Bidirectional enrichment of CityGML and Multi-View Stereo Mesh models

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Delegate of board of examiners: L. Qu

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TU Delft

Outline

1. Background & Research objectives
2. Bidirectional enrichment
3. Proposed methodology & Analysis
4. Conclusions & Future work

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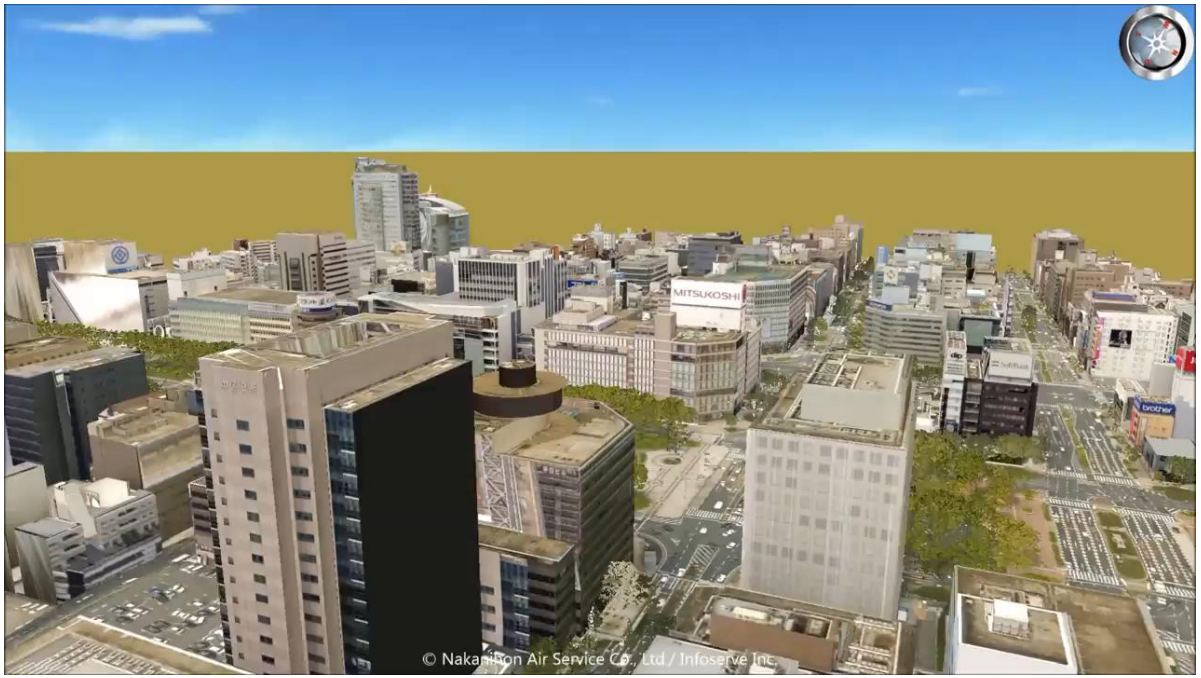
3D city model



Source: *Nagoya city - 3D CityGML modeling example*
Link: *https://www.youtube.com/watch?v=9CTbQTKPtsg*

3D city model

- Helsinki 3D+ (2016)
- Solar Irradiation Analysis Rennes (2016)
- Berlin Solar Atlas (2017)

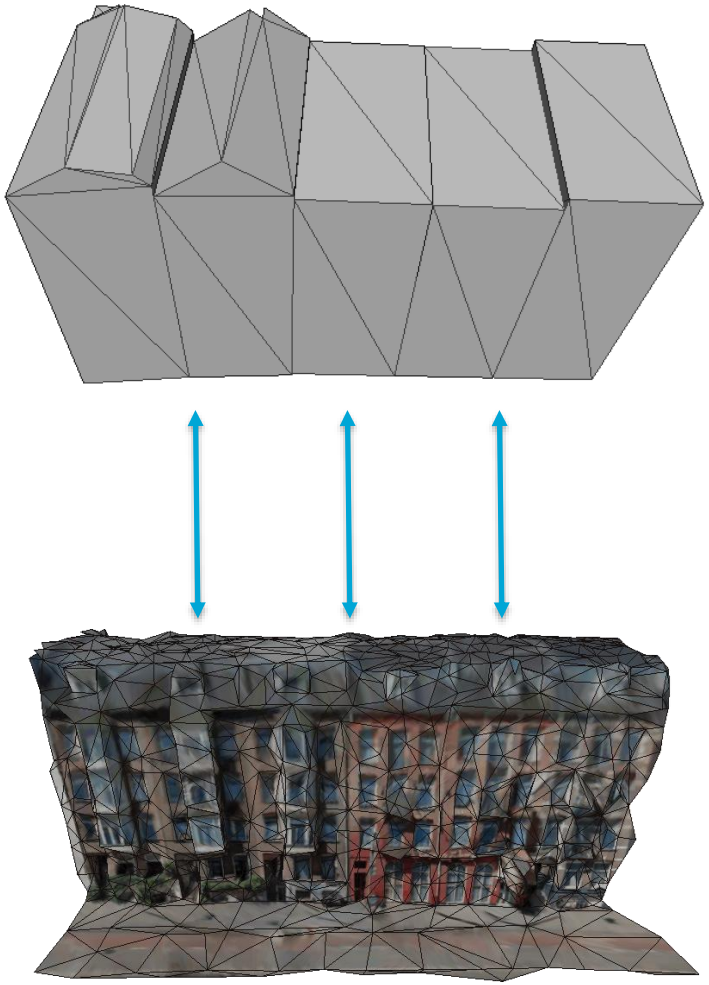
3D city model

Source: *virtualcityMAP - Demonstration of Solar Irradiation Analysis Rennes, France*

Link: *https://www.youtube.com/watch?v=OzVGzPi1Me0*

Problem

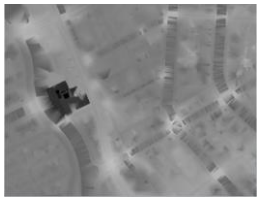
CityGML model

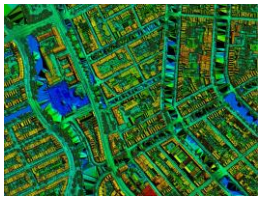


MVSM model

CityGML model

Creation:





kadaster

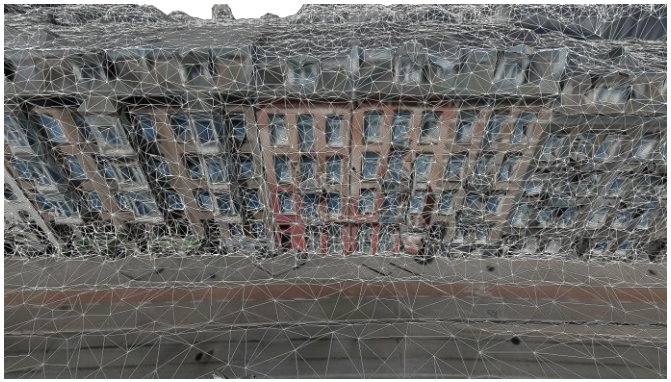
Source: Biljecki et al. (2016)

Characteristics:

- Rich in semantics (e.g. roof, wall, ground)
- Semi-automatic construction
- Plain (not all geometric aspects)

Multi – View Stereo Mesh model

Creation:



Characteristics:

- Fully automatic construction
- Plenty of geometric information
- Rich textures
- No semantics

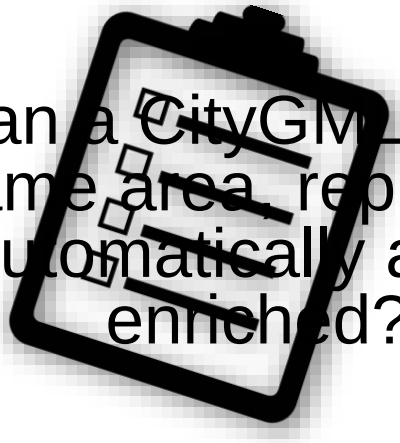
CityGML vs MVSM models

Standard\ Criteria	*CityGML*	*MVSM*
Geometry	B-rep	Mesh
Semantics	Rich in semantics	No semantics
LOD	5 discrete LODs	Not supported
Texture	Basic support	Rich textures
Construction	Semi-automatic	Fully automatic

Source: Kavisha and Saran (2015)

Research objectives

To what extent can a CityGML model and a MVSM model of the same area, representing the same features, be automatically and bidirectionally enriched?



To what extent can a CityGML model and a MVSM model of the same area, representing the same features, be automatically and bidirectionally enriched?

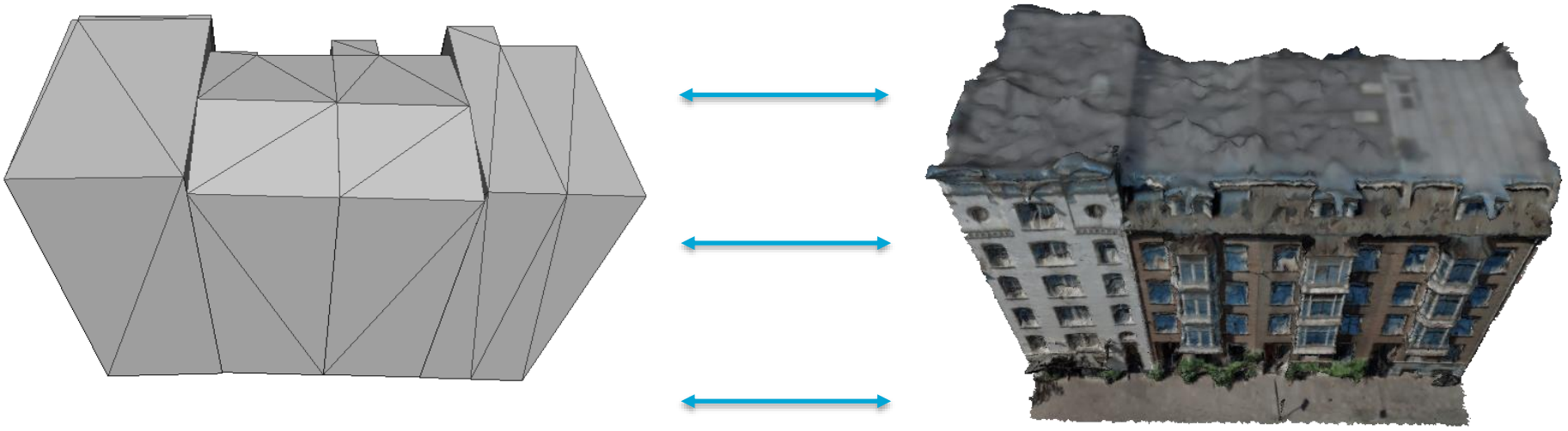
Bidirectional enrichment

Bidirectional enrichments between models

Bidirectional enrichment methodologies

Research objectives

To what extent can a CityGML model and a MVSM model of the same area, representing the same features, be automatically and bidirectionally enriched?



Match faces

Semantic segmentation

Transfer attributes

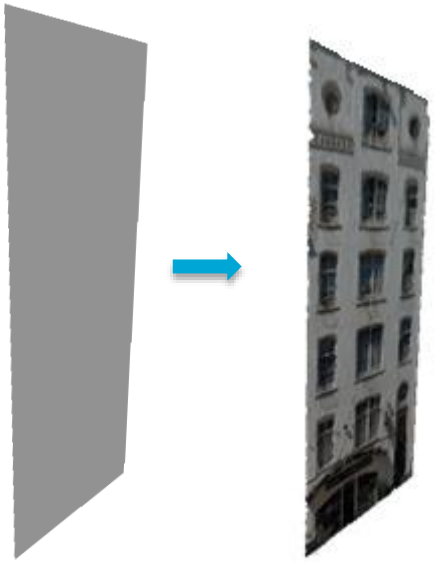
Segment per building

Research objectives

To what extent can a CityGML model and a MVSM model of the same area, representing the same features, be automatically and bidirectionally enriched?

Validation of the matching

Detection of errors



Texturing

Related work

- Interoperability of information
- Straightening of meshes
- Semantic enrichment of 3D models
- Matching of meshes
- Mesh comparison

Related work

- Straightening of meshes
- Interoperability of information
- Semantic enrichment of 3D models
- Matching of meshes
- Mesh comparison

Veltkamp (2001)

Ericson (2004)

Eberly (2006)

Guezlec (2001)

Point-to-polygonal-mesh distance

Hausdorff distance

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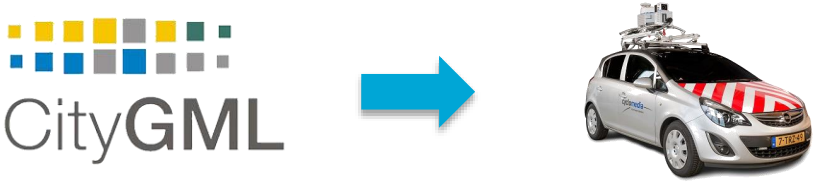
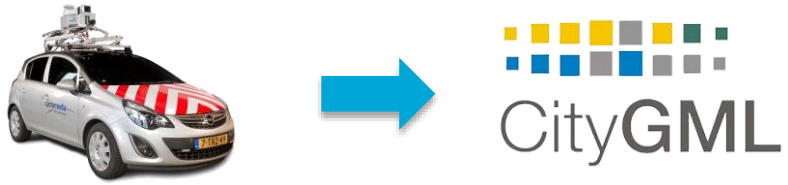
Bidirectional enrichment

Enrichments



- **Semantic segmentation**
- **Transfer attributes**
- Straightening
- Simplification



- **Texturing**
- **Validation**
- Update
- Creation of 3D CityGML model

Enrichment methodologies

- Creation and comparison of planes
- Probabilistic methods
- Predefined shapes of features
- Template matching techniques
- Machine learning techniques
- Clustering techniques
- **Heuristic rules**
- **Distance computation methods**

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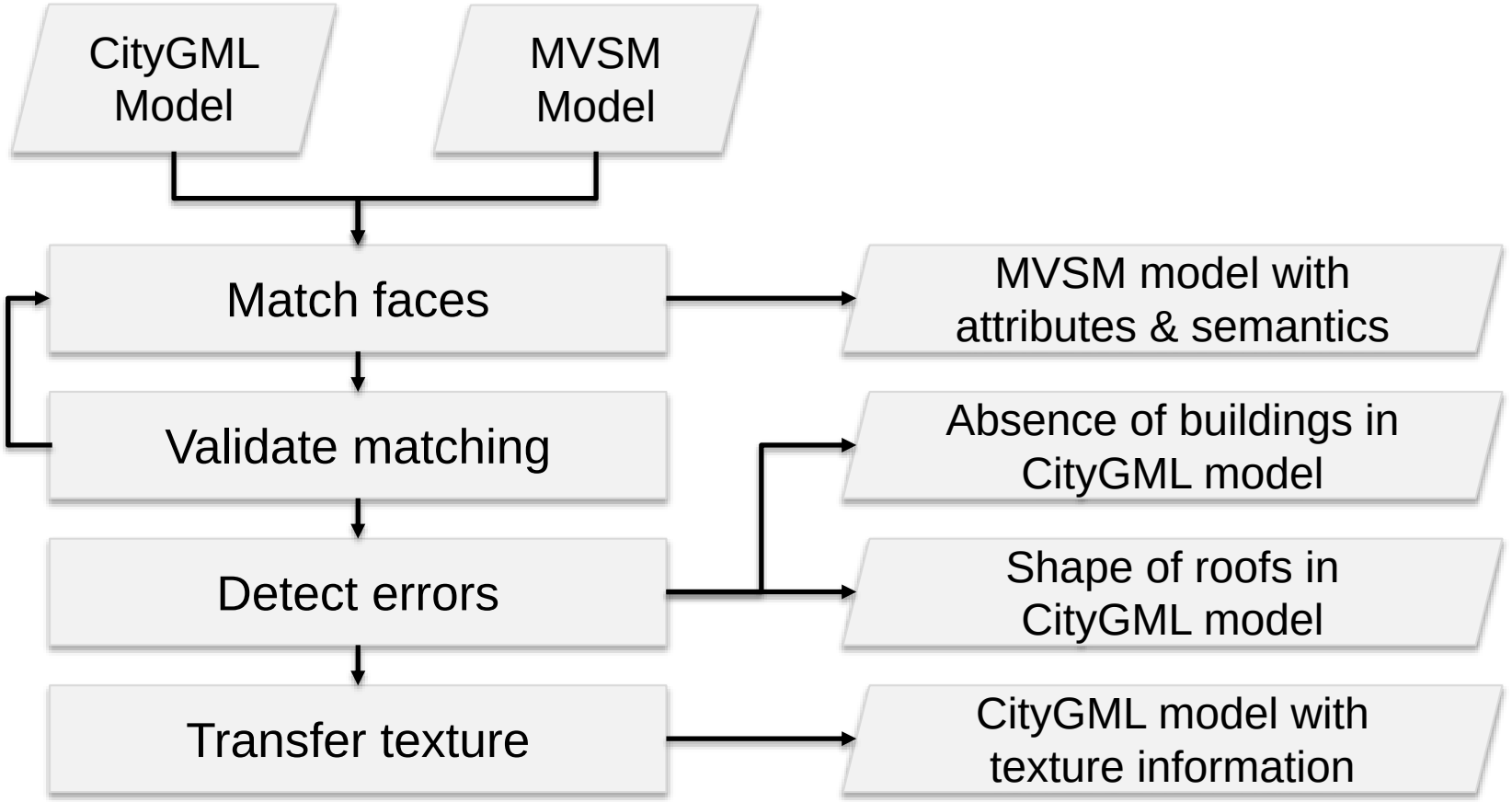
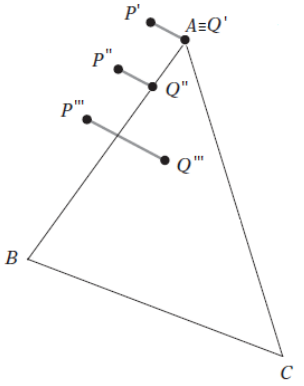
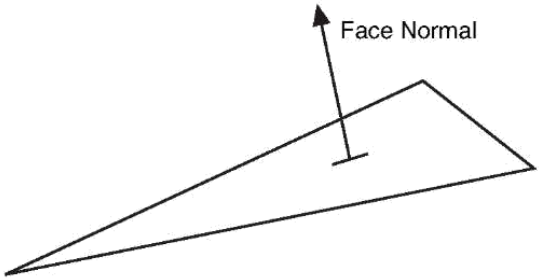
Proposed methodology

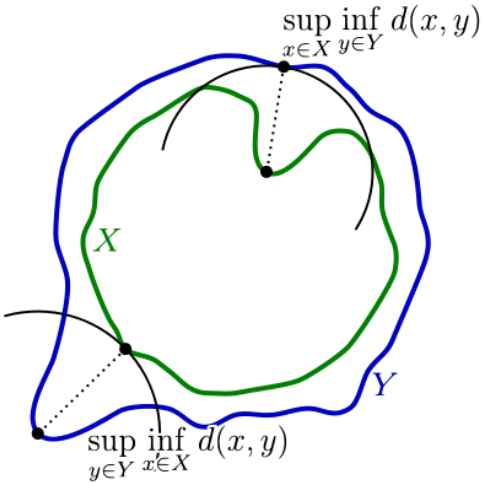


Proposed methodology

- Use point-to-polygonal-mesh distance
- Use Hausdorff distance
- Compute the normals of the triangles
- Create heuristic rules

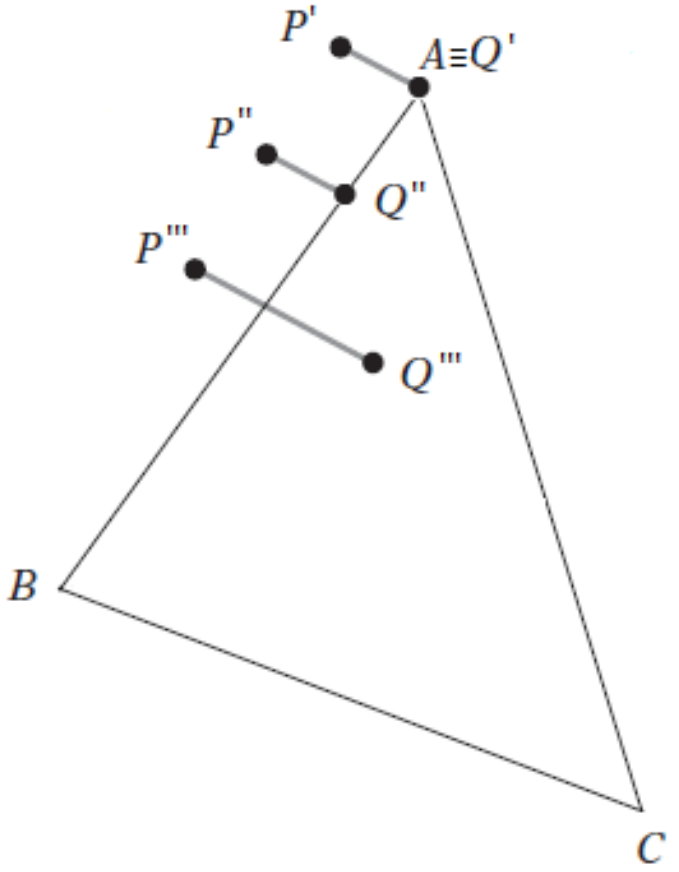






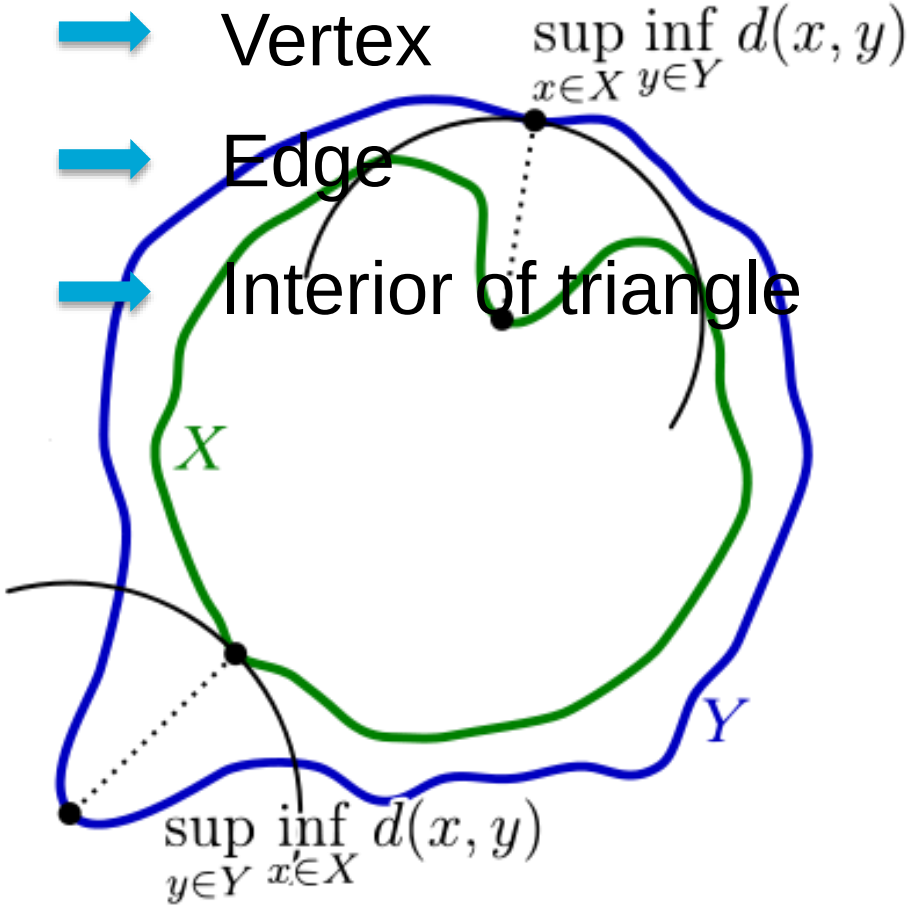
Proposed methodology

Point to polygonal mesh distance:



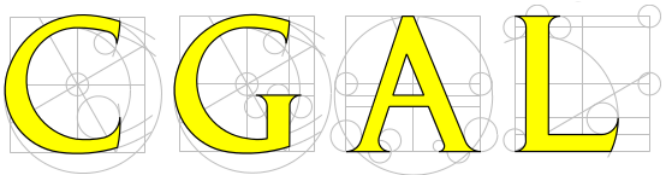
Hausdorff distance:

- Vertex
- Edge
- Interior of triangle

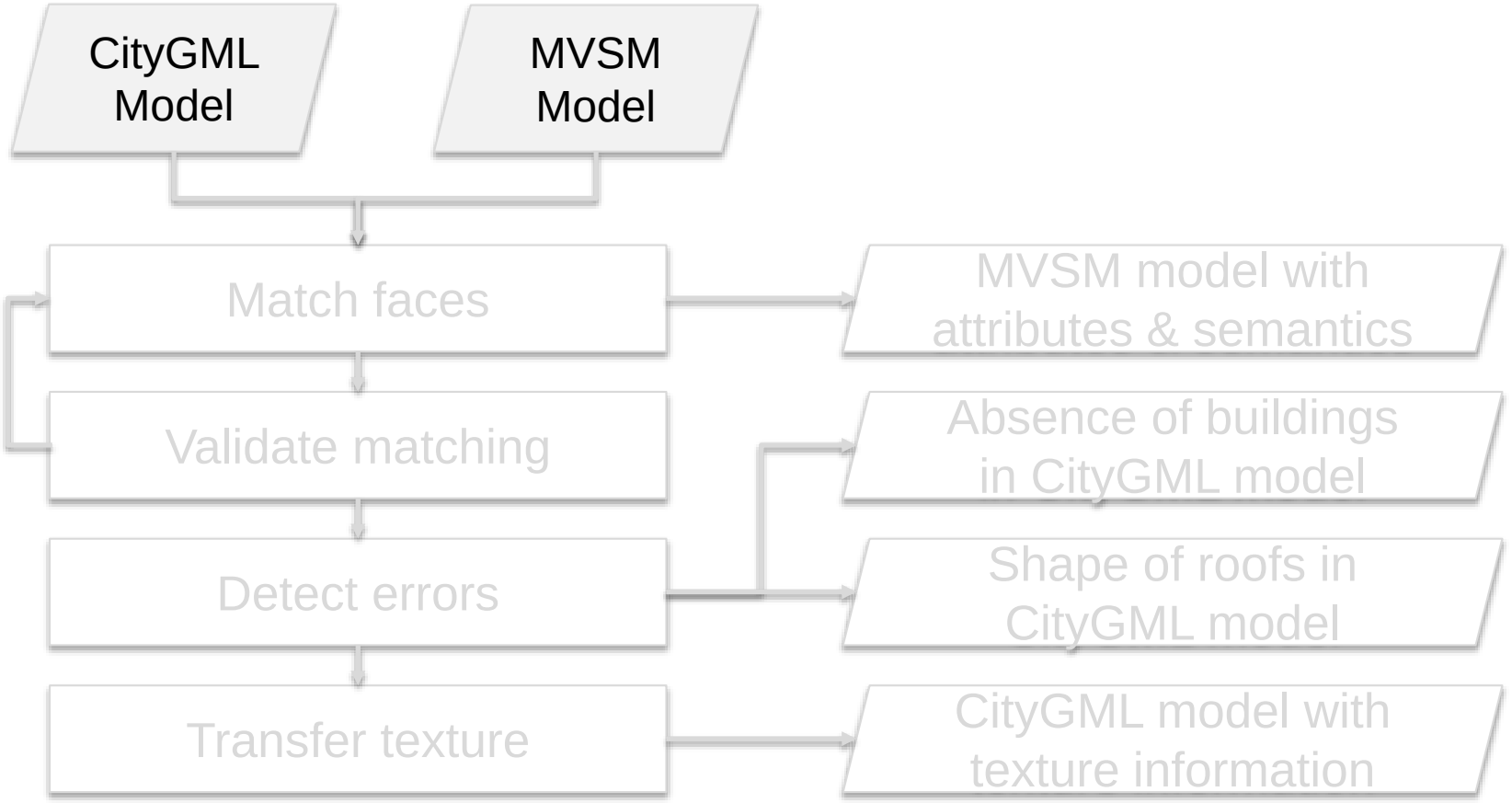


Source: https://en.wikipedia.org

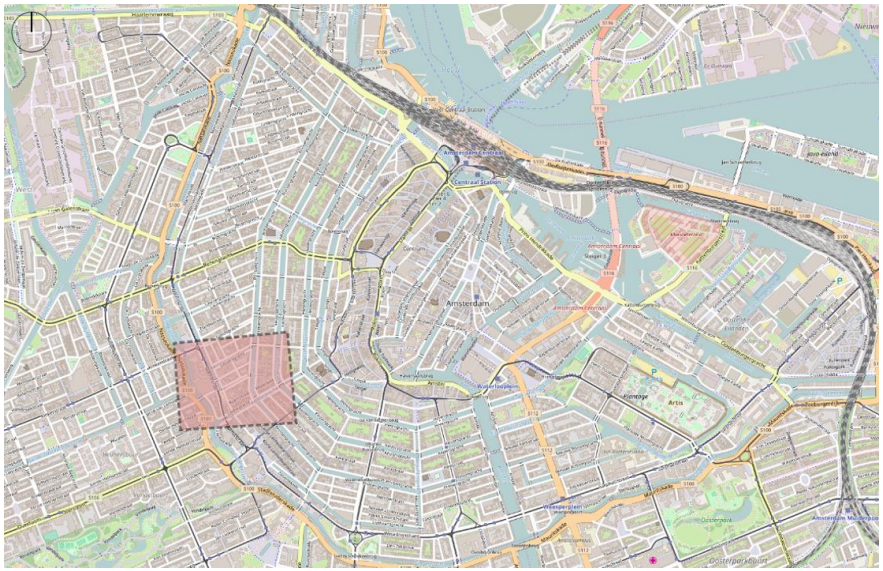
Tools



Proposed methodology



Data



- 655 buildings
- ≈720000.000 m^2
- Same CRS

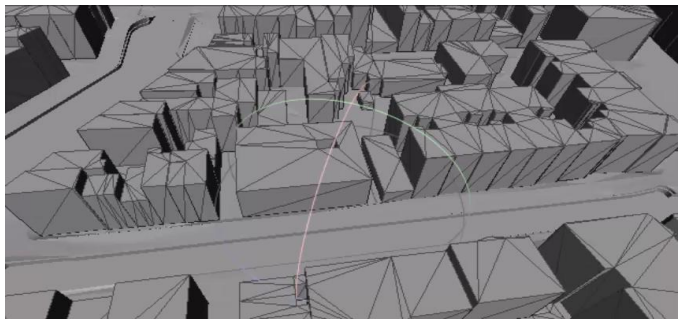
CityGML model:

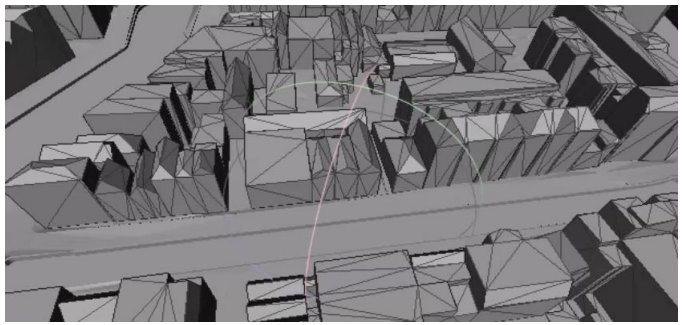
- <1 point per m^2

MVSM model:

- ≈60 points per m^2

Data





LOD1

LOD2

virtualcitySYSTEMS

.xml
file format

.dae
COLLADA
file format

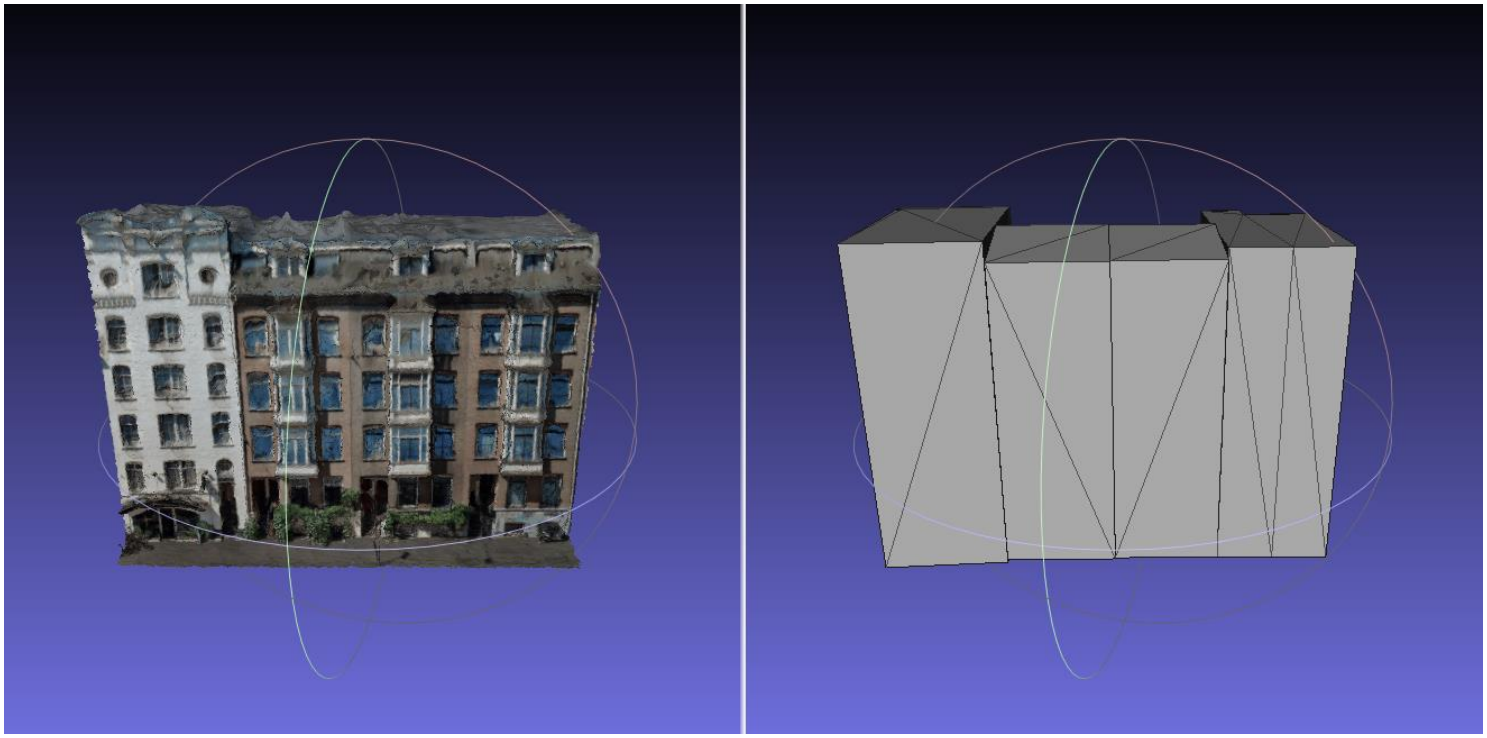
1st Implementation

Testing dataset

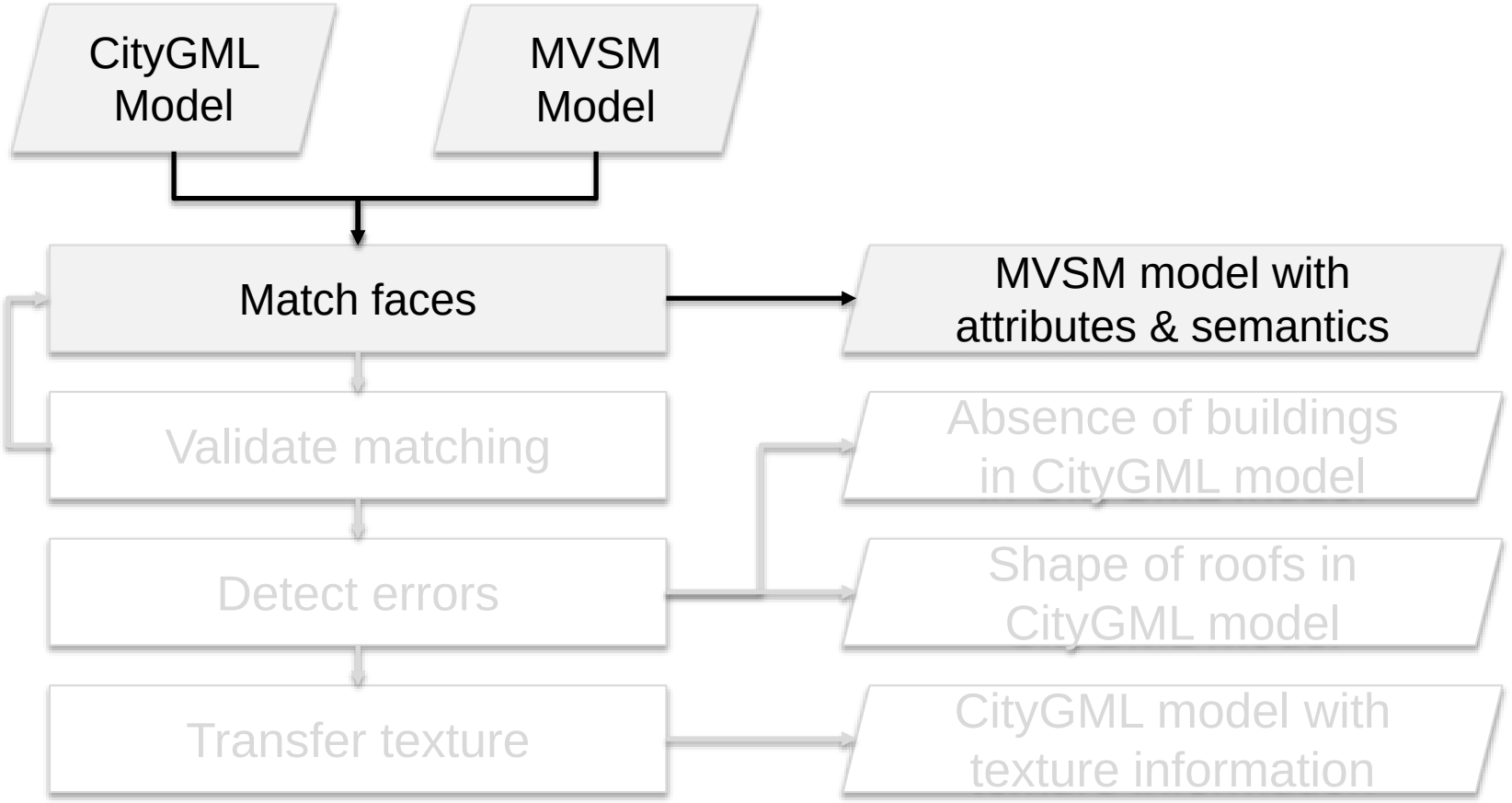
1st Implementation
4 buildings

≈1222.406m^2

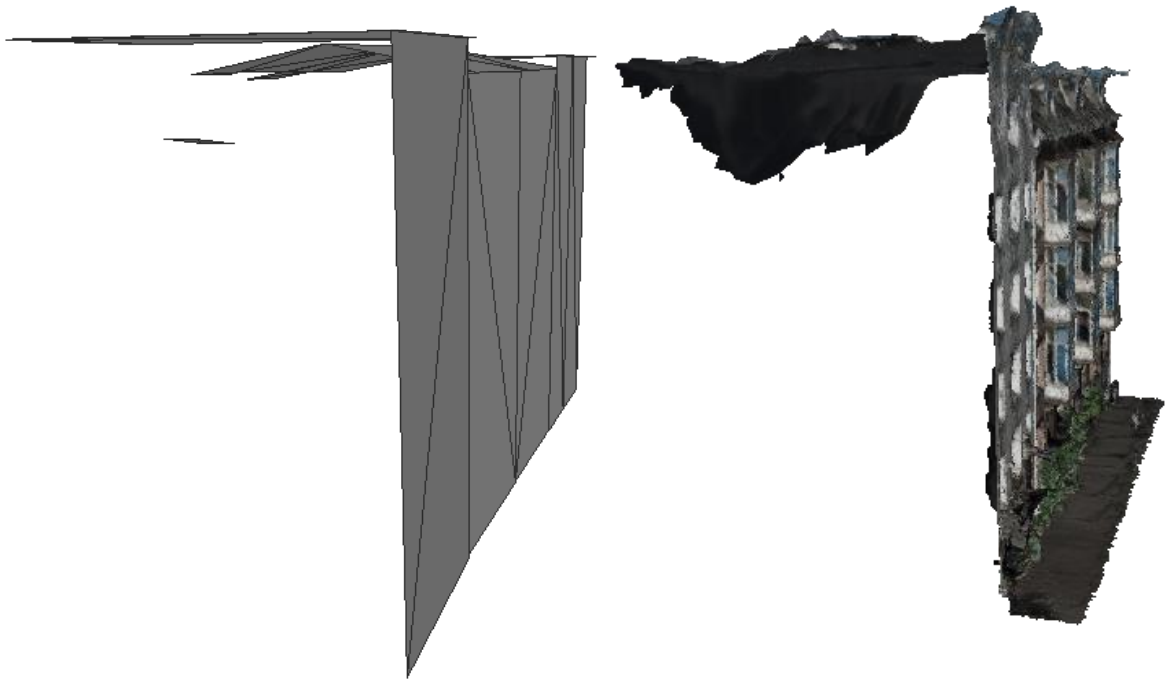
LOD2



Proposed methodology



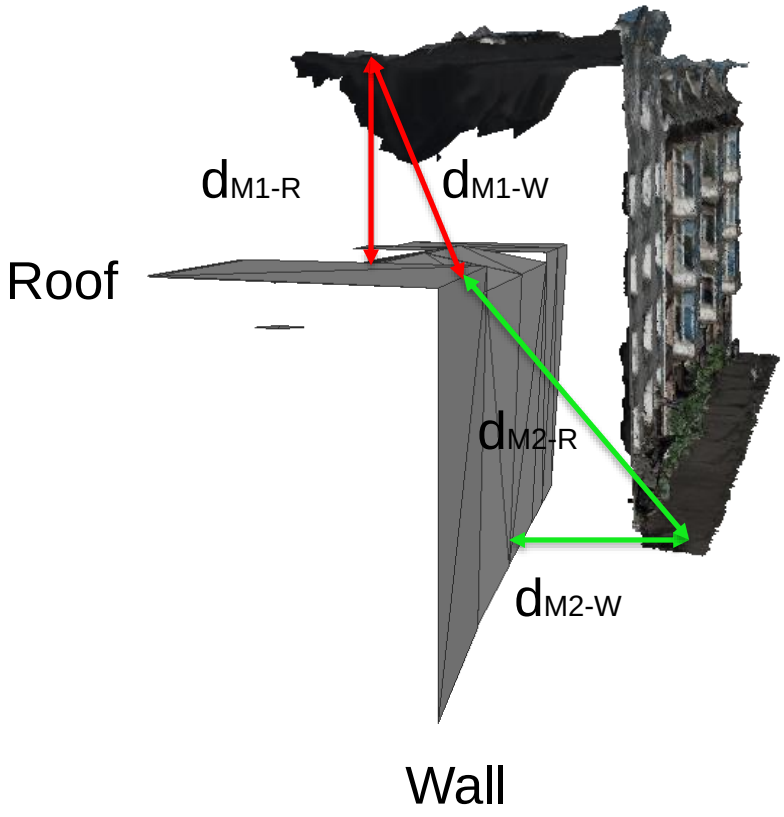
Match faces



- Roof
- Wall
- Uncertain

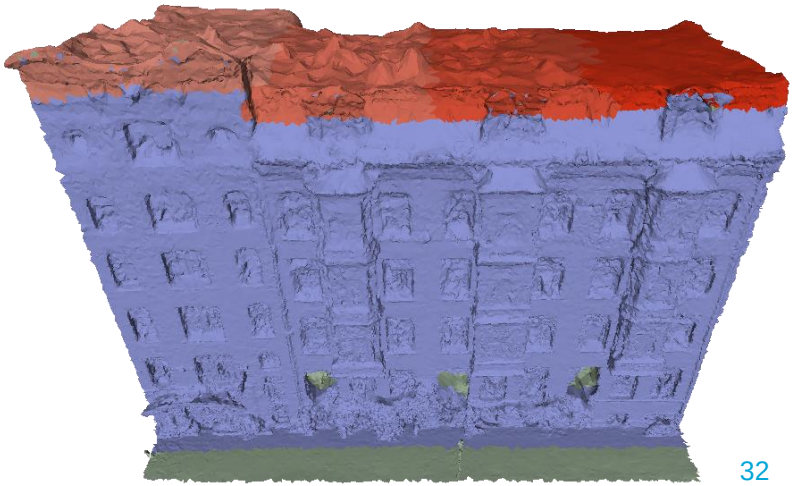
- 3 Heuristic Rules (HR)

Match faces

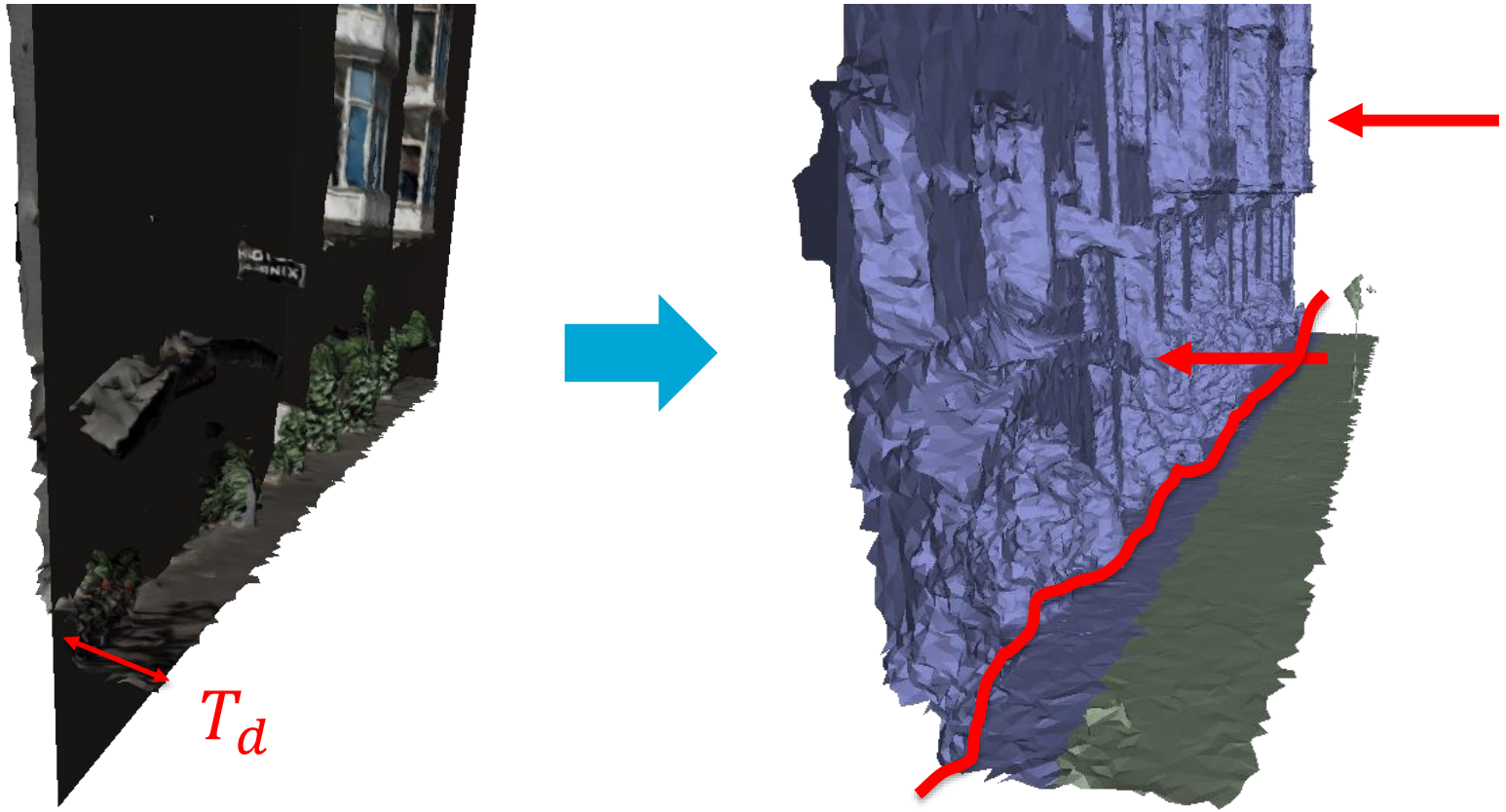


HR 1: Closer to roof, then **roof**.

HR 2: Closer to wall and larger than T_d, then **uncertain**.

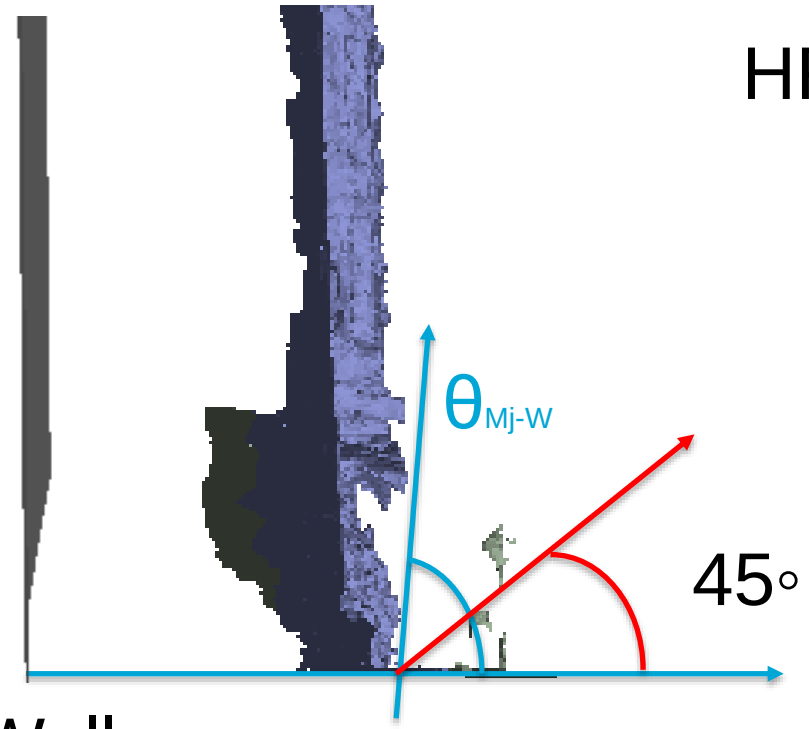


Match faces



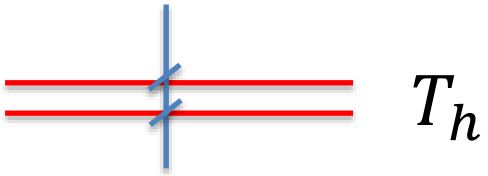
Match faces

Vertical sections:

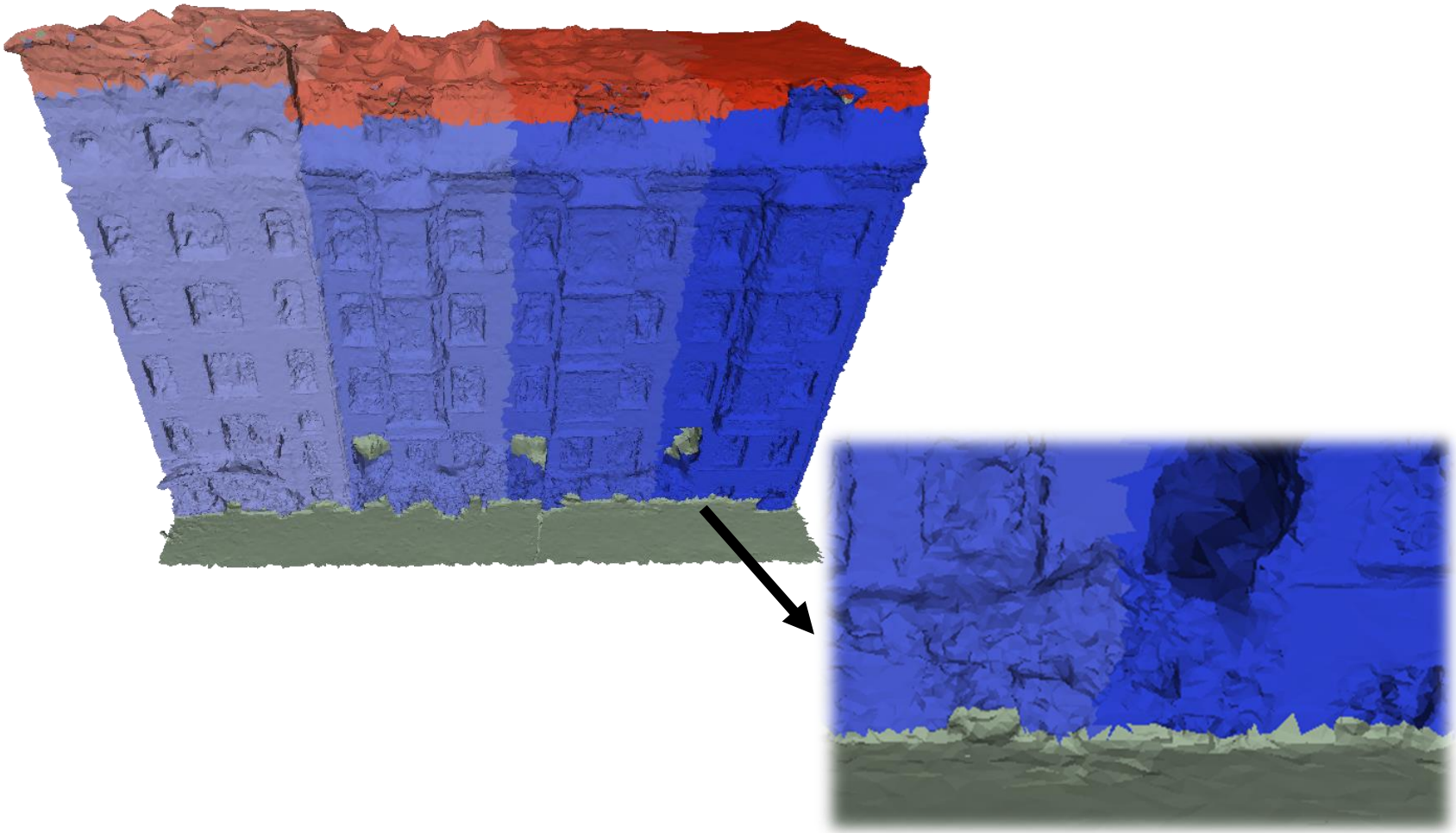


HR 3:

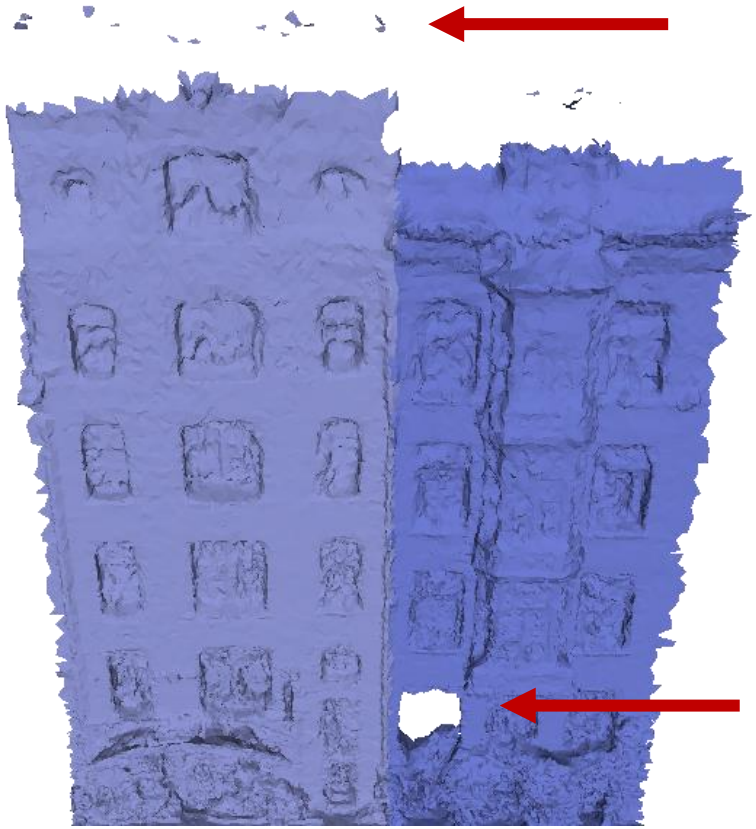
$h_{Mj} < h_{min} + T_h$
and
$\theta_{Mj\text{-}W} > 45°$,
then **uncertain**.

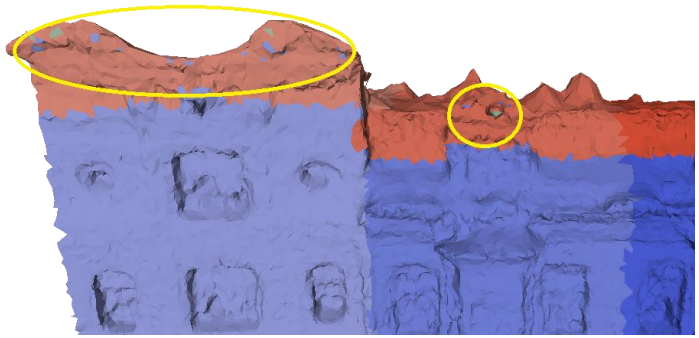


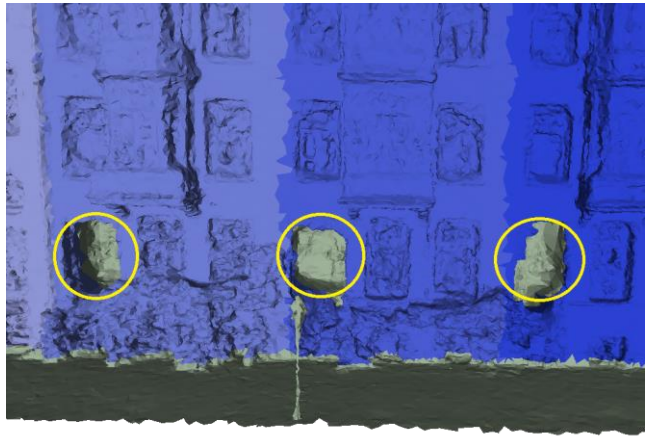
Match faces



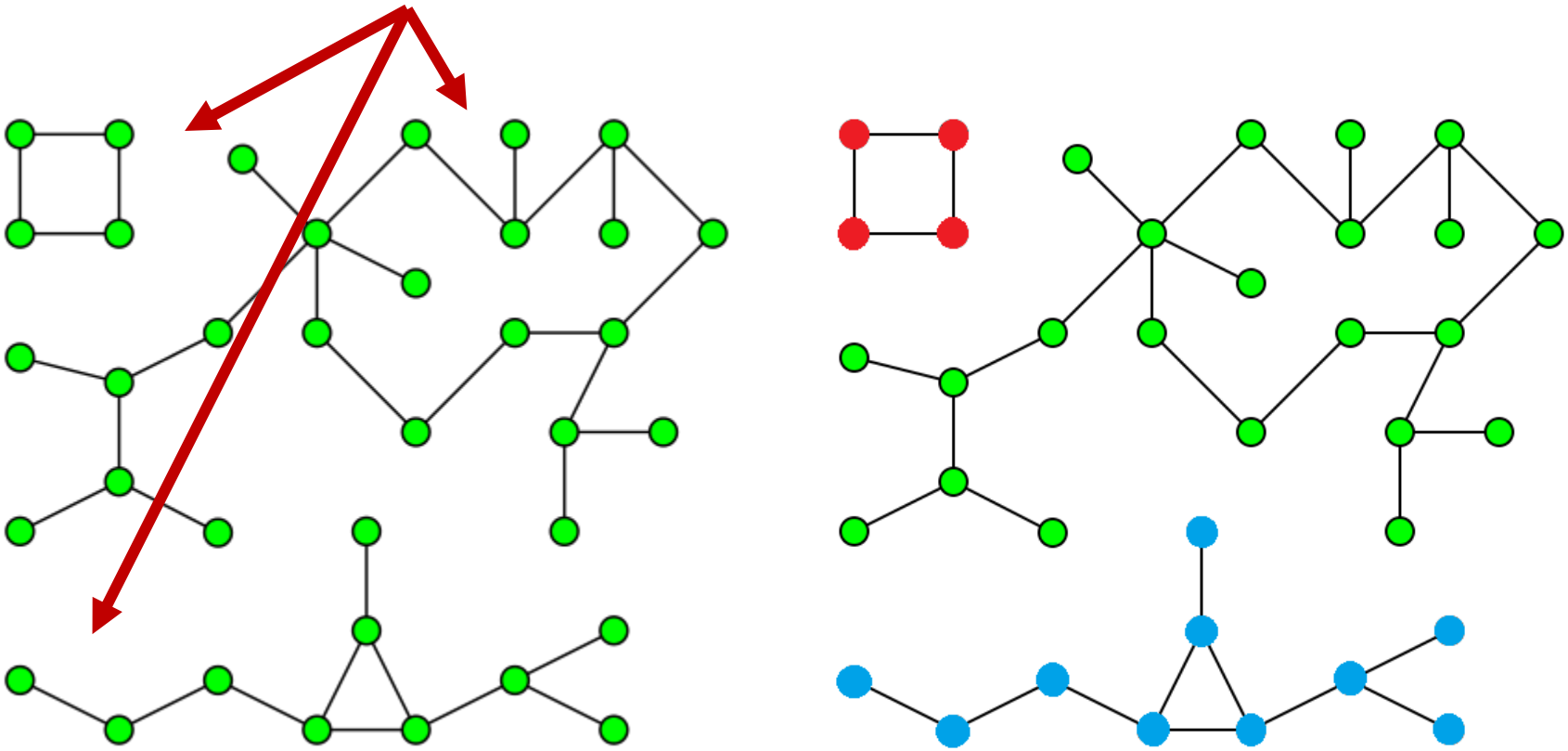
Connected components





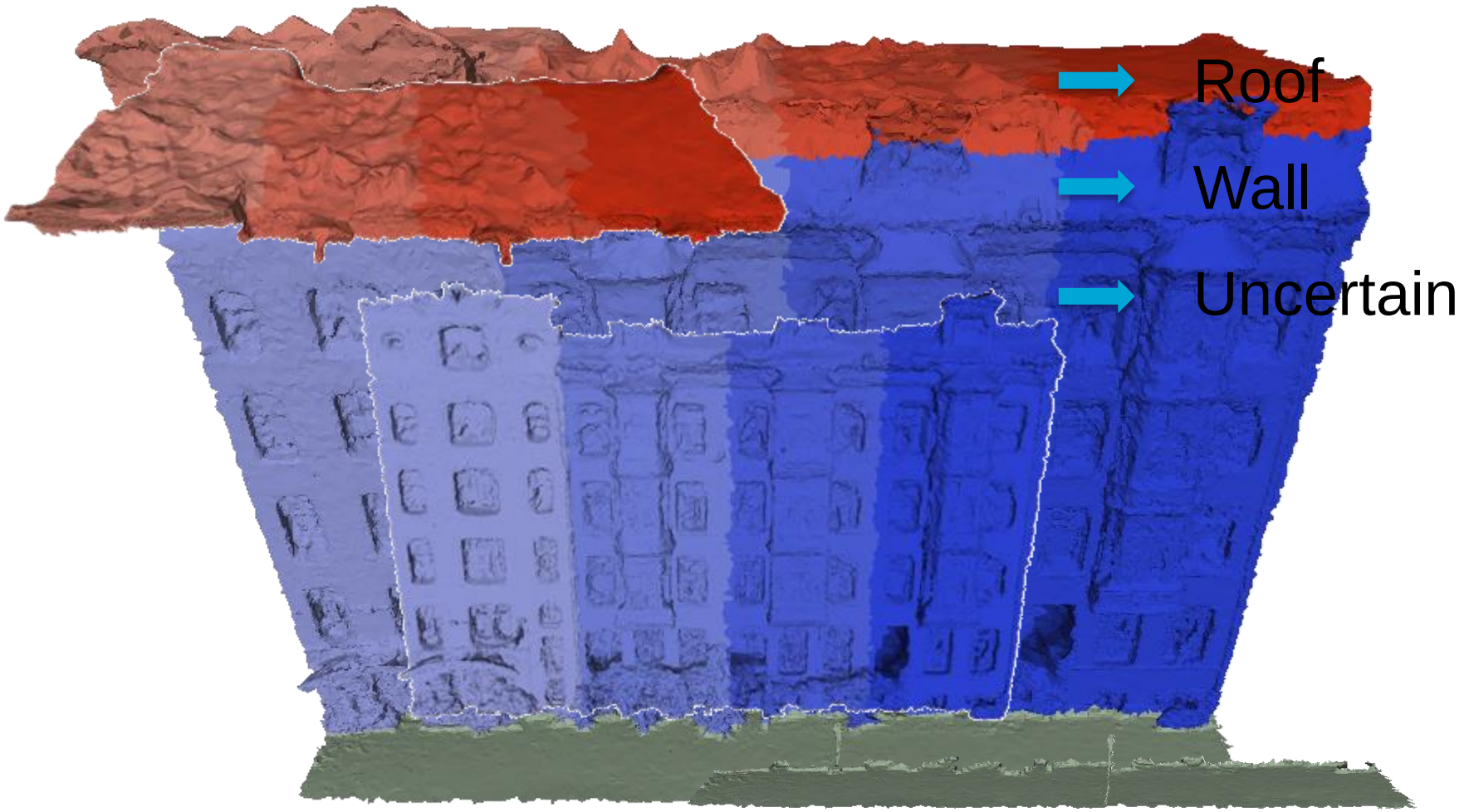


Connected components



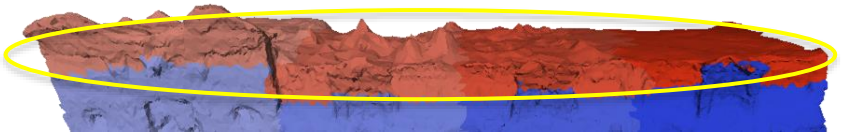
Source: https://breakingcode.wordpress.com

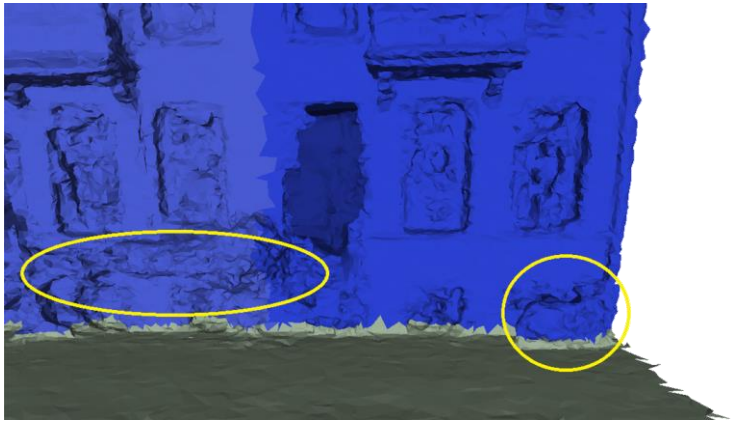
Match faces



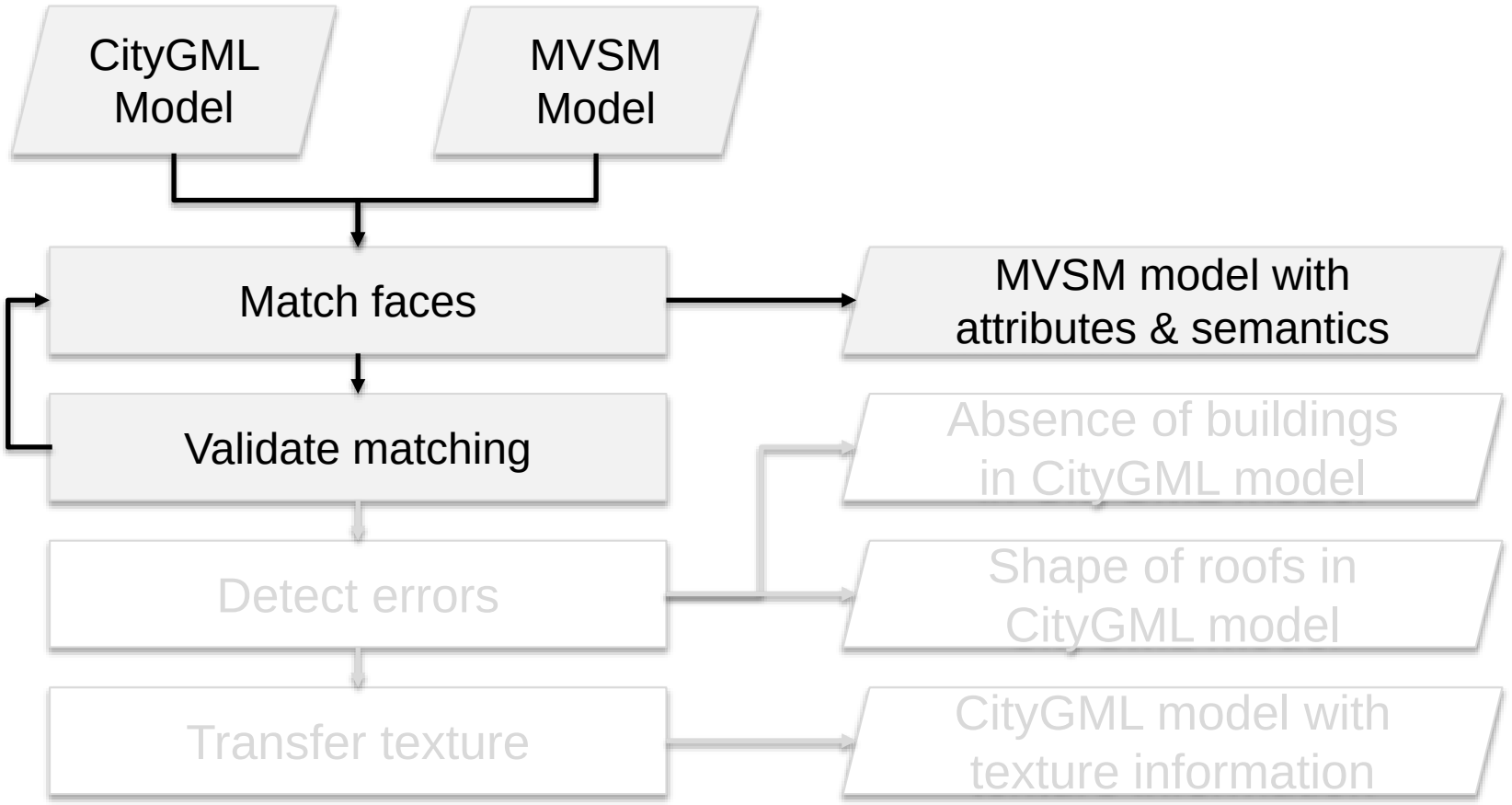
Match faces

- Roof class contains parts of the wall class
- Wall class contains parts of the uncertain

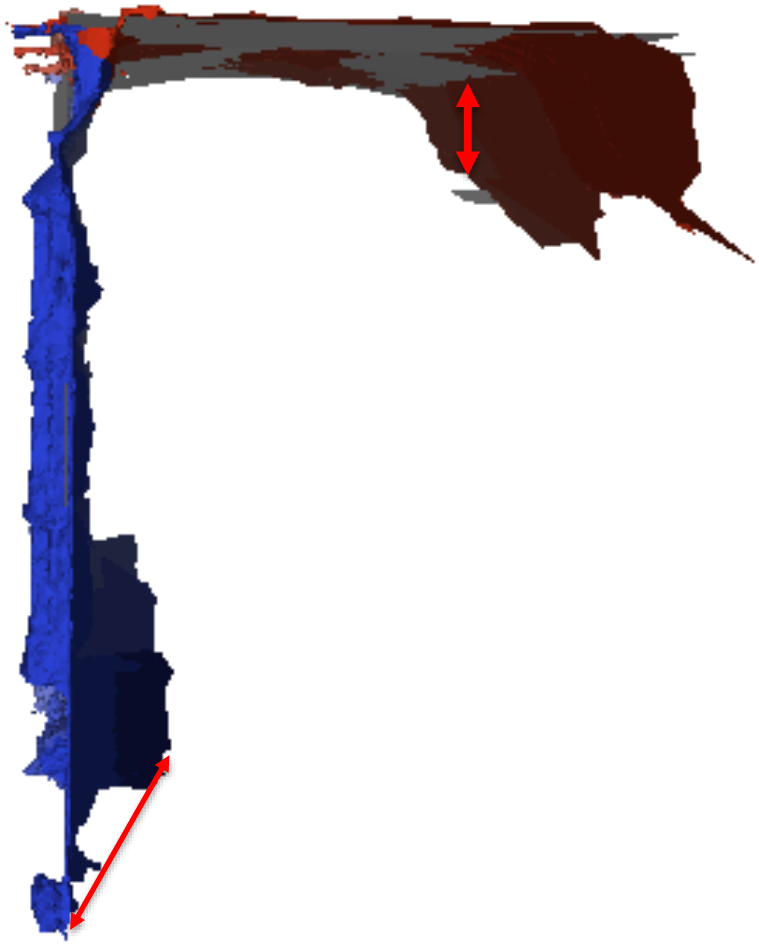




Proposed methodology



Validate matching

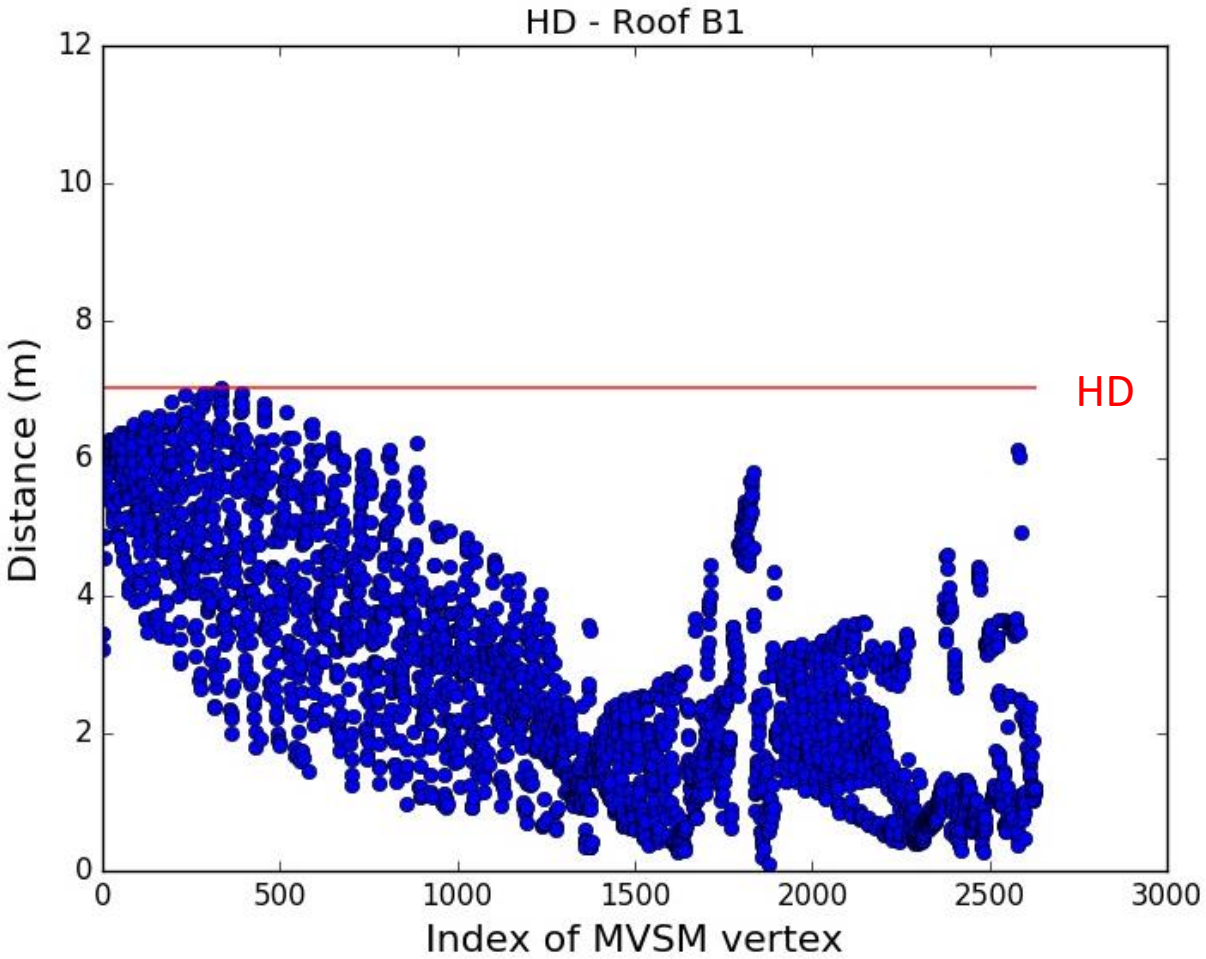


Category	Interval of HD
Excellent	0m – 5m
Good	5m – 8m
Medium	8m – 11m
Bad	> 11m

→ T_d (HR 2)

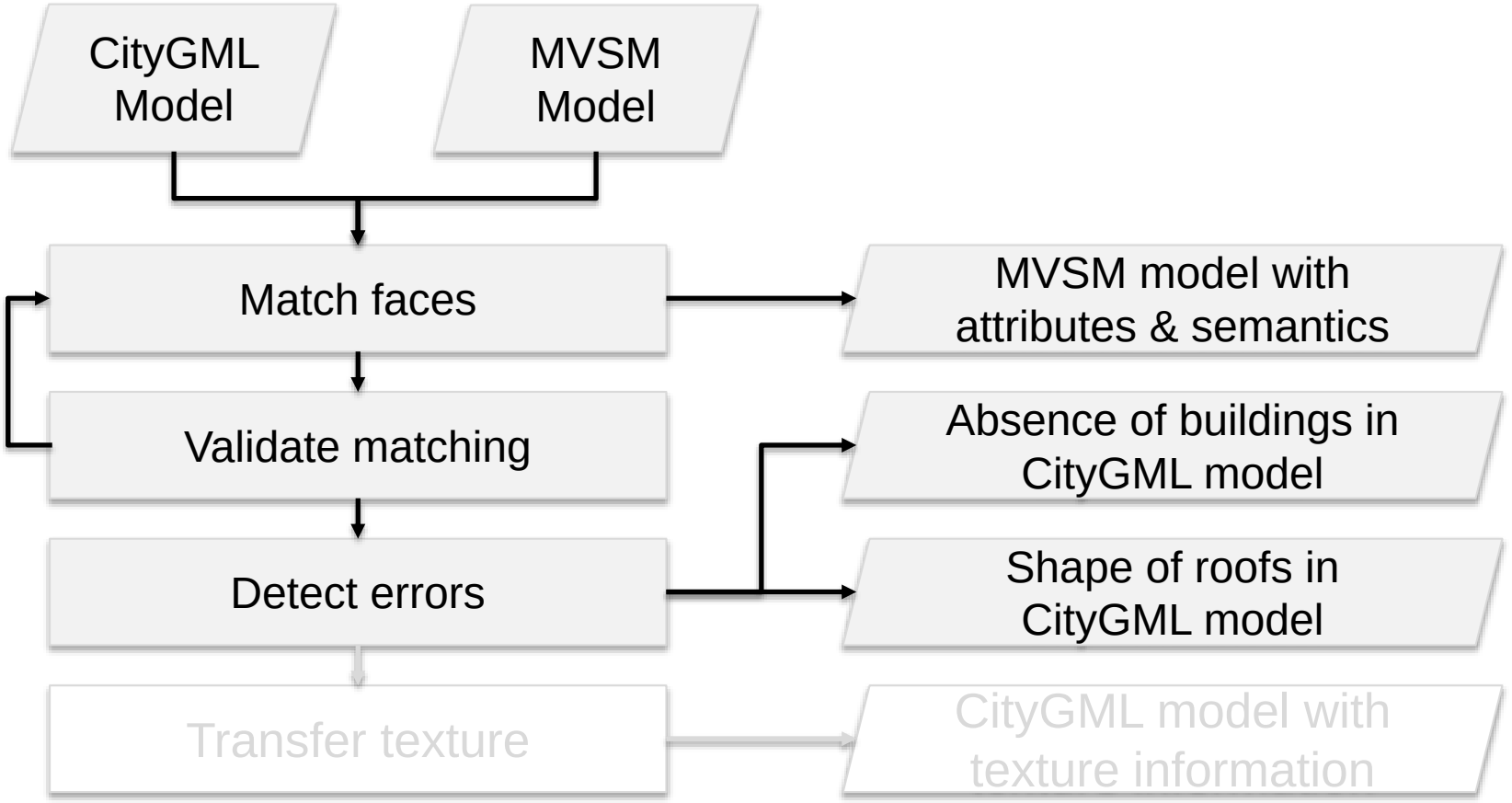
→ T_h (HR 3)

Validate matching

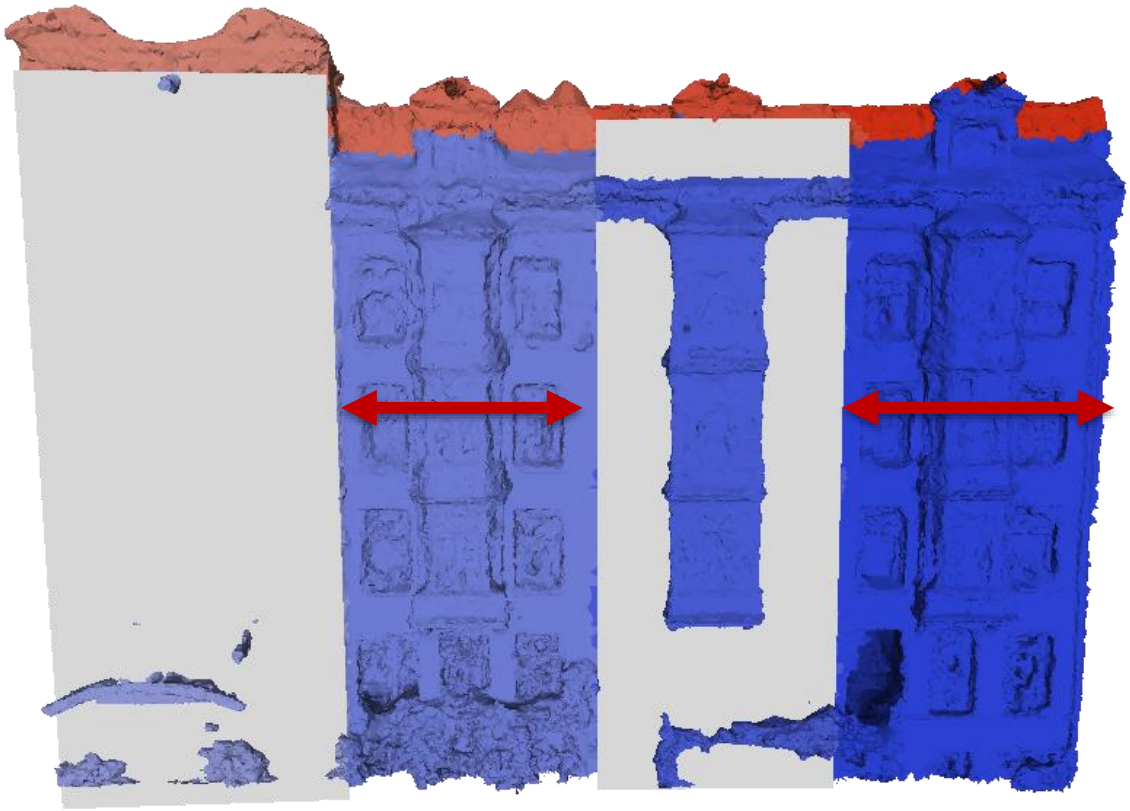


Good

Proposed methodology



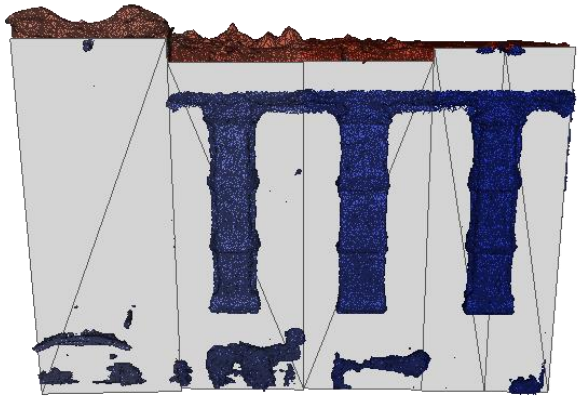
Detect errors



Detect errors

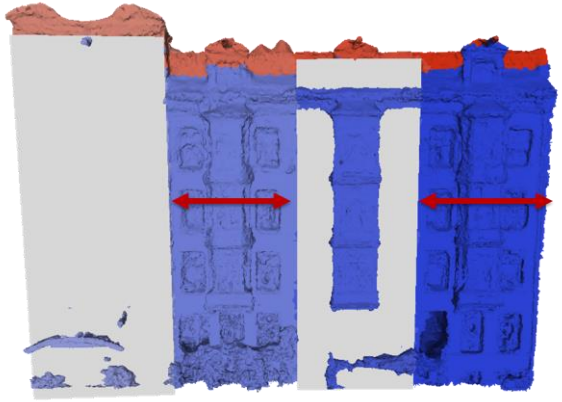
All buildings:

Building	HD (m)	Absence
B1	10.209	No
B2	9.527	No
B3	9.458	No
B4	9.399	No



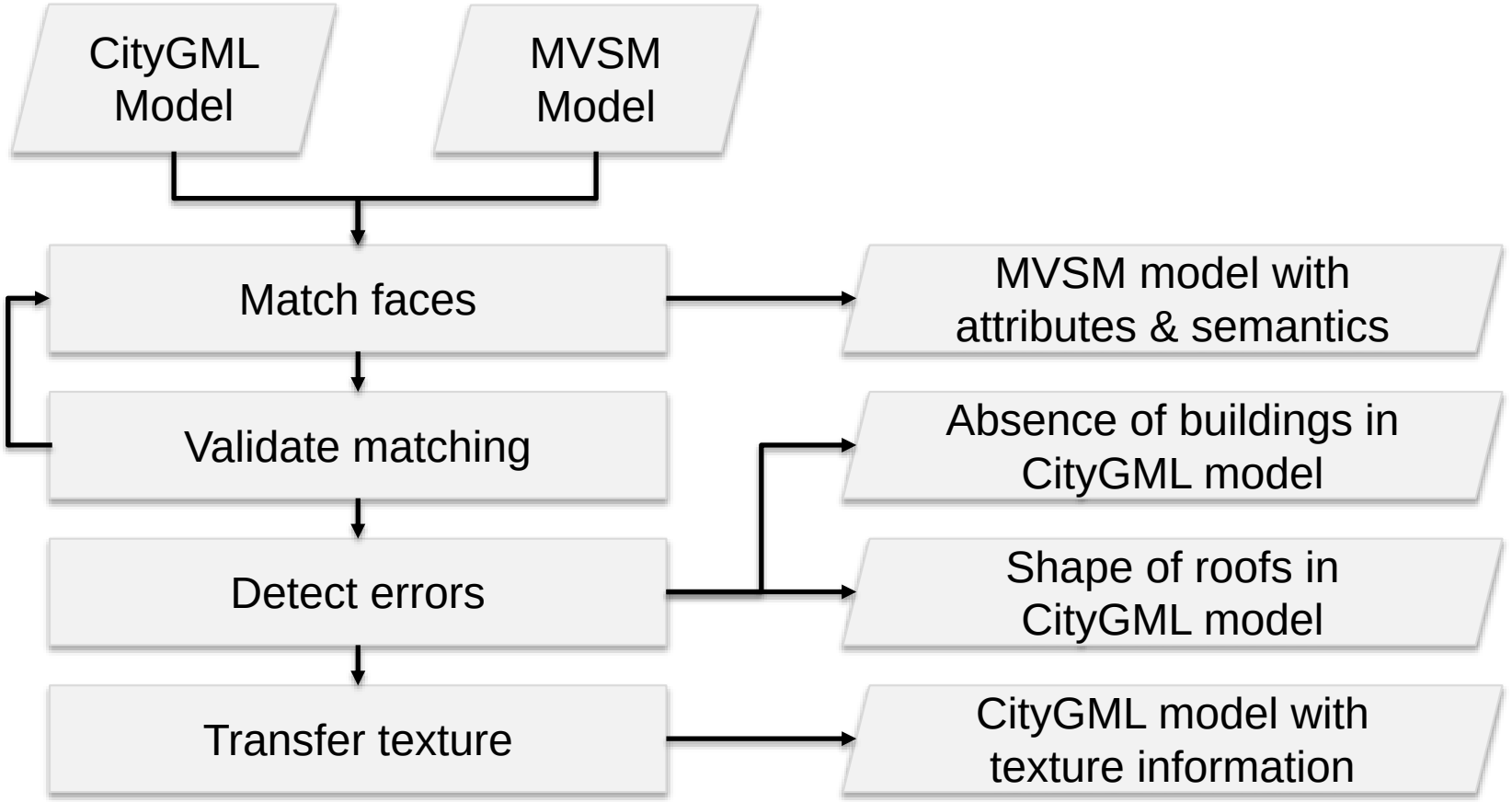
B2 and B4 are missing:

Building	HD (m)	Absence
B1	10.209	No
B2	11.549	Yes
B3	9.458	No
B4	11.048	Yes

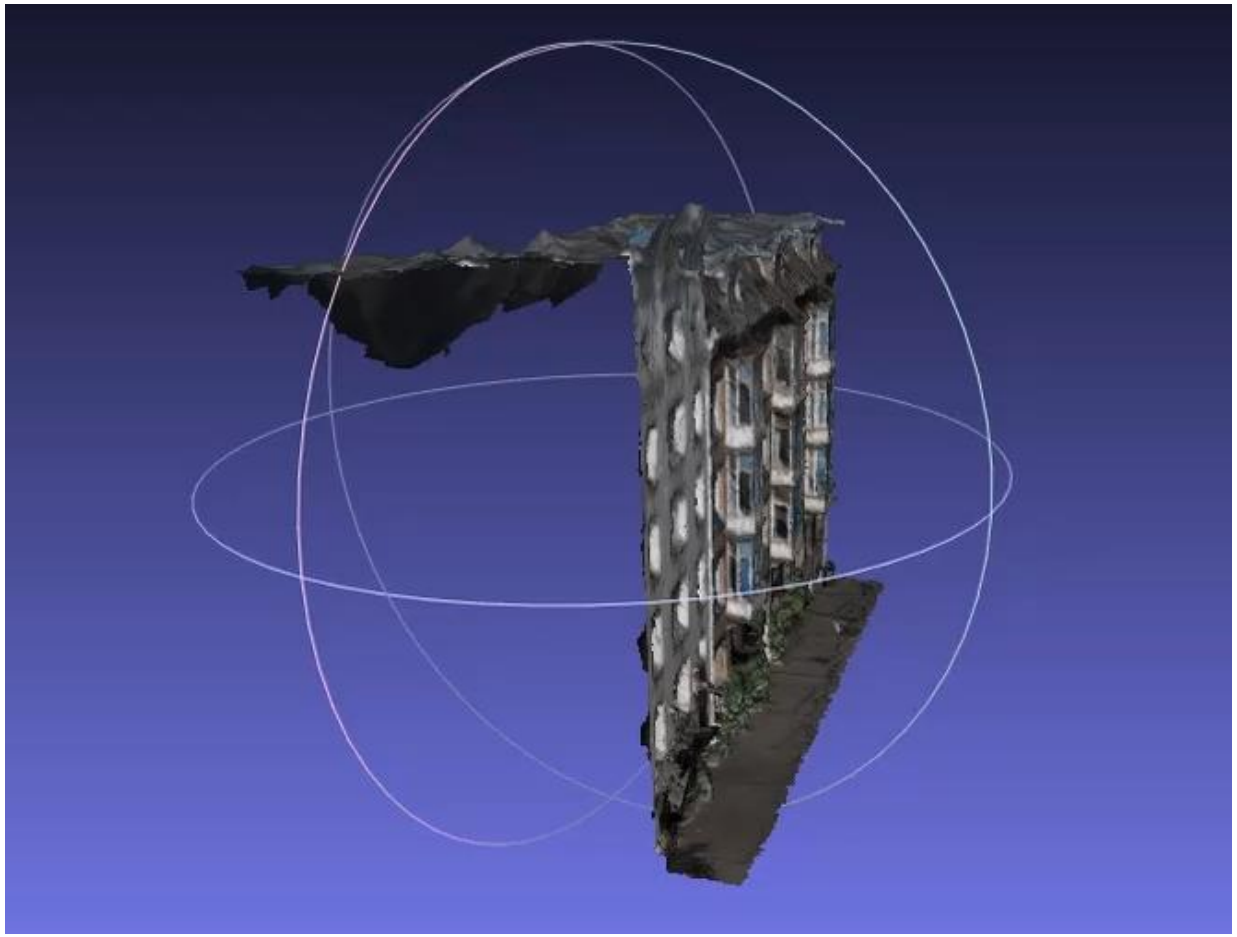


TU Delft

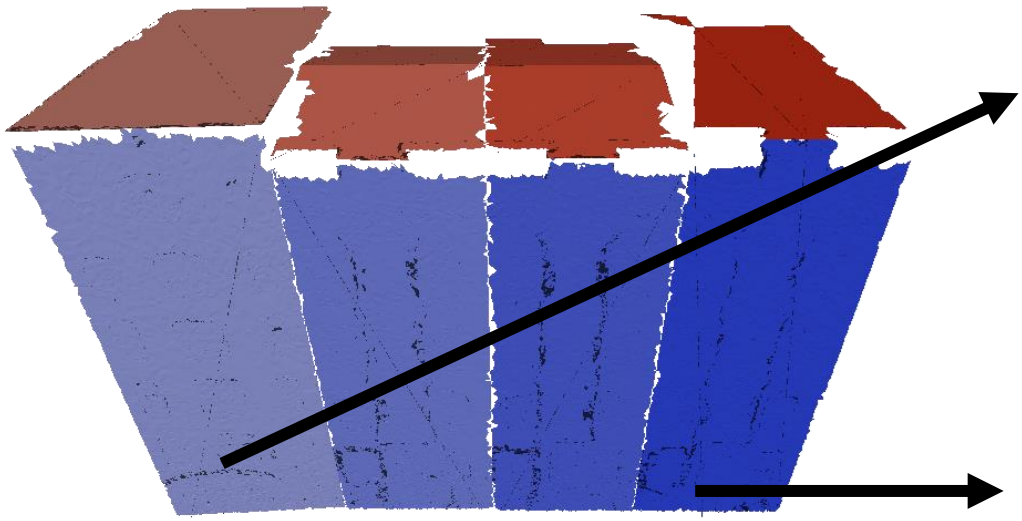
Proposed methodology



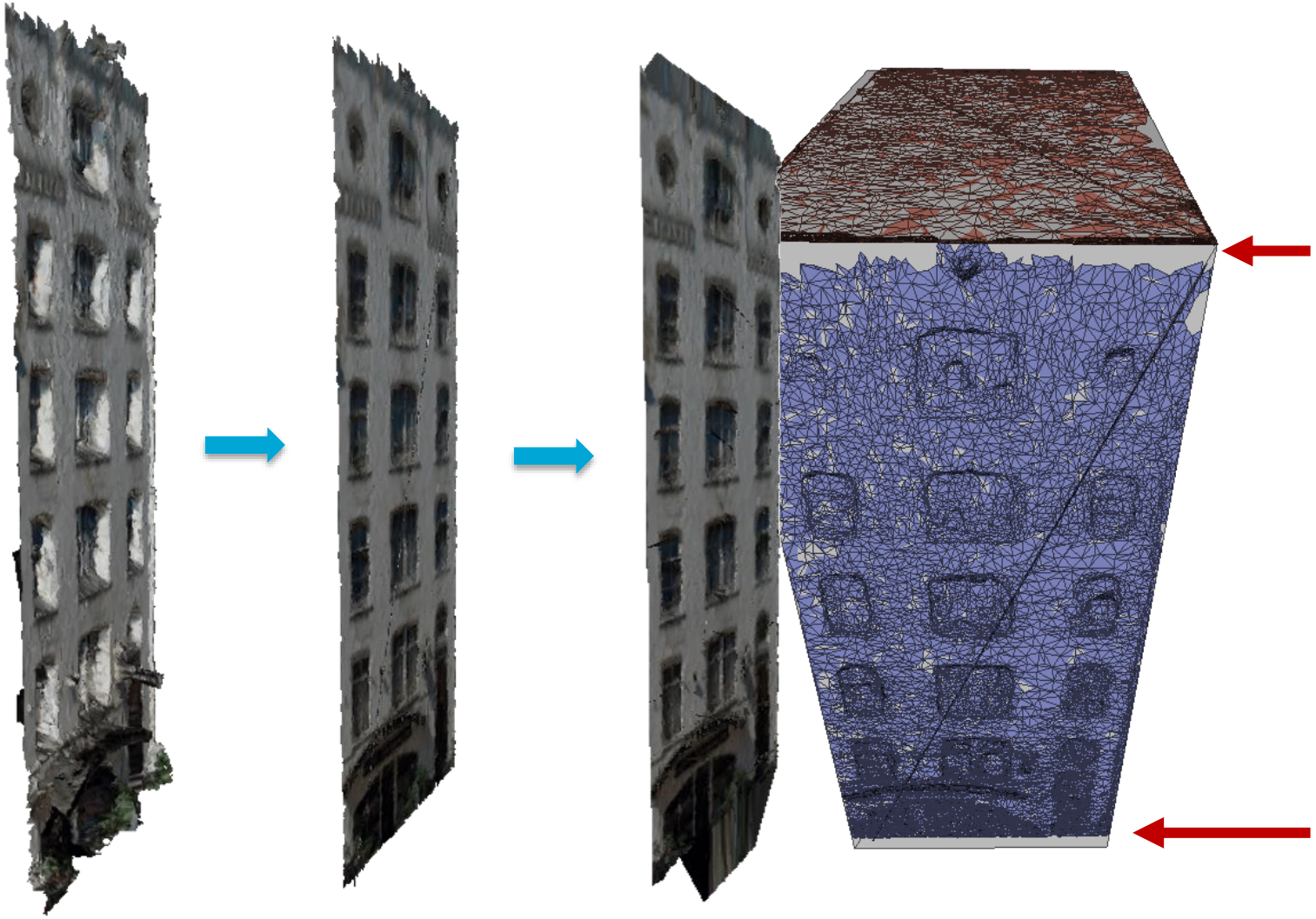
Transfer texture



Transfer texture



Transfer texture



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Transfer texture

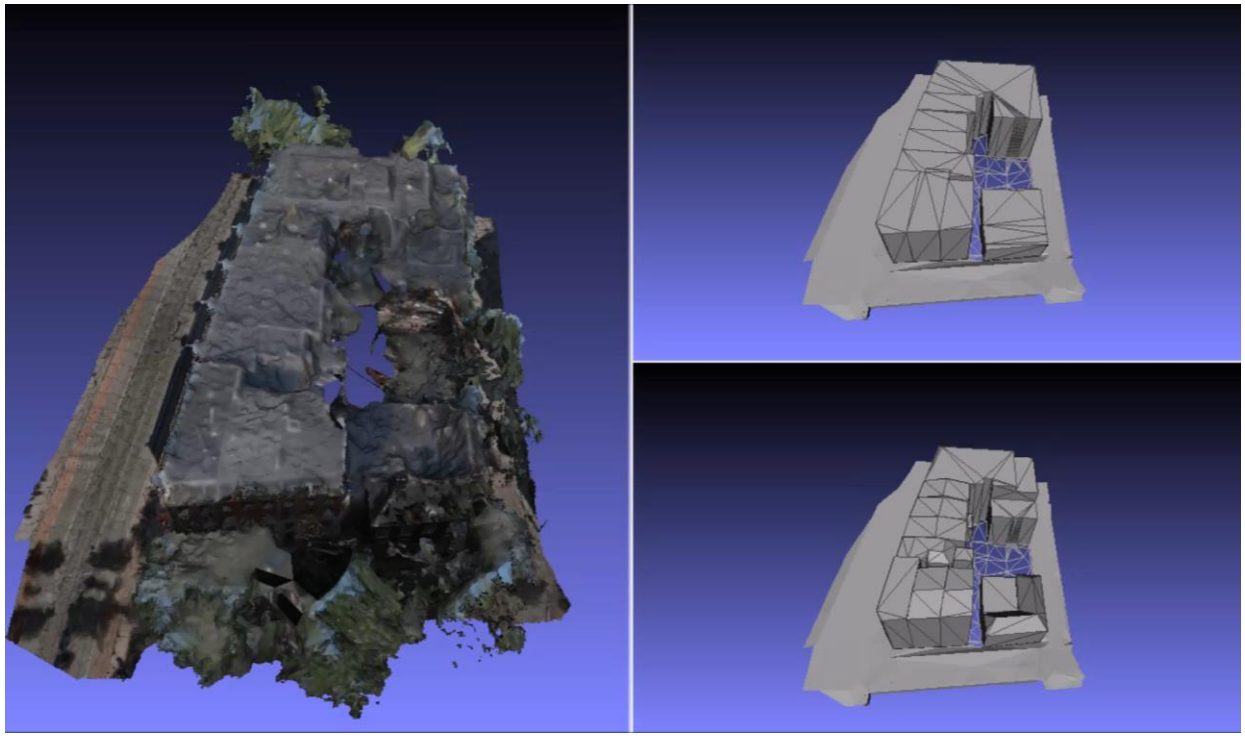
- Stretch to the corners of the boundary lines
- Close the holes of the MVSM model

2nd Implementation

Testing dataset

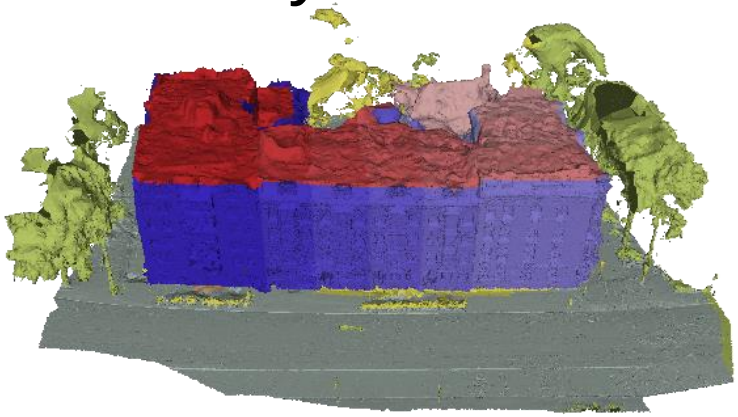
2nd Implementation Building block

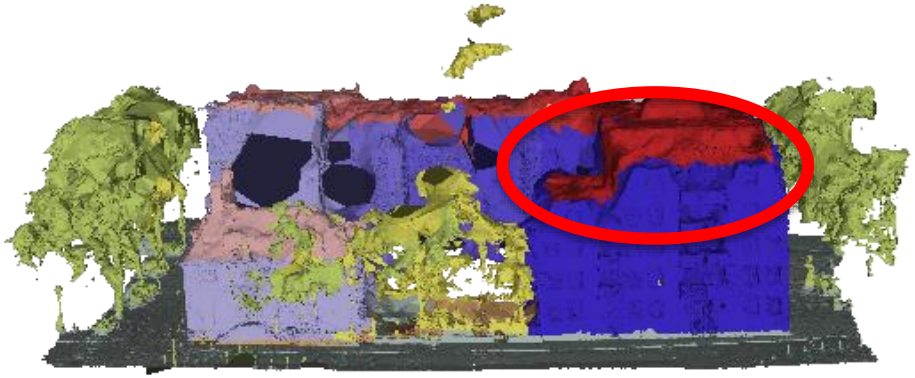
≈14247.427m^2



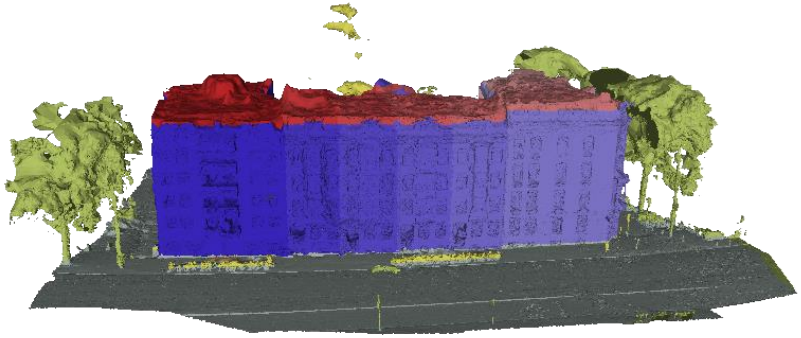
Matching faces

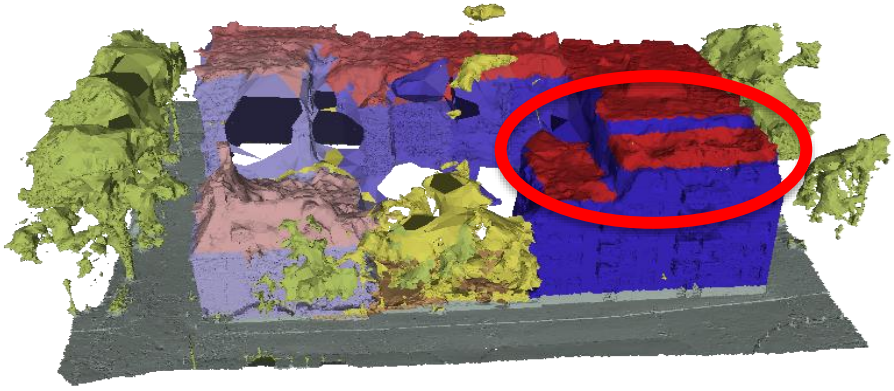
LOD1 CityGML and MVSM models: ➡ Bad





LOD2 CityGML and MVSM models: ➡ Good





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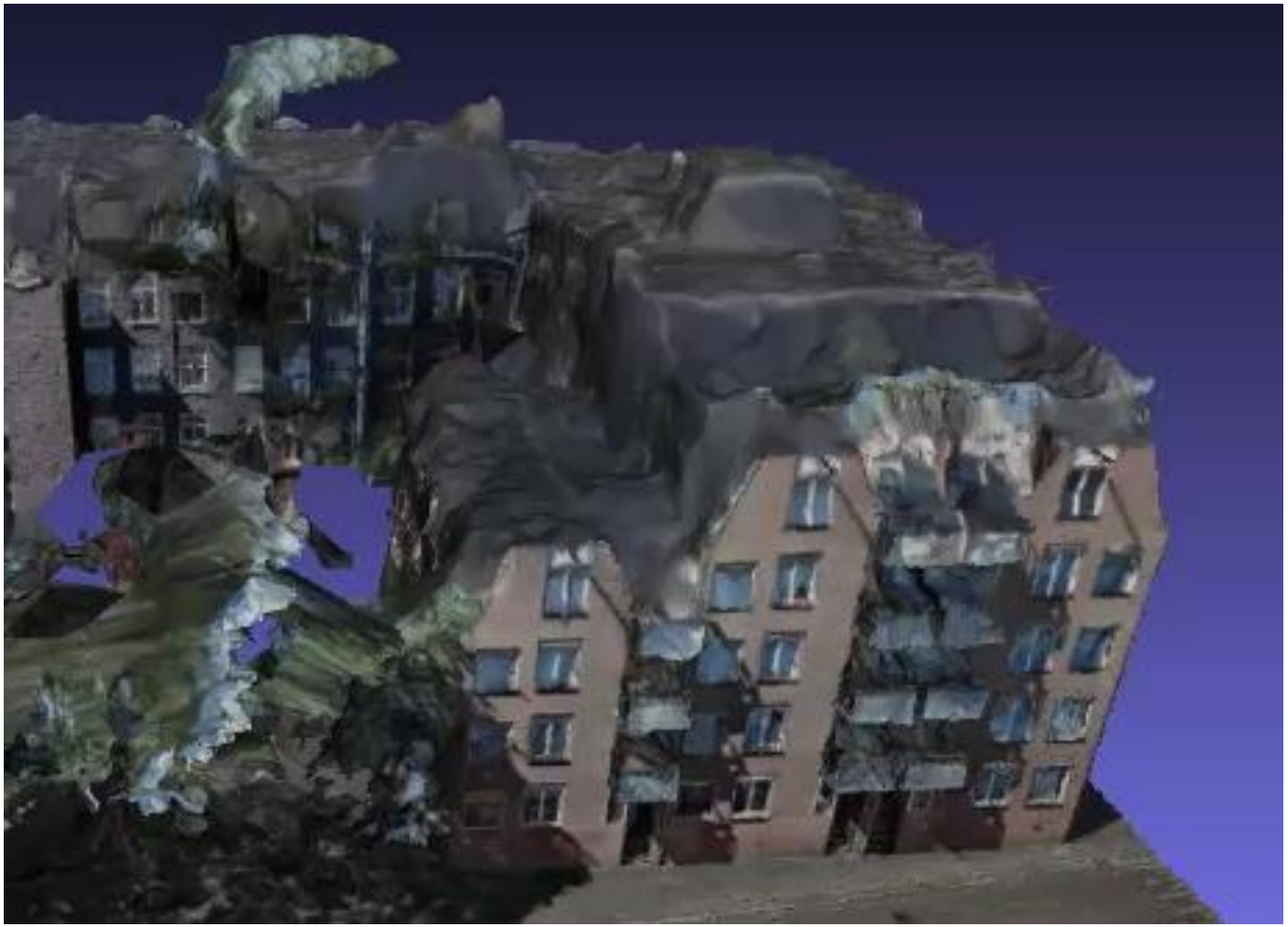
Detect errors



Transfer texture

LOD1 CityGML and MVSM models:

LOD2 CityGML and MVSM models:

Outline

1. Background & Research objectives
2. Bidirectional enrichment
3. Proposed methodology & Analysis
4. Conclusions & Future work

Conclusions

To what extent can a CityGML model and a MVSM model of the same area, representing the same features, be automatically and bidirectionally enriched?

- ✓ Bidirectional enrichment
- ✓ Bidirectional enrichments between models
- ✓ Bidirectional enrichment methodologies
- ✓ Match faces
- ✓ Semantic segmentation
- ✓ Transfer attributes
- ✓ Segment per building
- ✓ Validation of the matching
- ✓ Detection of errors
- ✓ Texturing

LOD1 vs LOD2:

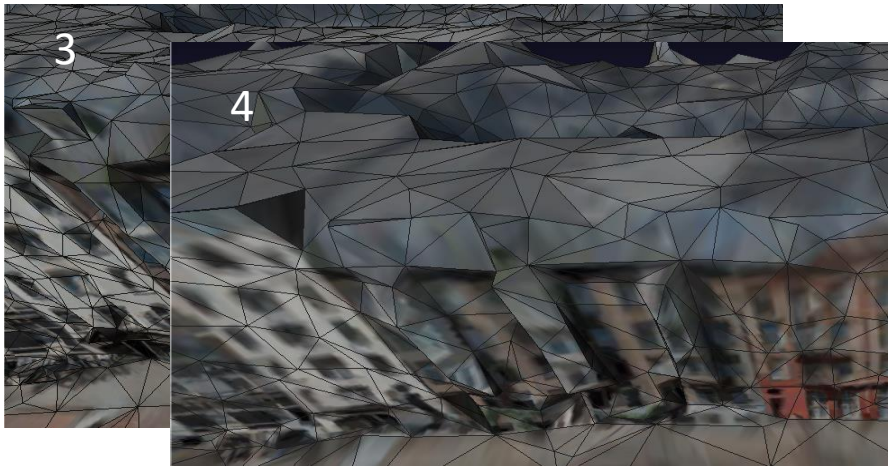
- ✓ Roof structures

Future work

- Extend the table of the enrichments.
- Explore practically more enrichment methodologies.
- Improve the proposed methodology.
- Extend the proposed methodology to other thematic classes e.g.vegetation, water bodies
- Fix the errors in the MVSM model e.g.holes

Future work and recommendations

- Test with LOD3 CityGML model
- Test with smoother and simplified MVSM models
- Test in different building types (more complex)
- Reduce the execution time



Thank you for your attention!

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