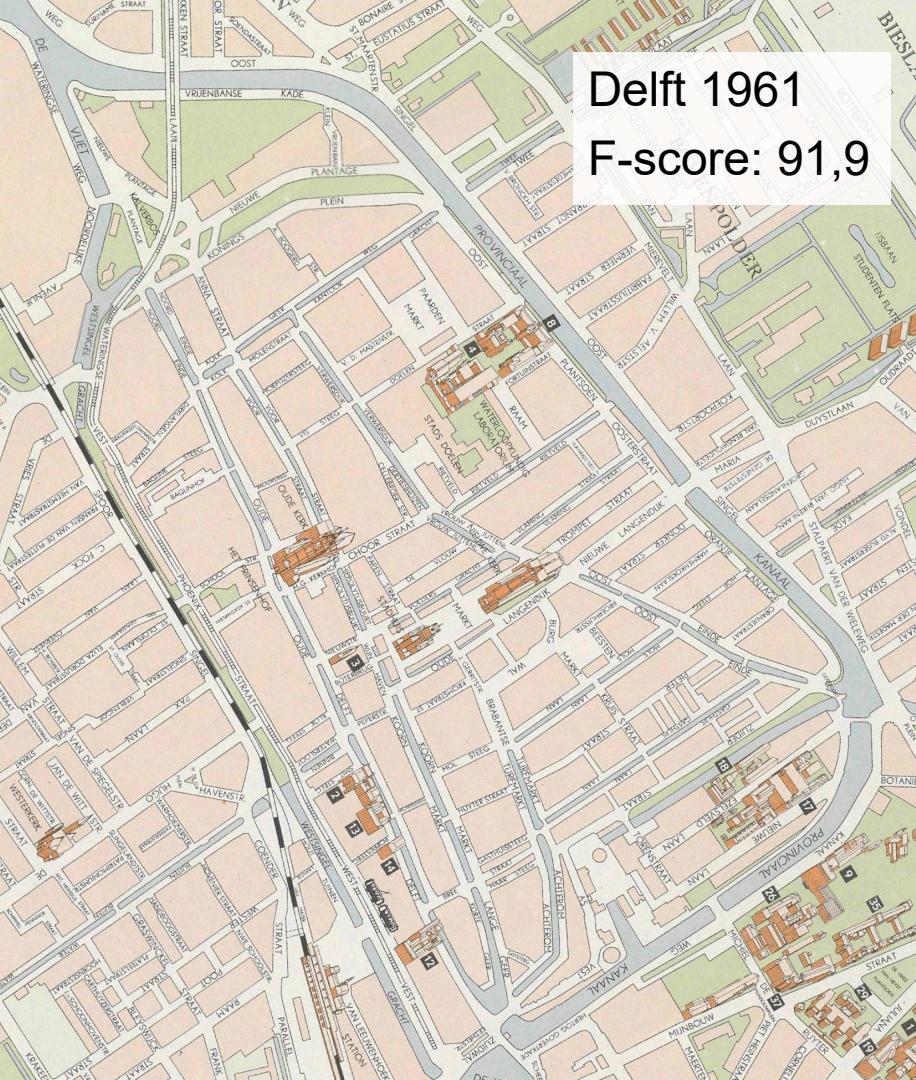
Historical maps	Precision	Recall	F-score
Delft 1880	60.7	67.4	63.9
Delft 1915	92.7	56.0	69.9
Delft 1961	93.6	88.9	91.2
Delft 1982	95.4	90.5	92.9
Brussels 1700	78.7	89.5	83.7
Brussels 1890	89.7	84.6	87.0
Brussels 1924	92.7	85.3	88.9

→ F-score > 83% for almost all maps



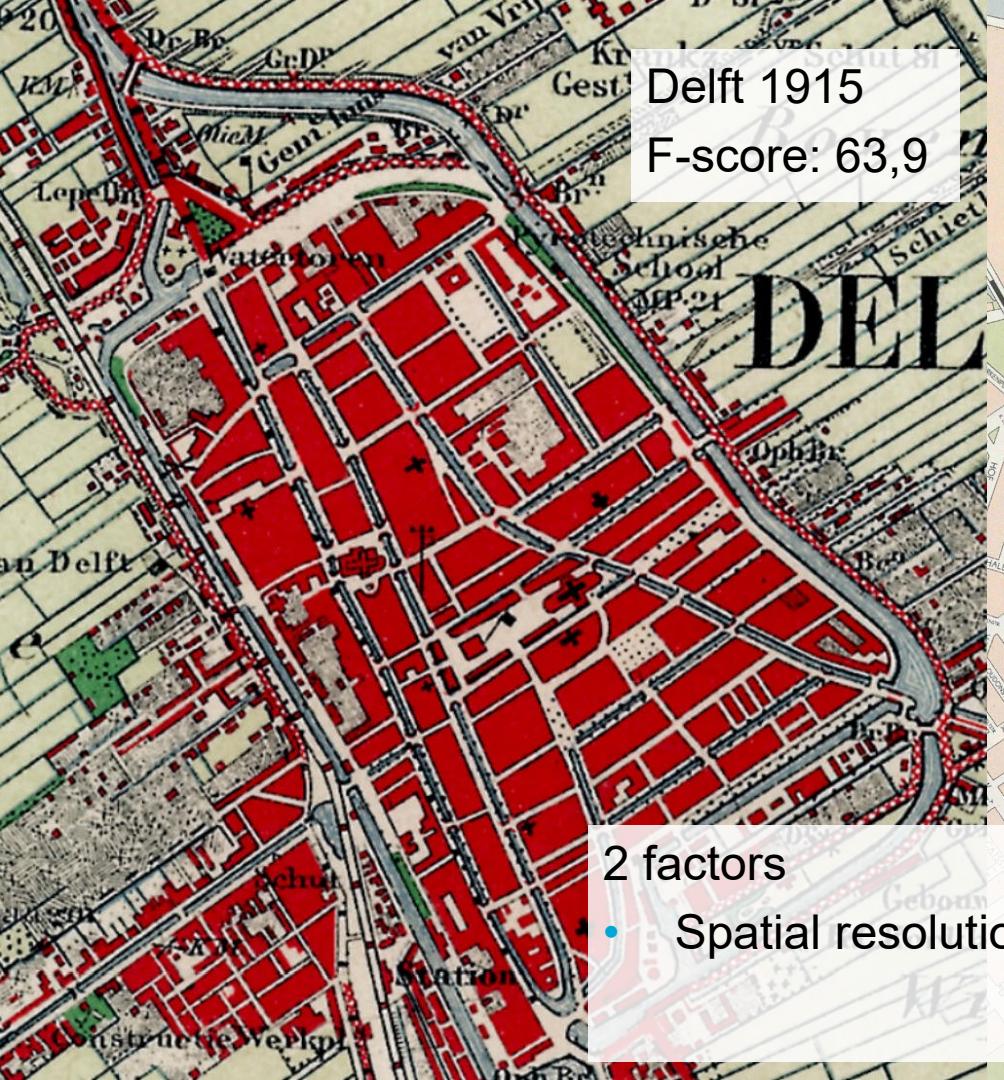
Delft 1915

F-score: 63,9



# Delft 1961

F-score: 91,9



Delft 1915

F-score: 63,9

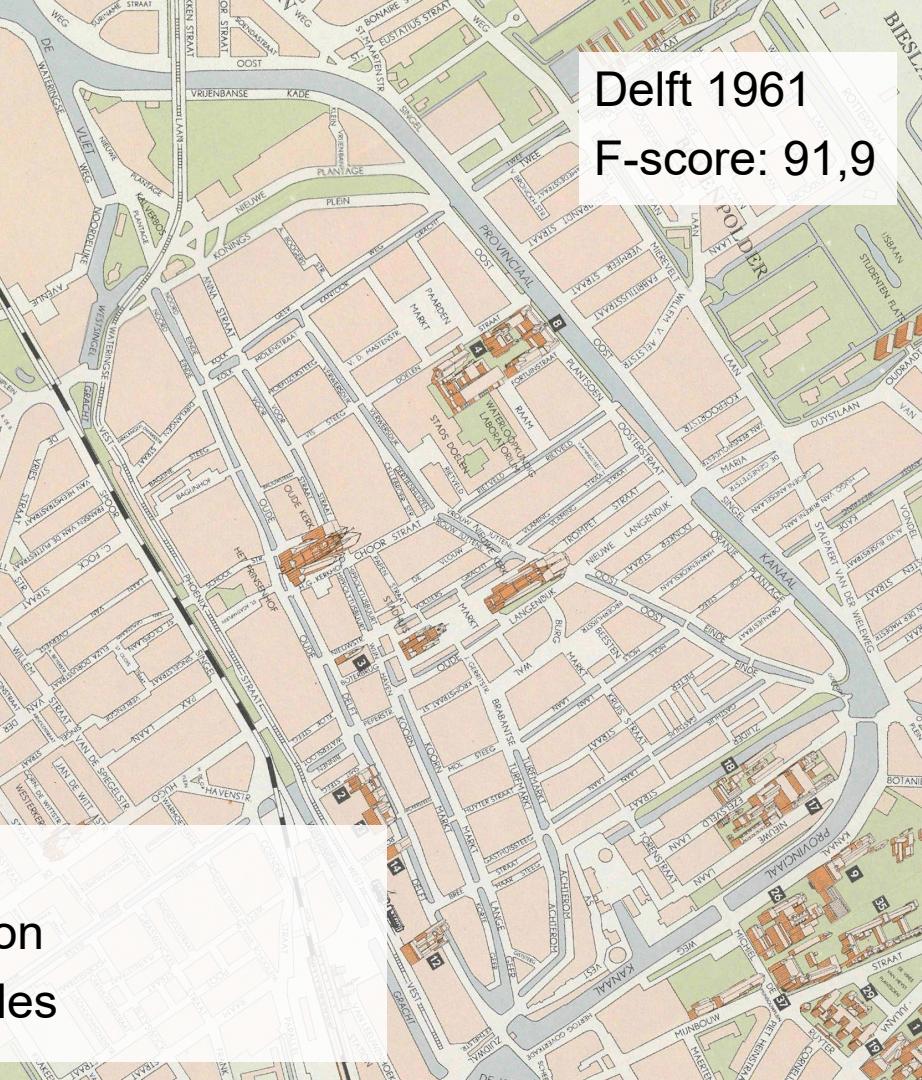
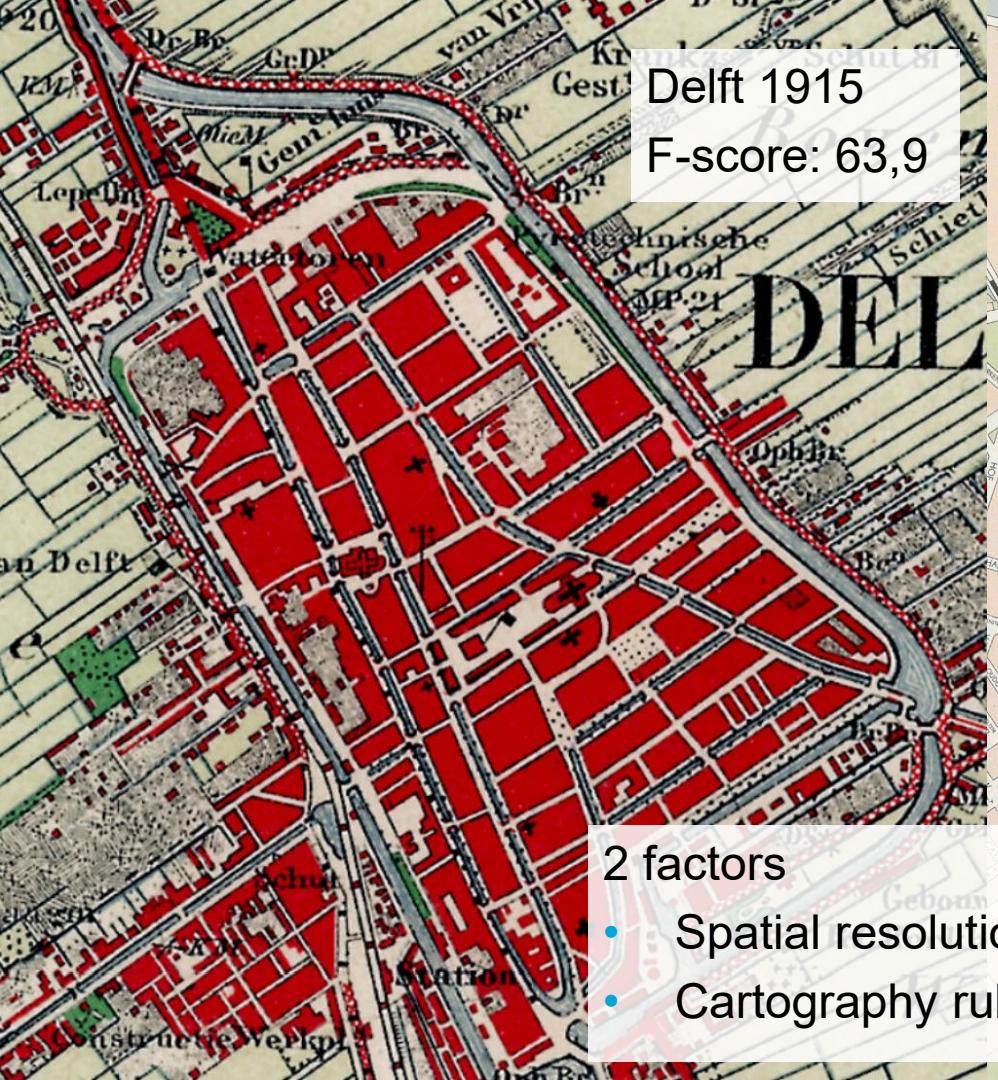


Delft 1961

F-score: 91,9

# 2 factors

- Spatial resolution



- 2 factors
- Spatial resolution
  - Cartography rules

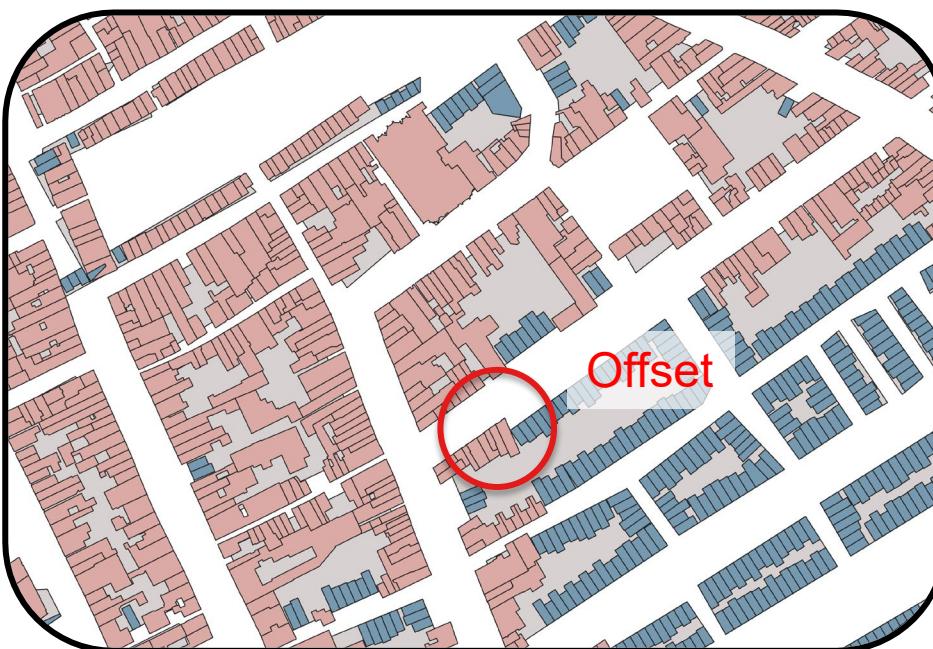
# Reconstruction of individual footprints

Maps alignment + 2D procedural modelling



# Reconstruction of individual footprints

Maps alignment + 2D procedural modelling

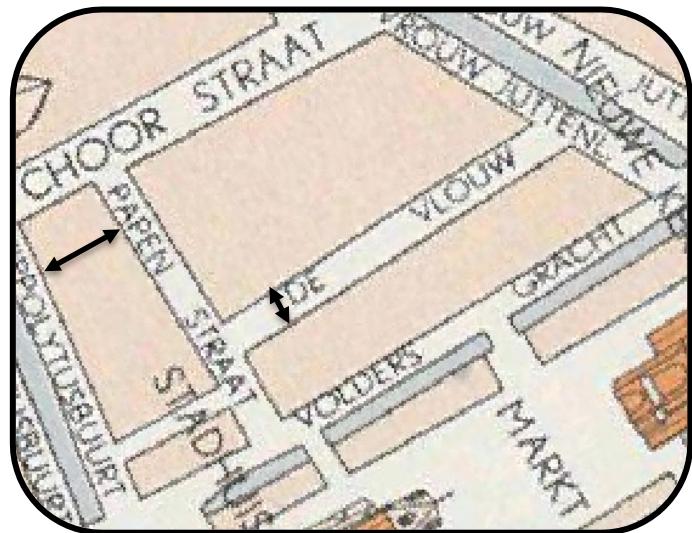


# Reconstruction of individual footprints

Inaccuracies?



Building plots 2021



Building plots 1961

# LoD2 buildings generation

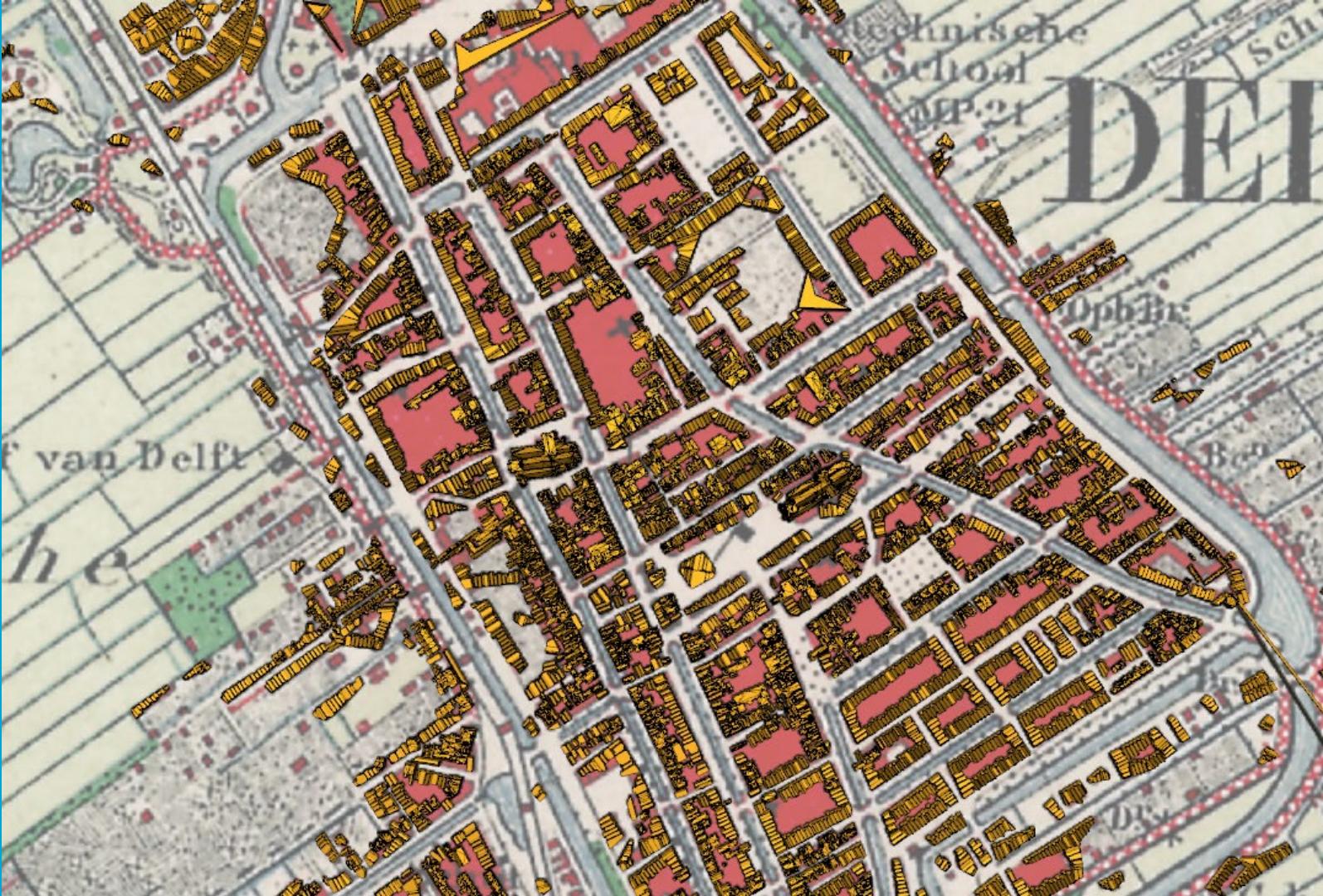
## 1. Delft

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



1700



1890



1924

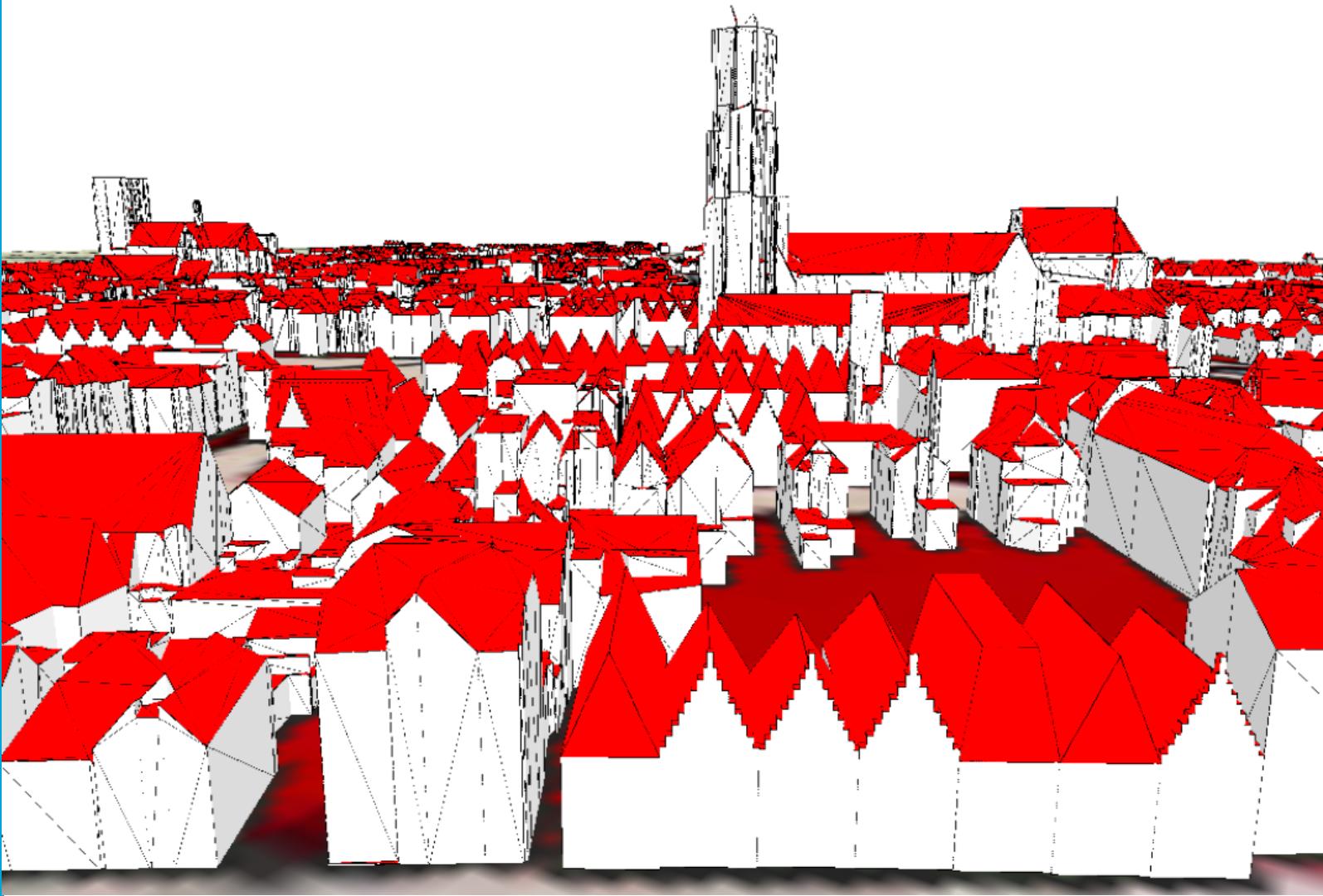
# LoD2 buildings generation

## Results assessment

- Visual assessment

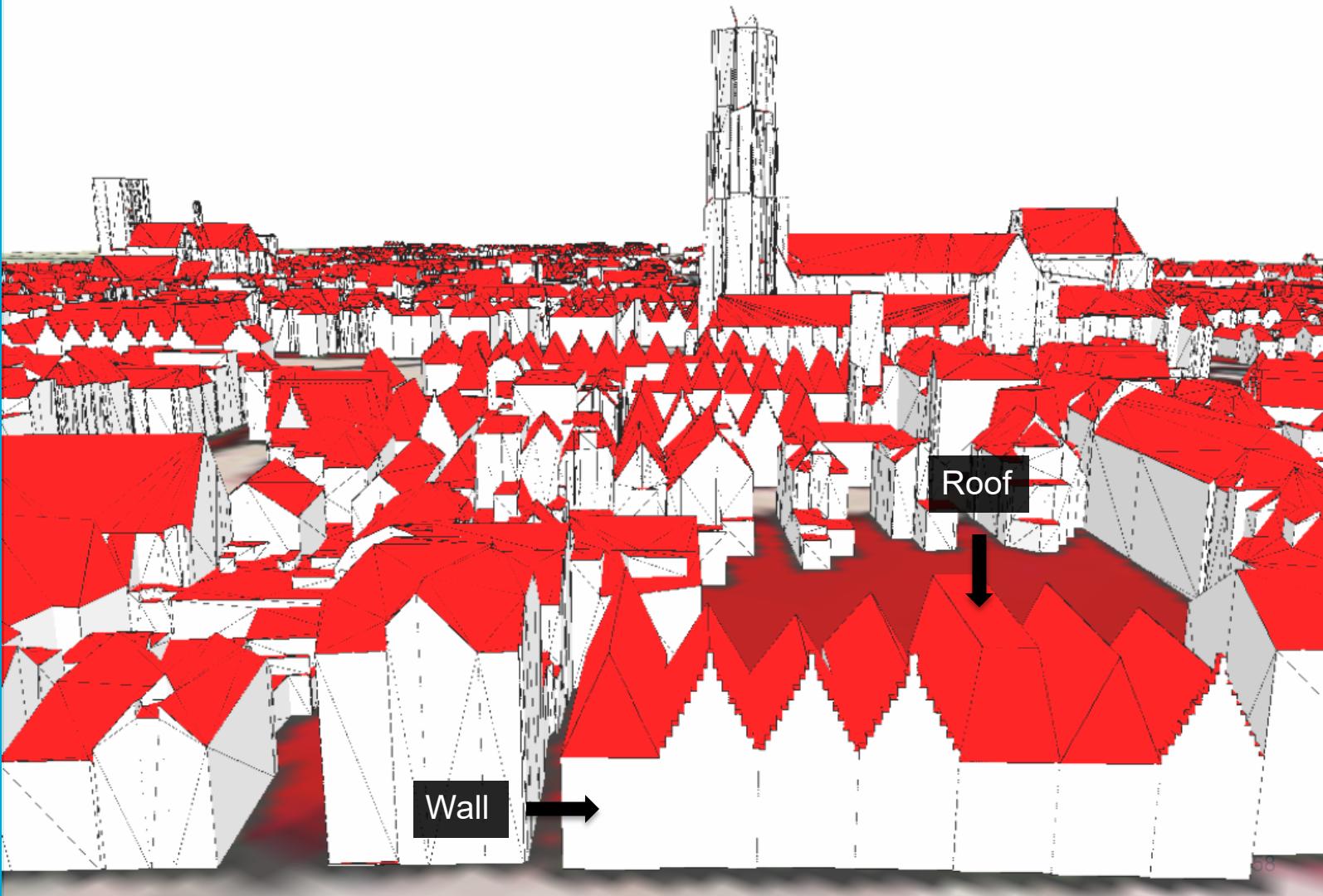
Are the buildings generated as expected?

Delft 1915

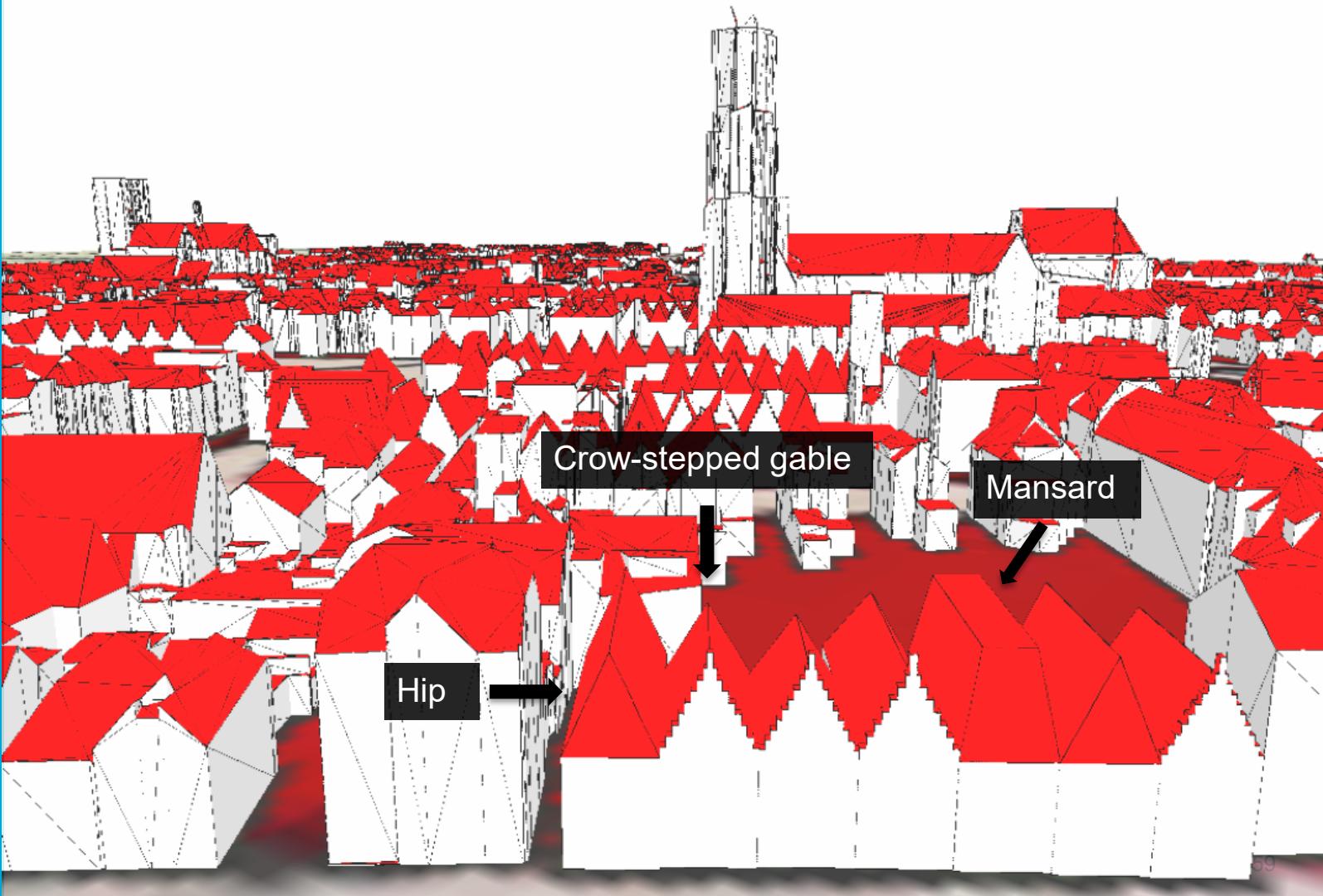


Delft 1915

Semantics

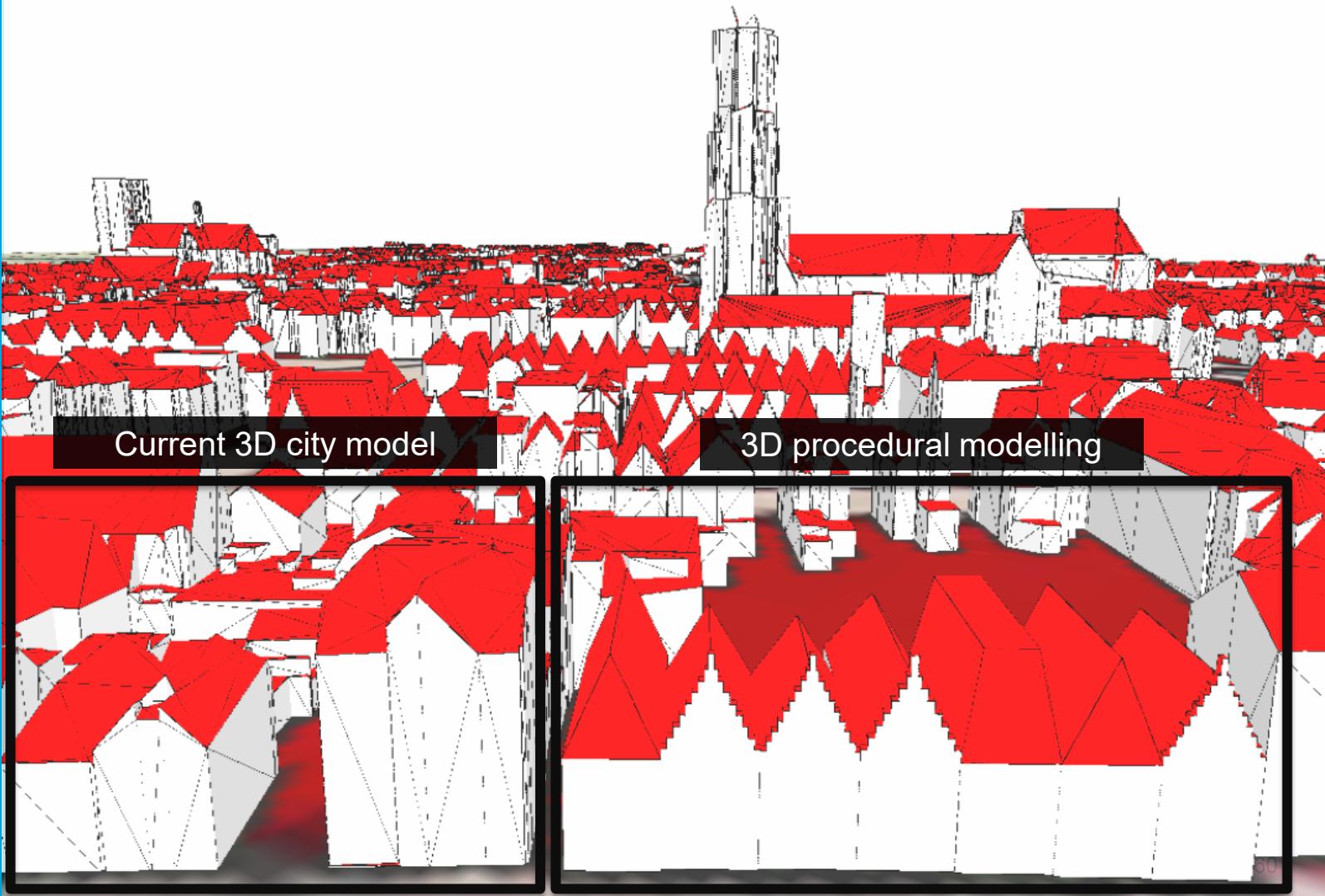


Semantics  
Roof types



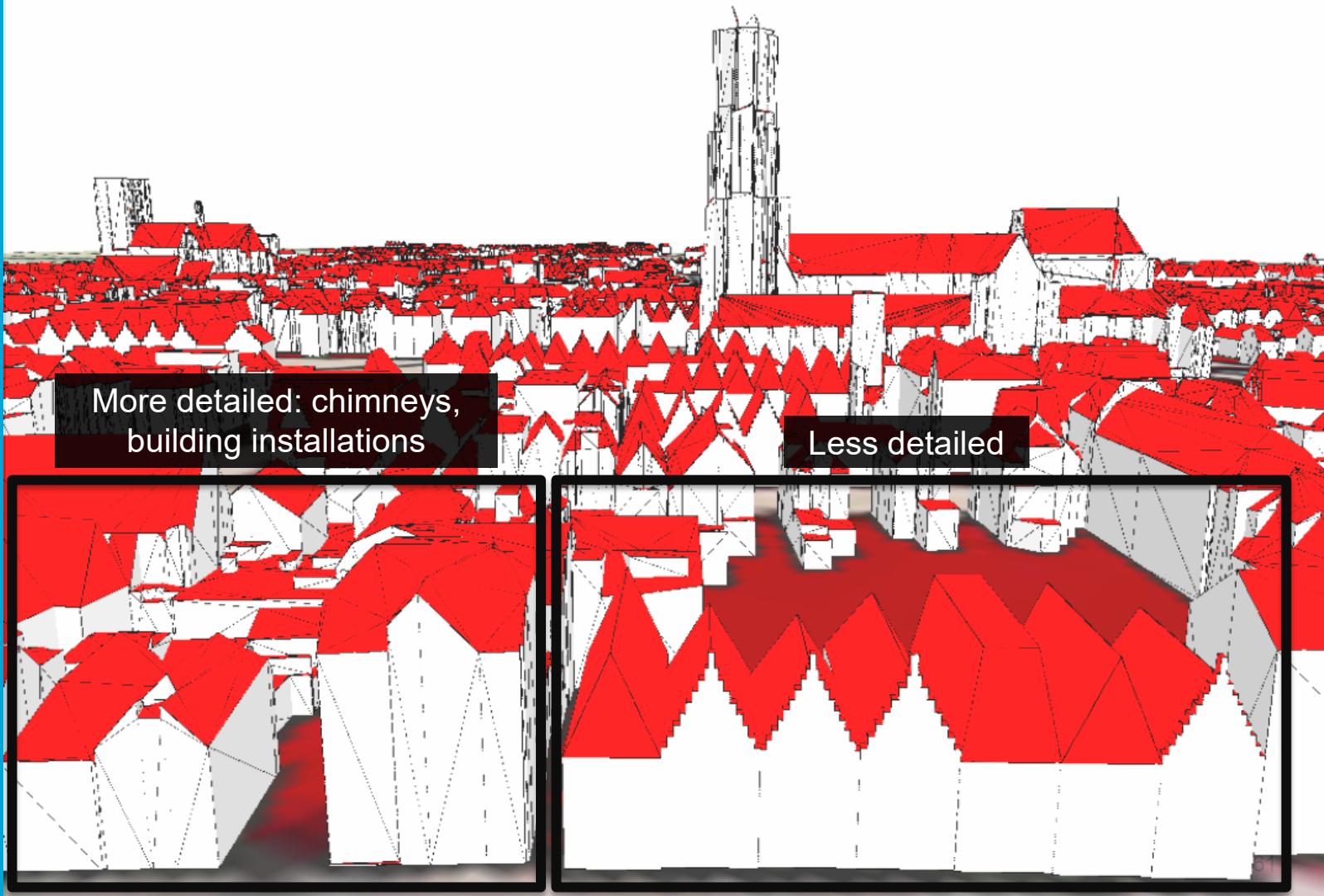
# Delft 1915

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]

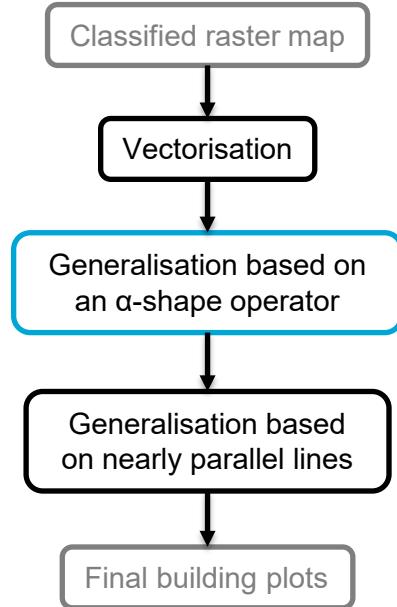
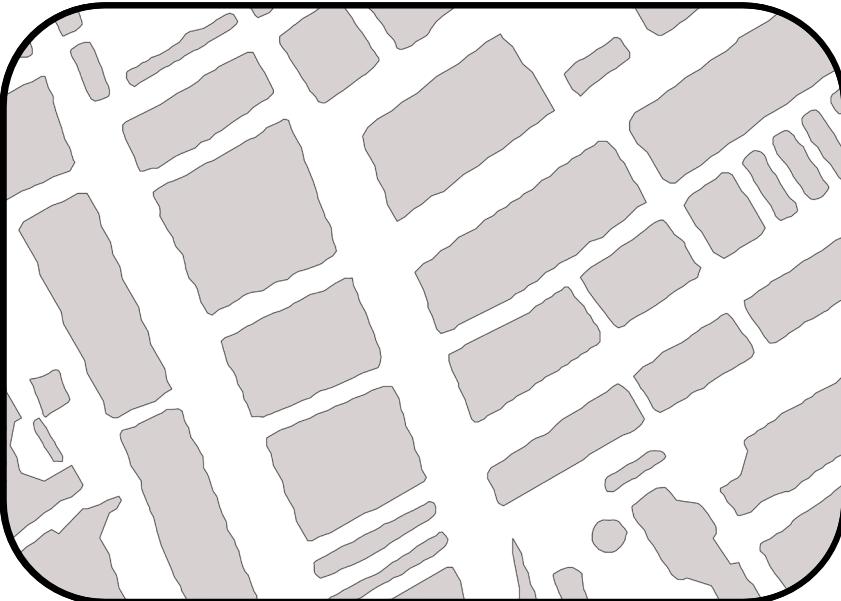
# Thank you !

# References

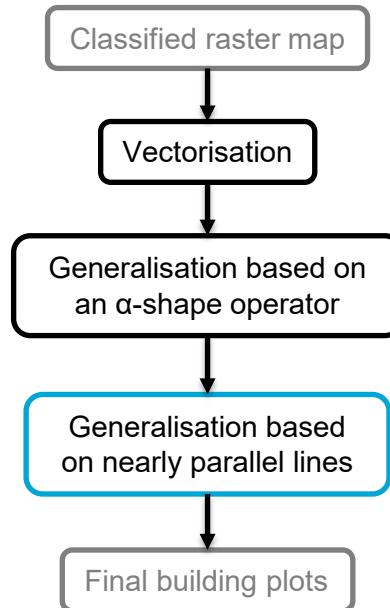
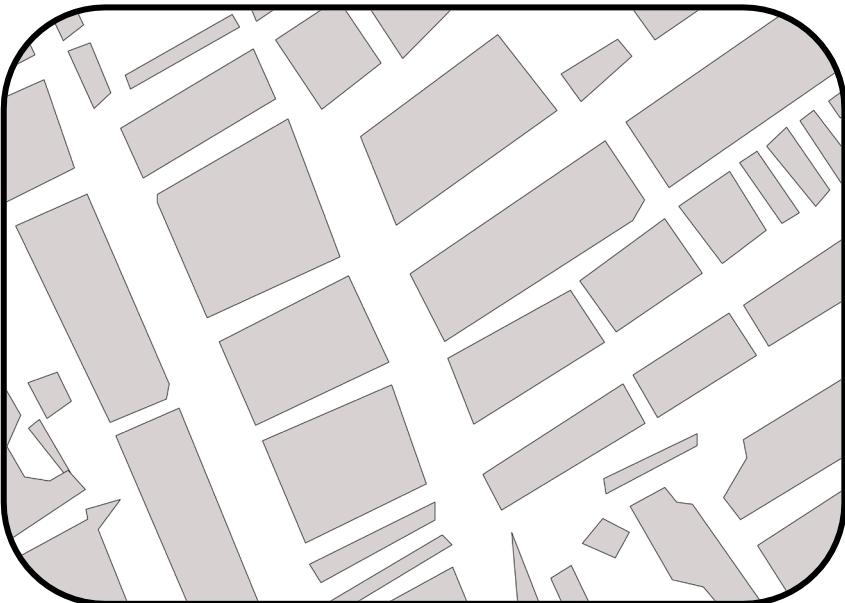
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- Ryckaert, M. (2012). Bruges (Belgium): houses at the Potterierei. [https://commons.wikimedia.org/wiki/File:Brugge\\_Houses\\_Potterierei\\_R02.jpg](https://commons.wikimedia.org/wiki/File:Brugge_Houses_Potterierei_R02.jpg)

# Extra slides

# Building plots extraction



# Building plots extraction



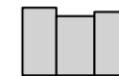
# Reconstruction of individual footprints

## 2D procedural modelling

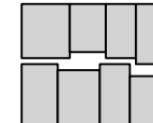
Case 1



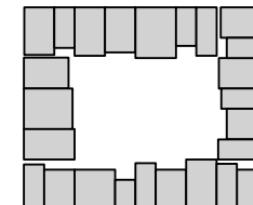
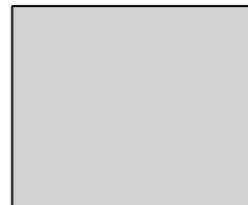
Case 2



Case 3



Case 4



# 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