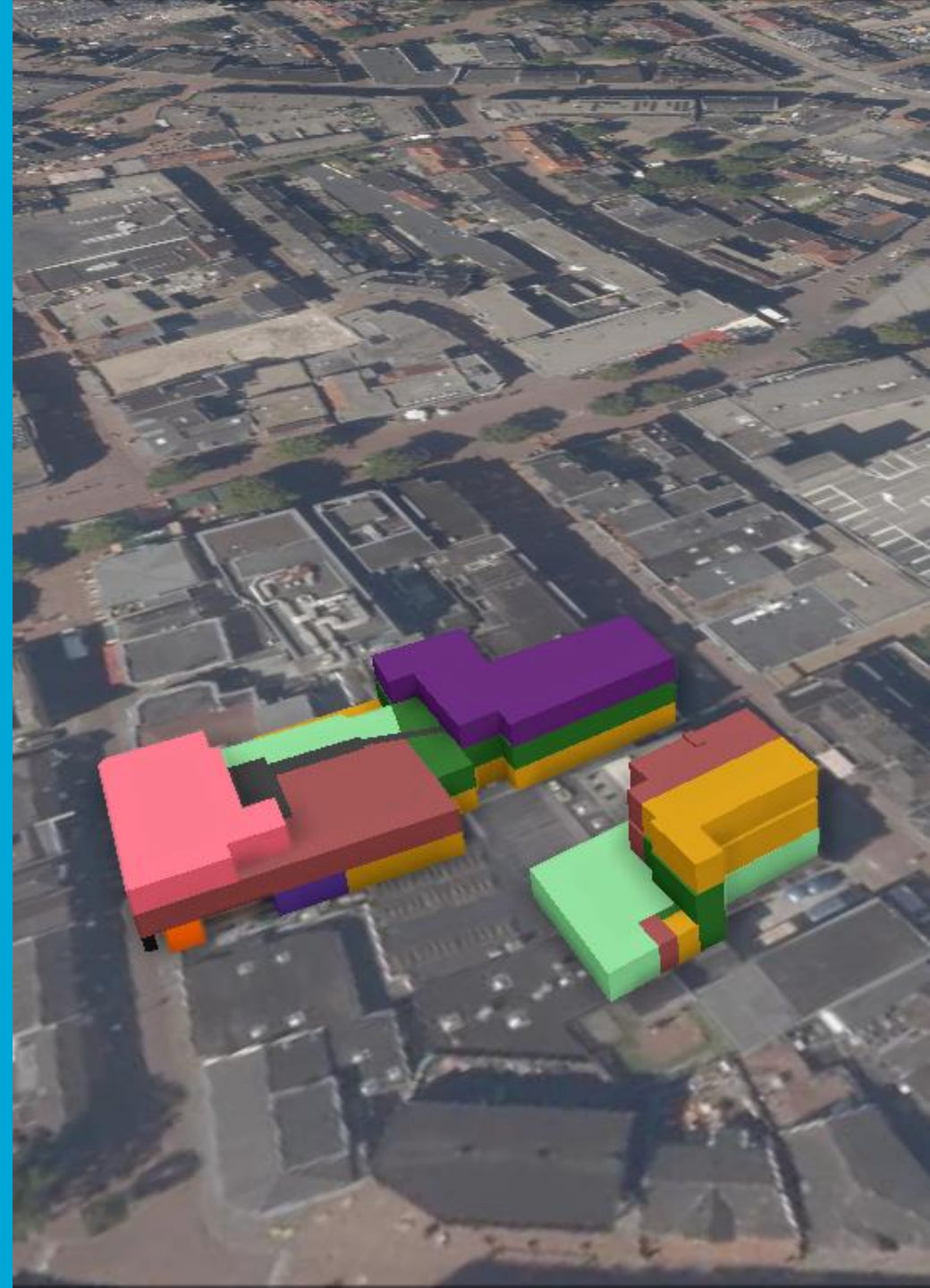


Reconstructing legal 3D apartment models from 2D division drawings

Lotte de Niet

18-6-2025

Jantien Stoter, Ken Arroyo Otori, Amir Hakim, Bhavya
Kausika, Jasper van der Vaart





Reconstructing
Method



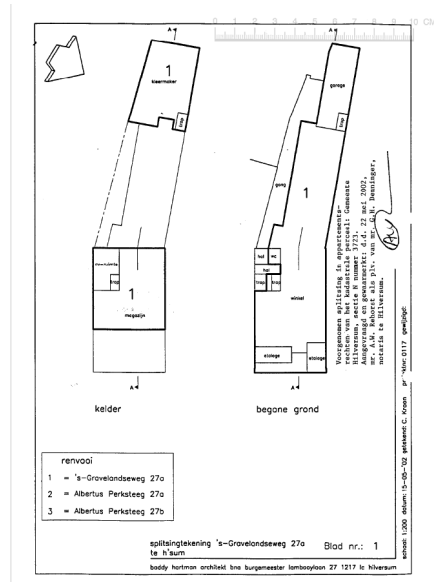
3D legal models
Context



2D division drawings
Starting data

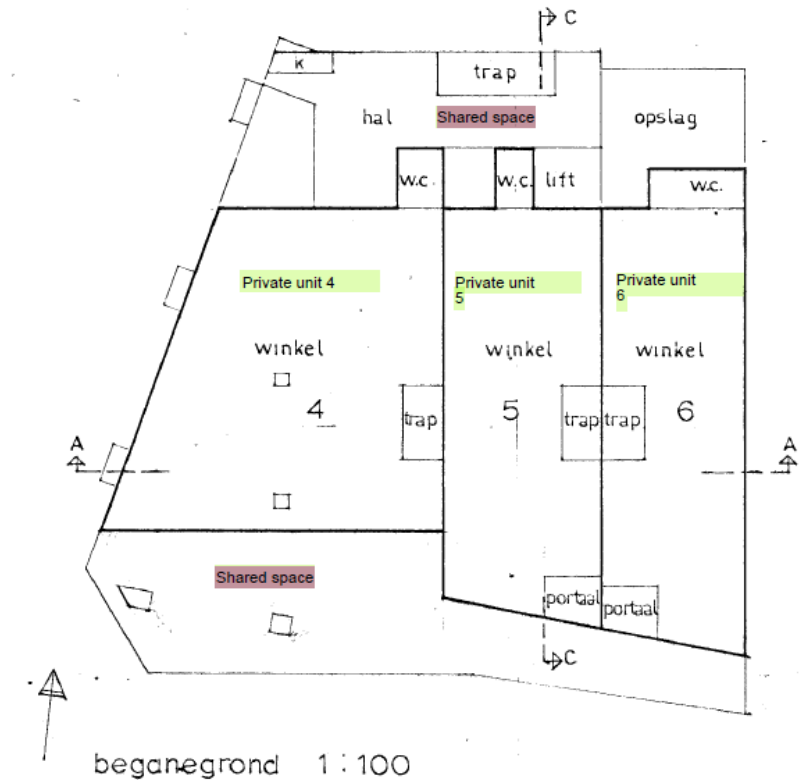
Registration apartment complex

- Notarial deed (*Splitsingsakte*)
- Division drawing (*Splitsingstekening*)



What Are Division Drawings?

- Private/shared areas
- Drawbacks



2D



Not georeferenced



No “data”

3D Legal Registration

BIM Legal

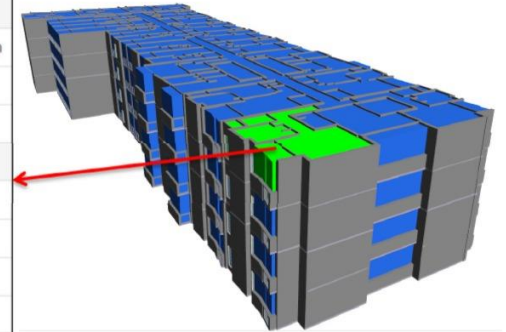
- 3D volumes of legal spaces
- From modern models in construction
 - Rich in detail & 3D

1



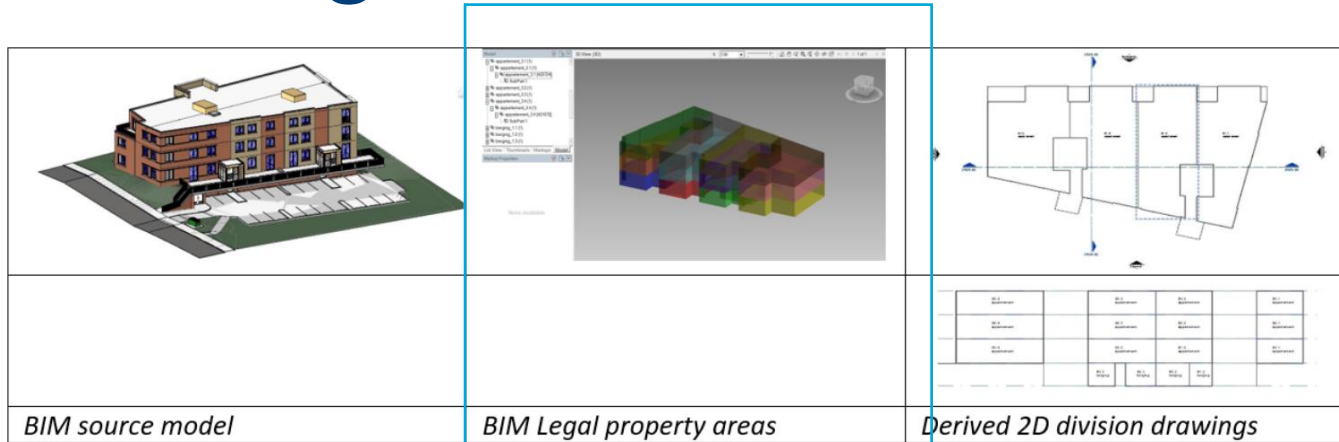
2

Tree	Types	Properties	Classifications
Legal Property Object Information			
Legal Property Object Unit		Single	
Lot Liability		35	
Legal Property Object State		Created	
Name		LOT-154	
Legal Property Object Class		Lot	
Land Use		Residential	
RRR		Ownership	
Interest Holder Information			
Name		John Smith	
Type		Person	
Share		100	
Title Information			
Number of Parent Title		03422	
Security Number		613852	
Volume		10564	
Creation Date		9/24/2012	
Folio		725	
Parent Title Information			
Volume		03422	
Folio		283	

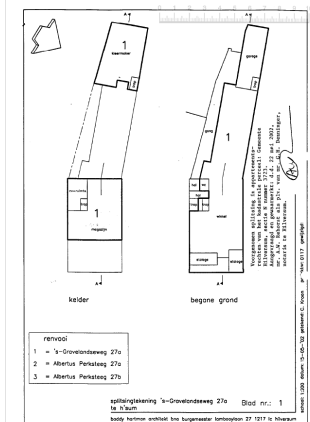


BIM Legal

3



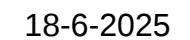
- No BIM?



- For (older) existing buildings
 - Integration
 - Visualization
 - Data management

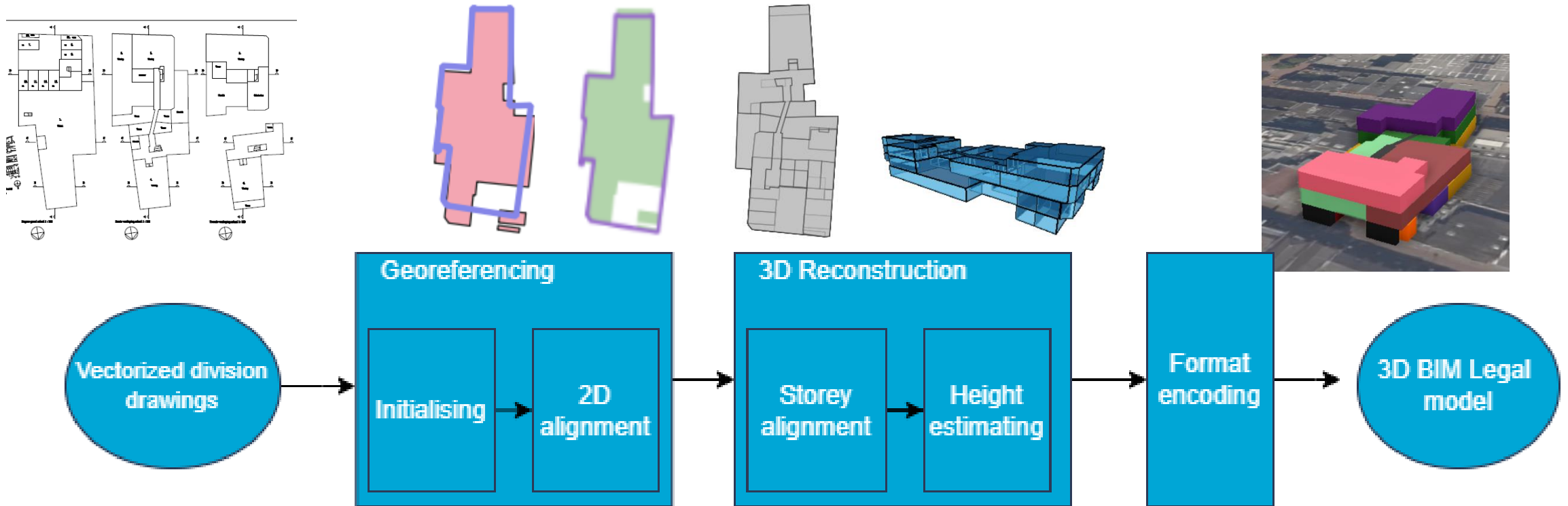
Goal:
To develop a mostly automatic method
of reconstructing 3D
BIM legal apartments from 2D
vectorized division drawings.

-



Method overview

Automatic!

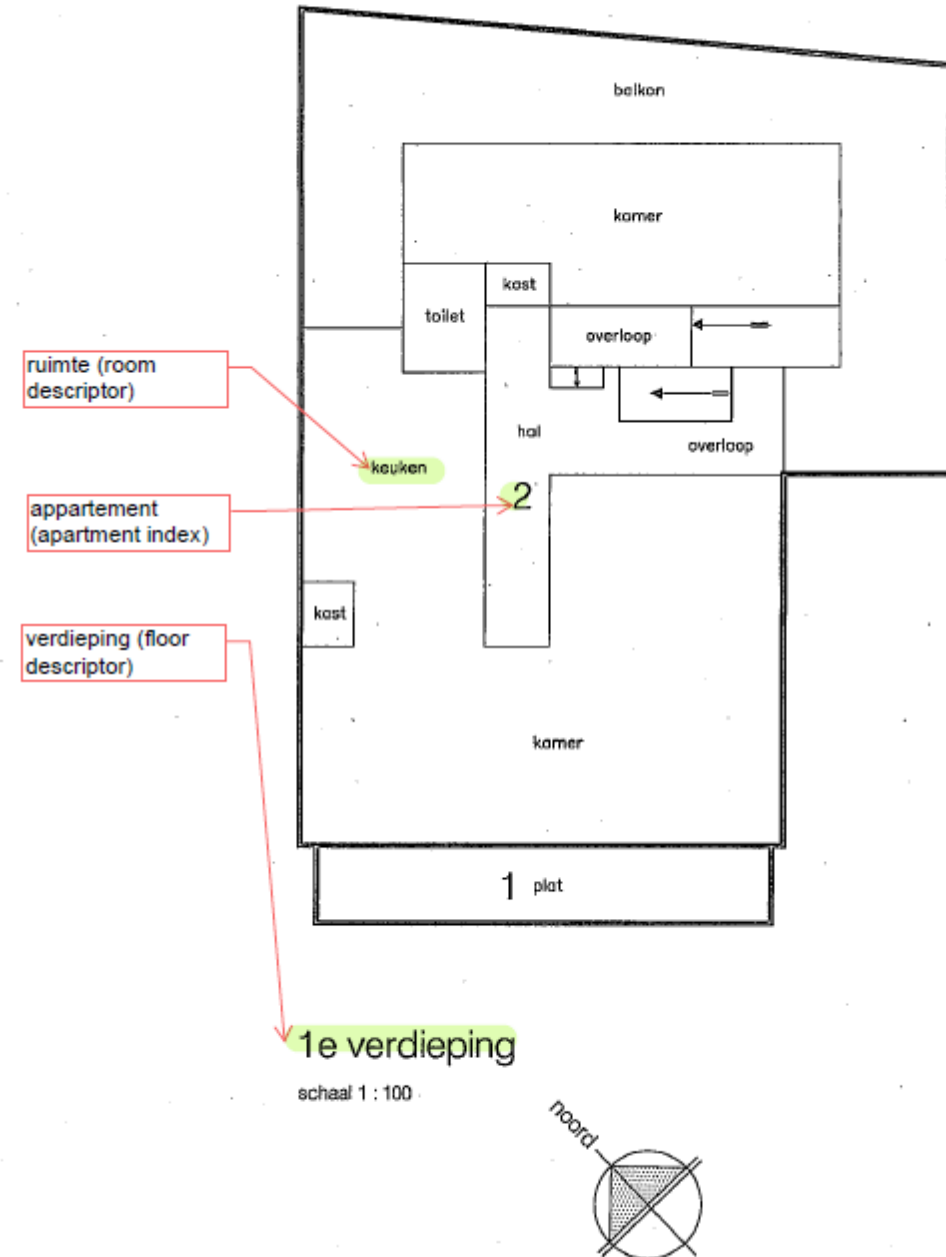


Behind the scenes

- ~1,700 lines of final Python code
- 34 experimental scripts
- ~3000 experiment runs
- Developed custom automated pipeline
- Multiple spatial data sources (BGT, BAG, JSONs)
- Parsing, alignment, transformation, optimization, special case handling

Overview Data

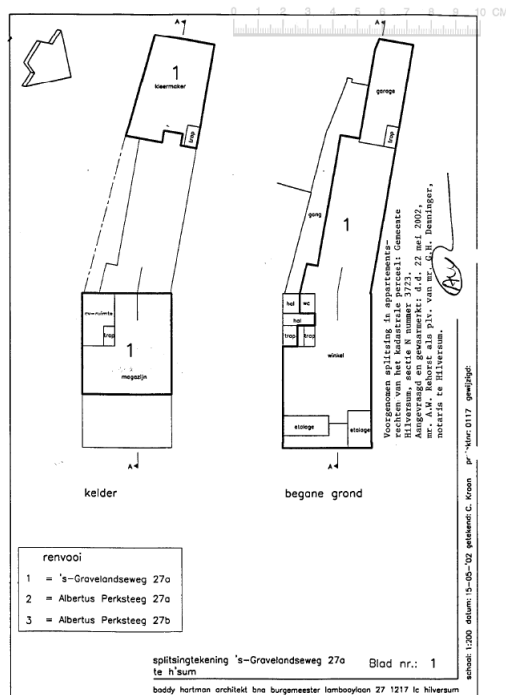
- Schematic
- “Spaces”
- No distortion



Georeferencing

- PDF ground floor (*begane grond*)

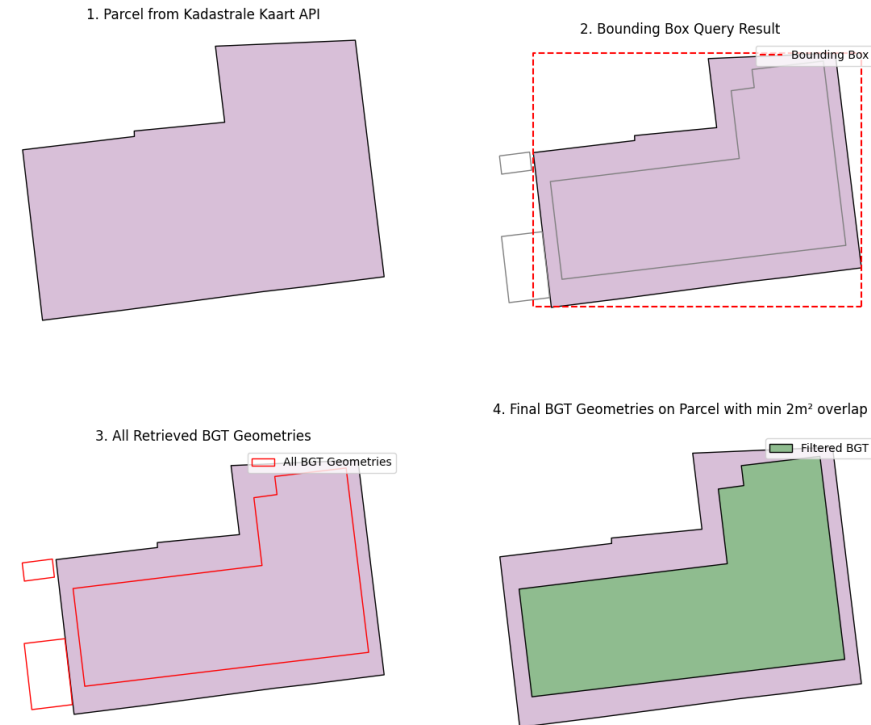
-> Reference map data (BGT)

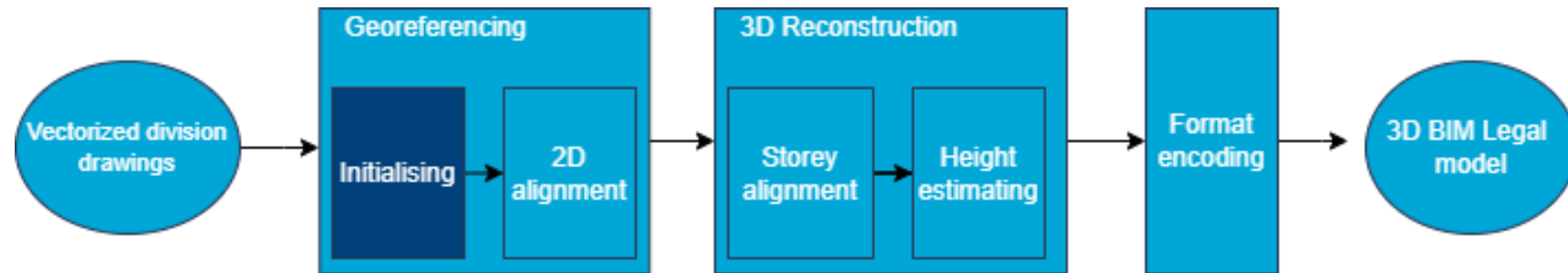


Georeferencing

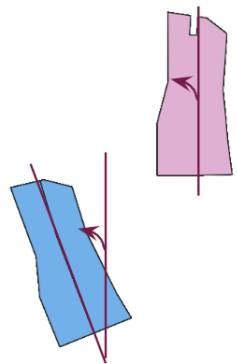
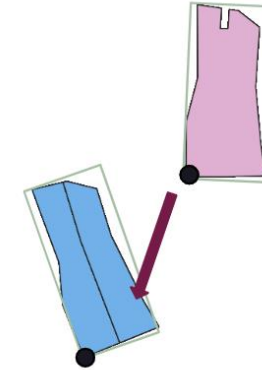
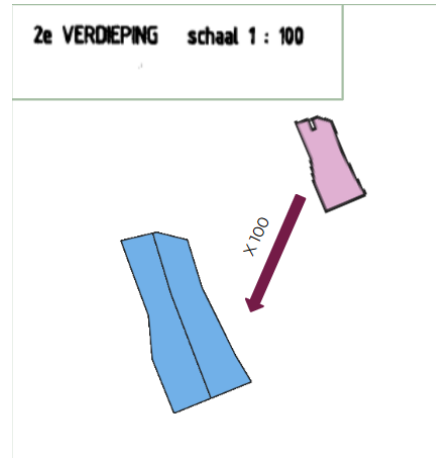
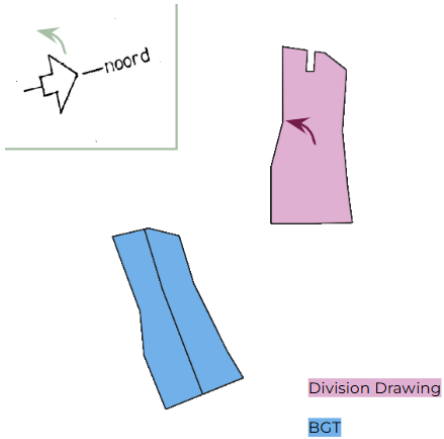
- Aligning to real world map data
- Parcel (*Perceel*)
- BGT building (*Pand*)

Voorgenomen splitsing in appartementsrechten van het kadastrale perceel: Hilversum N 2643.

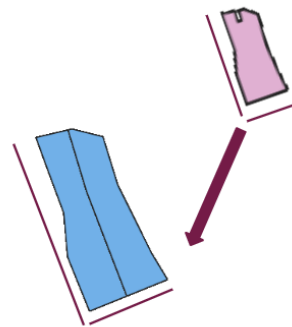




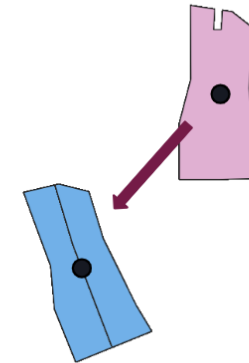
Georeferencing - Initializing



Rotate



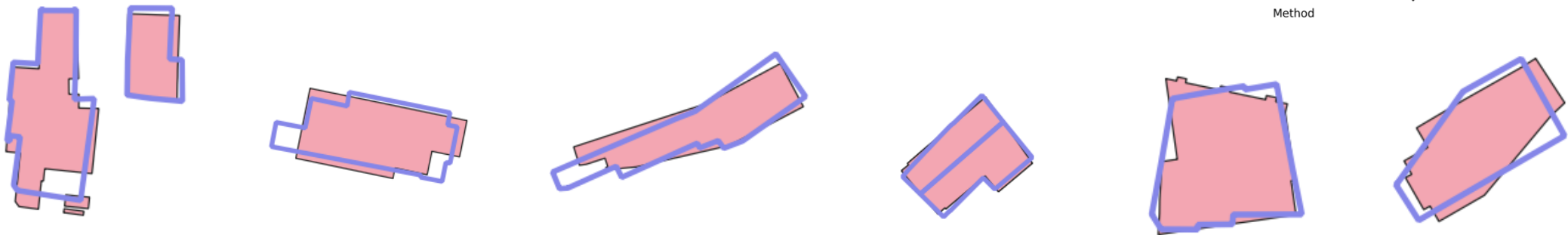
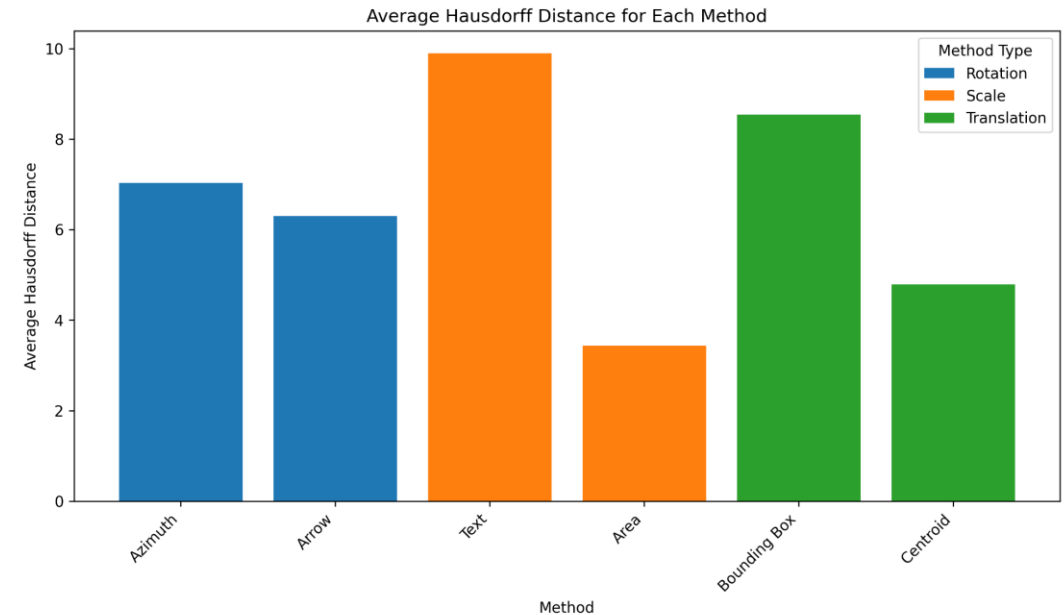
Scale

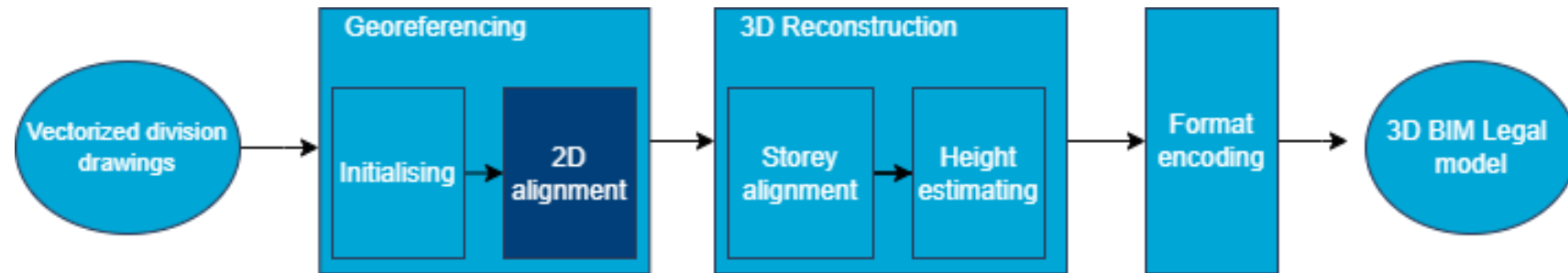


Translate

Georeferencing - Initializing

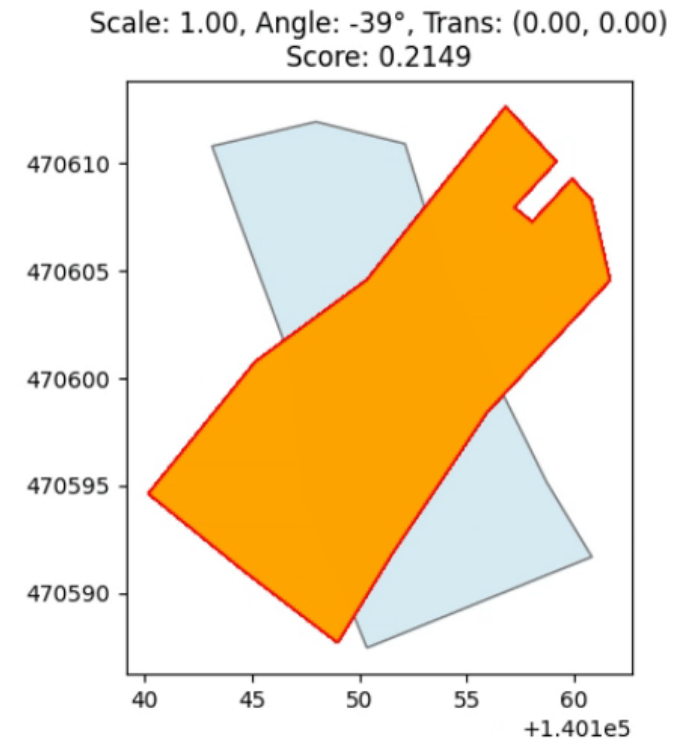
- Best performing:
 - Using area scaling
 - Centroid alignment
 - No rotation
- Unless scale and north arrow vectorized



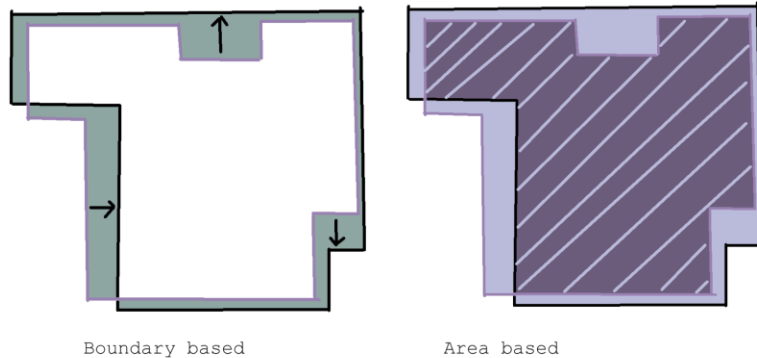
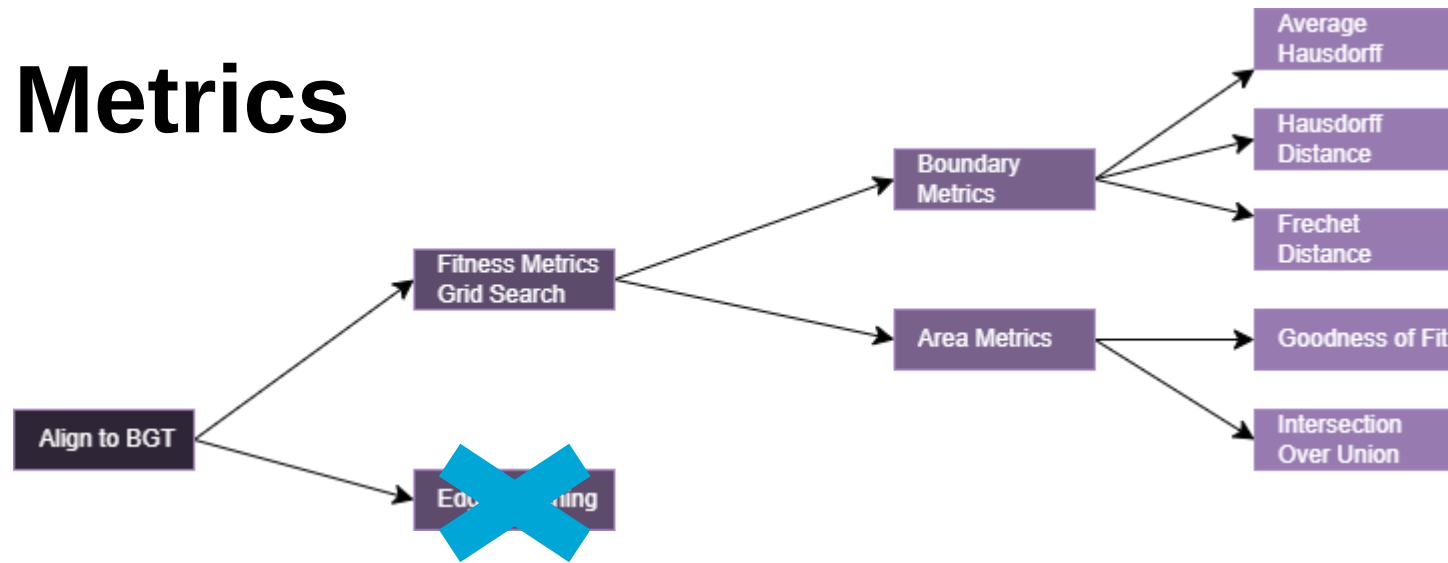


Georeferencing – 2D alignment

- Test every translation, scale and rotation
- Within a range
- Test how well it fits the BGT
- Best fit = best transformation



Metrics



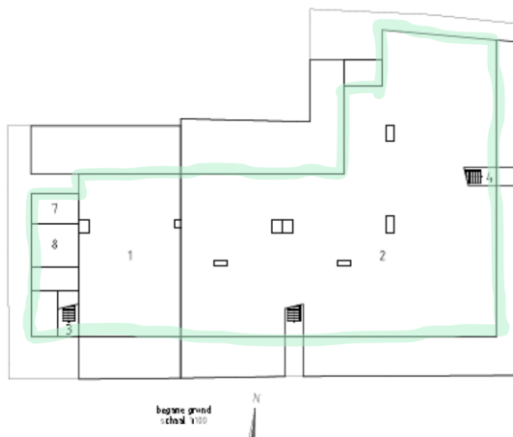
Metric Combination	$\alpha = 0.0$	0.2	0.5	0.8	1.0
Hausdorff and GoF, no translation	Good	Okay	–	–	Poor
Hausdorff and GoF, no translation or initialization	Okay	Good	Good	Okay	Okay
Hausdorff and GoF	–	Good	Good	Good	–
Average Hausdorff and GoF	Good	Good	Okay	Poor	–
Hausdorff and IoU	Good	Okay	Okay	Okay	Okay
Average Hausdorff and IoU	Okay	Okay	Poor	–	–
Fréchet and IoU	Poor	–	Okay	–	–

Table 6.1.: Visual alignment quality for different metric combinations and α weights.

- Hausdorff distance and Goodness of Fit

Georeferencing - Results

- Limitation: low similarity
 - Outside spaces (81.5%)
 - Others: 95.2% containment

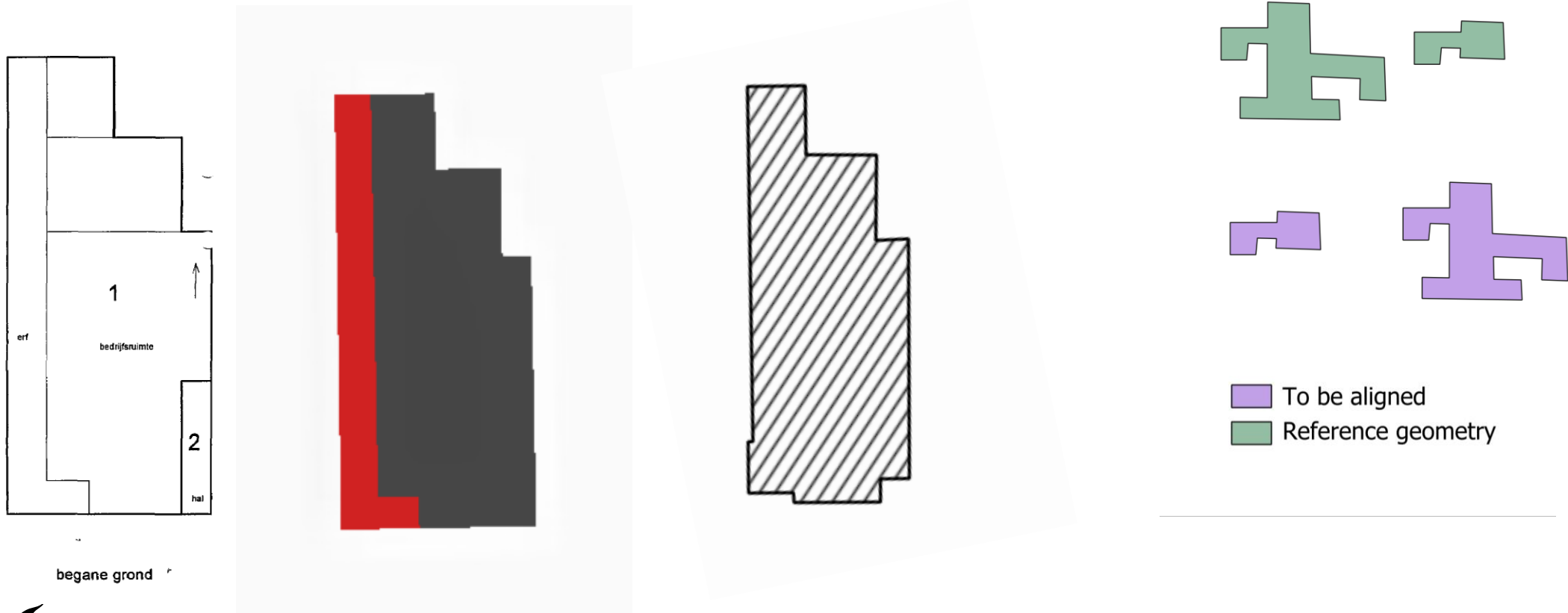


ID	Image Alignment	Shape Similarity	Containment	Issue (<85%)
9252		30.9%	80.3%	Both
555/556		91.8%	98.1%	-
1878/1879		54.2%	94.4%	Drawing
1882		38.0%	86.3%	Drawing
2359		90.6%	97.8%	-
2643		64.1%	86.1%	Drawing
2848		30.4%	91.2%	Drawing
3211		94.8%	96.7%	-
3723		20.7%	73.4%	Both
4216		85.5%	92.9%	-
Mean		60.1%	89.7%	
Min		20.7%	73.4%	
Max		94.8%	98.1%	
Std Dev		27.6	7.7	
<85%		6/10	2/10	

Table 6.3.: Overview Georeferencing Results

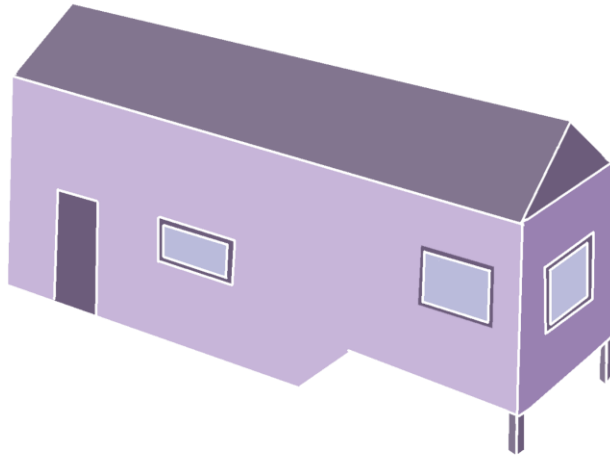
Georeferencing – Difference in datasets

- Partial match
- Difference BGT and division drawing

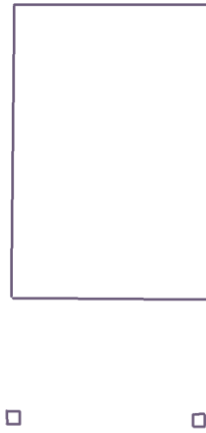


Georeferencing – Difference in datasets

- Pillars



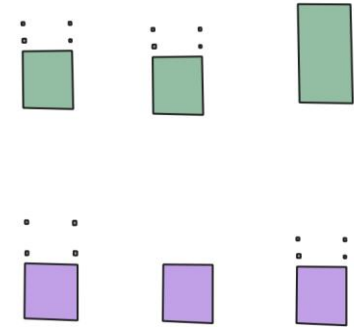
Example building



Floor plan
BGT

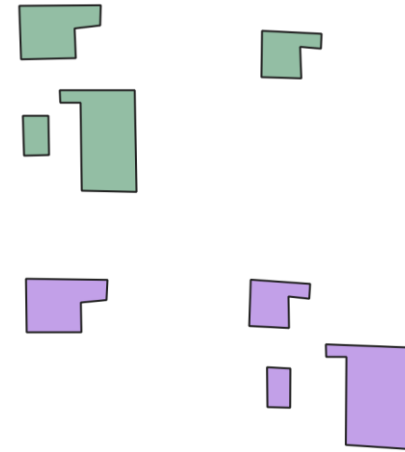
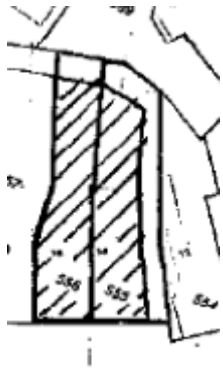
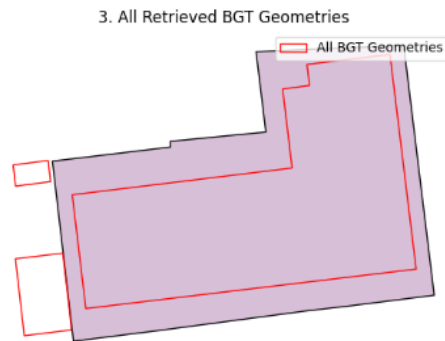


Floor plan
Division drawing



Georeferencing – Difference in datasets

- Multiple footprints



Georeferencing - Results

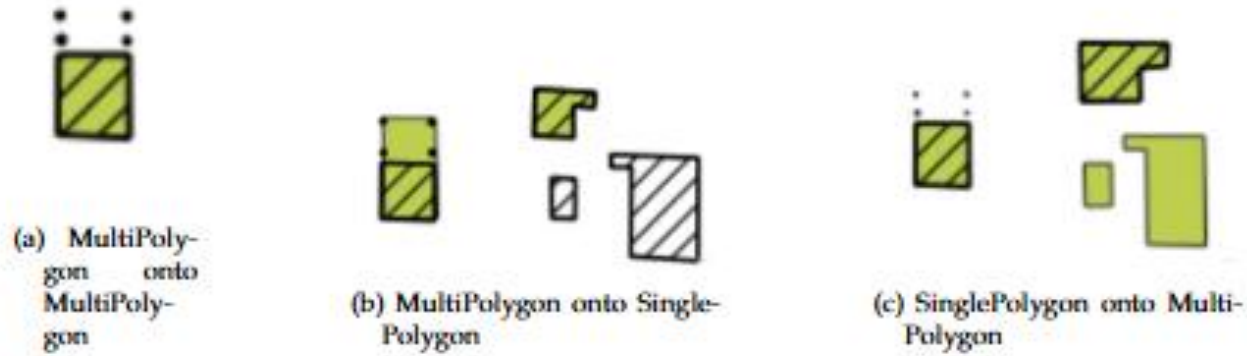
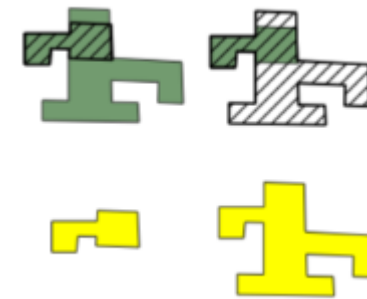
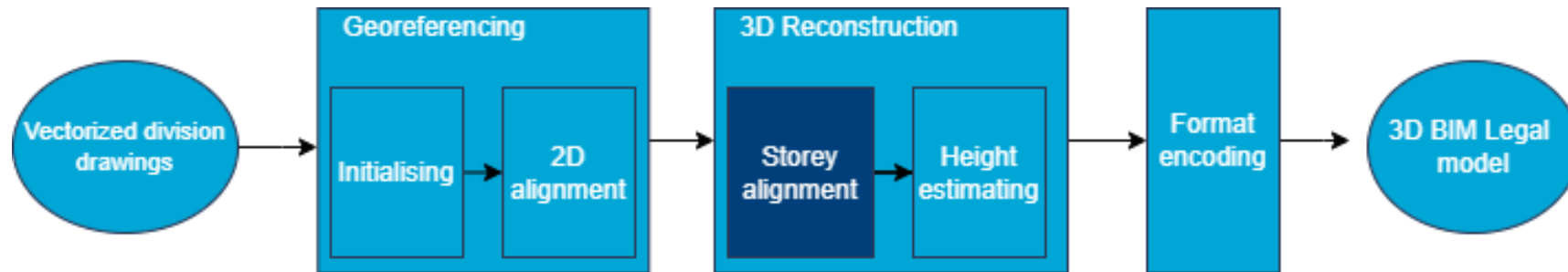


Figure 6.6.: Alignment Single and MultiPolygons

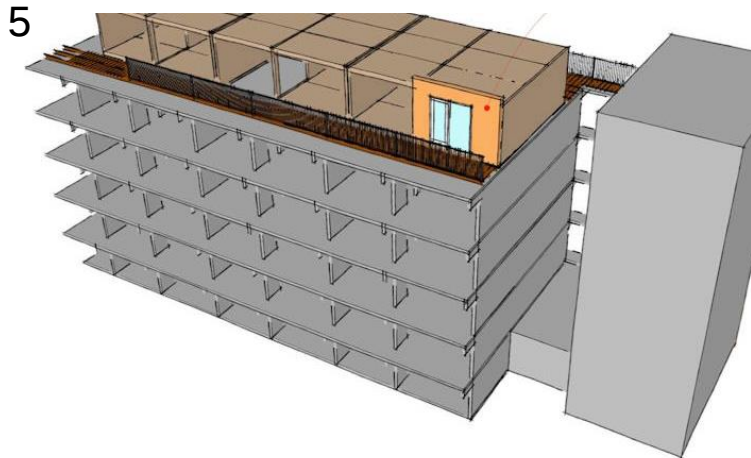


Division Drawing Geometry	BGT Geometry	Optimal Weight α
MultiPolygon	MultiPolygon	0.25 / 0.75
MultiPolygon	SinglePolygon	0.25
SinglePolygon	MultiPolygon	0.75



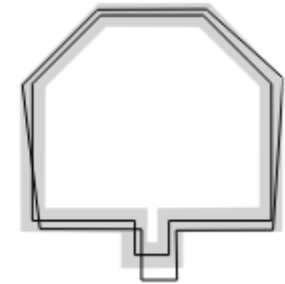
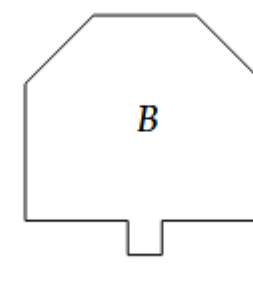
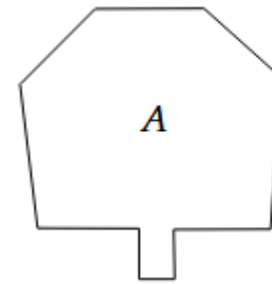
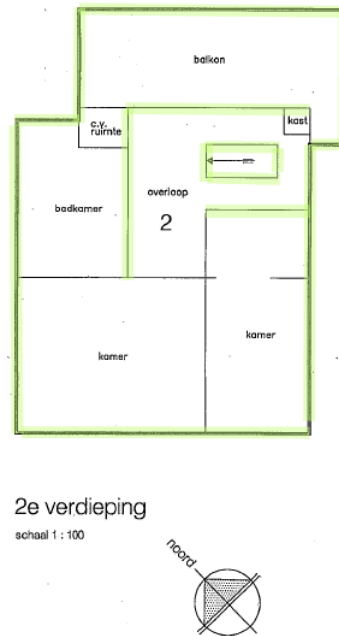
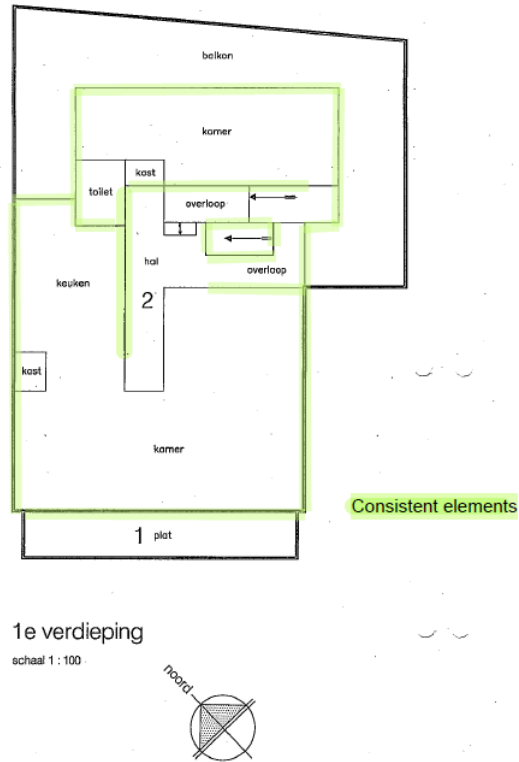
Storey alignment - Method

- Position floors on top of each other
- Repeating structure
 - Outer walls, load-bearing walls, staircases..

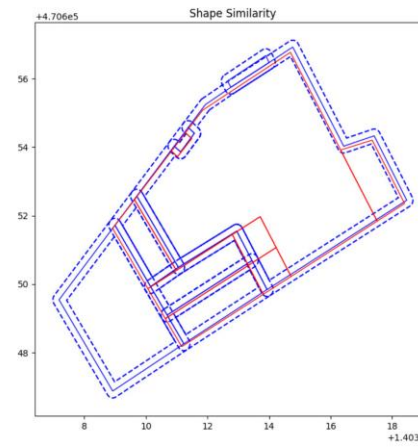


Storey alignment - Method

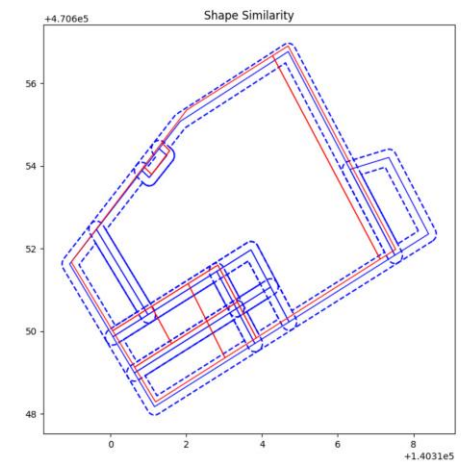
- Shape similarity



2

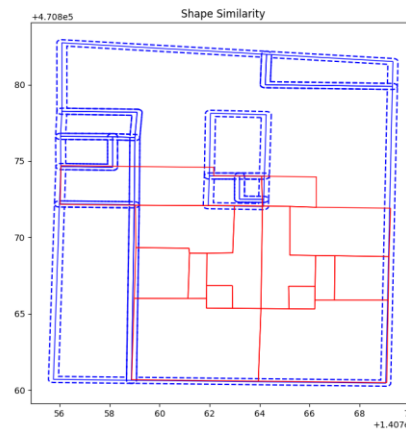
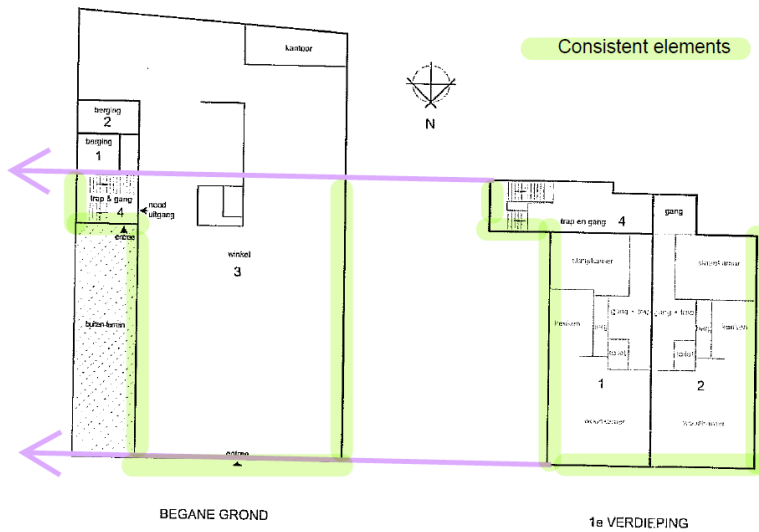
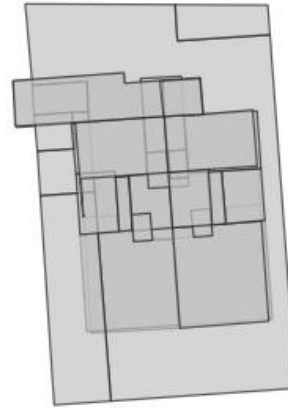


3



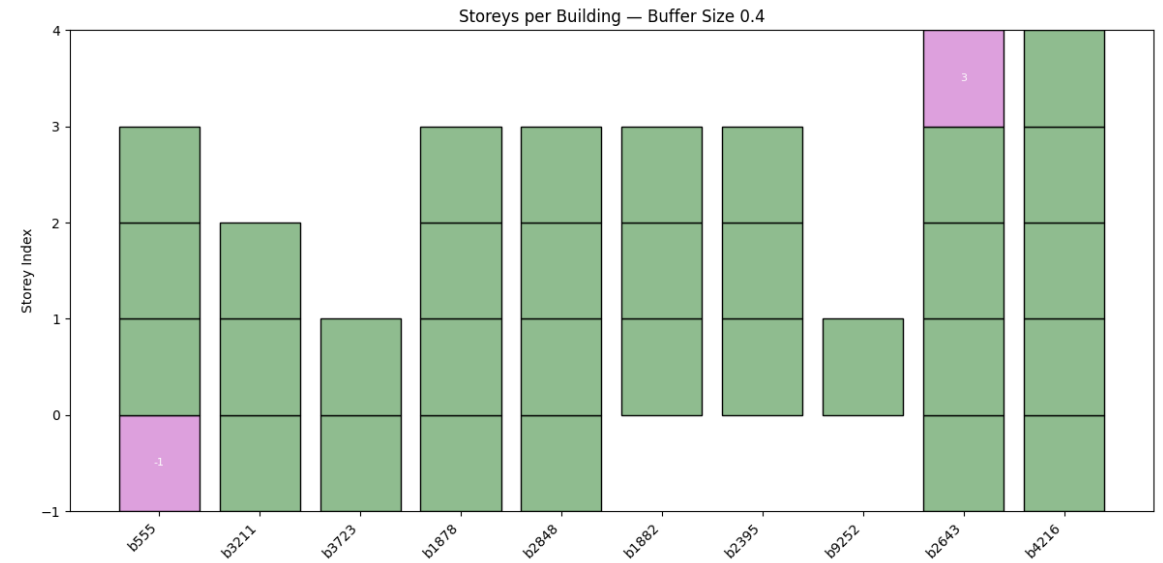
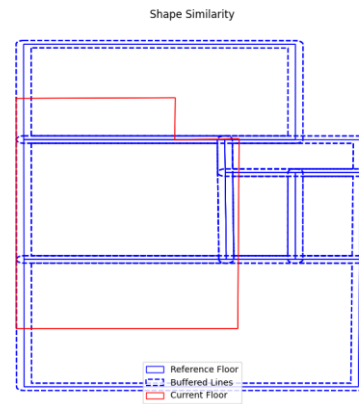
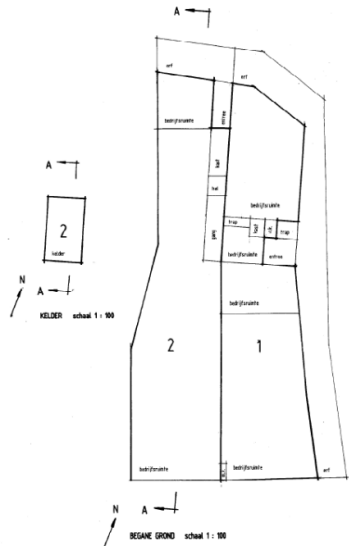
Storey alignment – Special cases

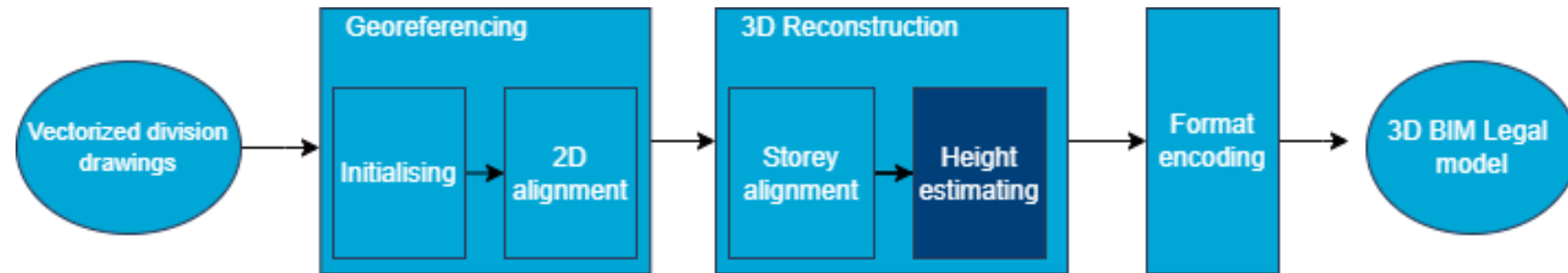
- Low similarity
- Use layout
 - Restrict search range



Storey alignment - Results

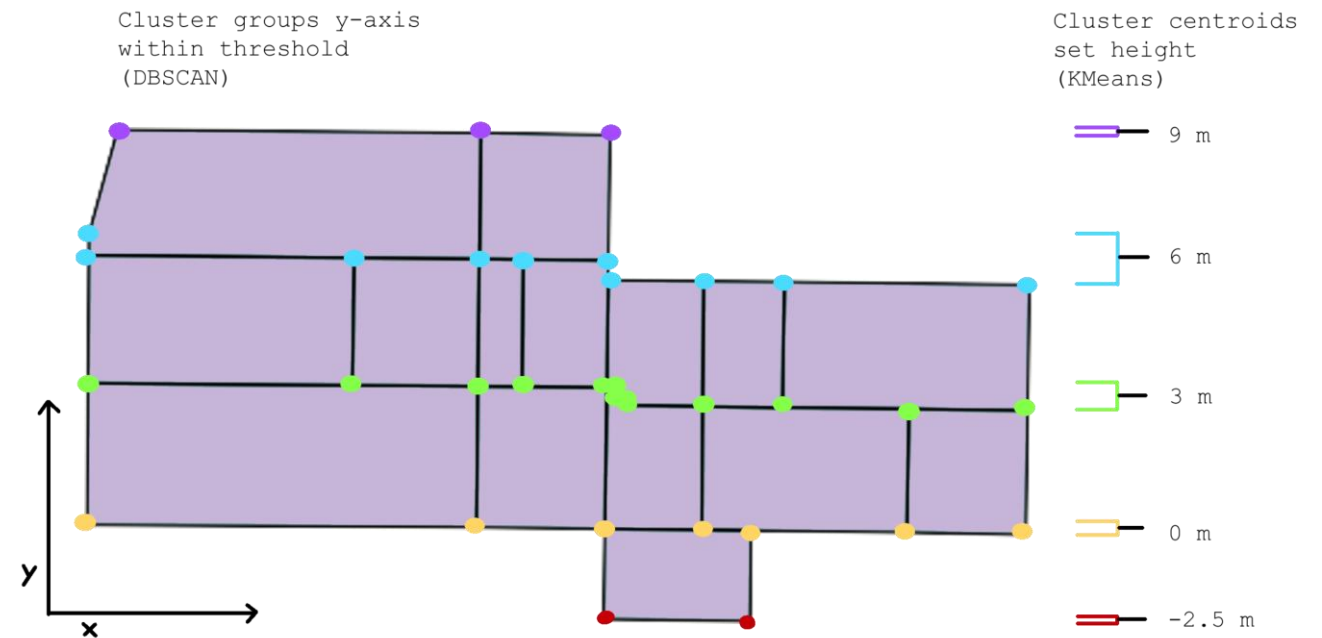
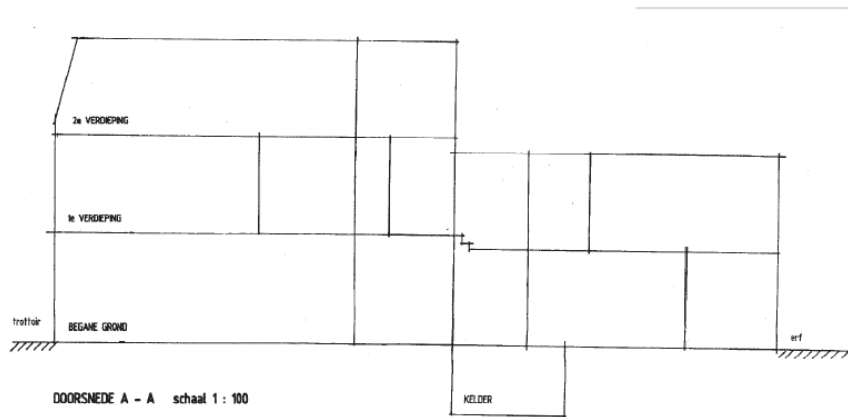
- Limitations:
 - Dissimilarity





Height estimation

- Cross section information
 - Cluster y-vertices
 - Height per storey



Height estimation

- Limitations:
 - Extra points: stepped roofs, stairs..
 - Incorrectly vectorized

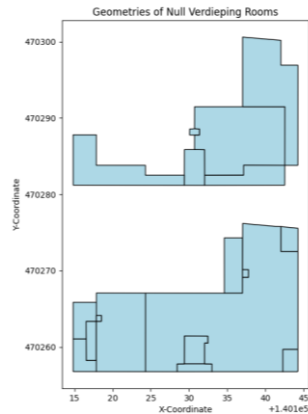


Table 5.2.: Detected number of storeys per building for different epsilon values

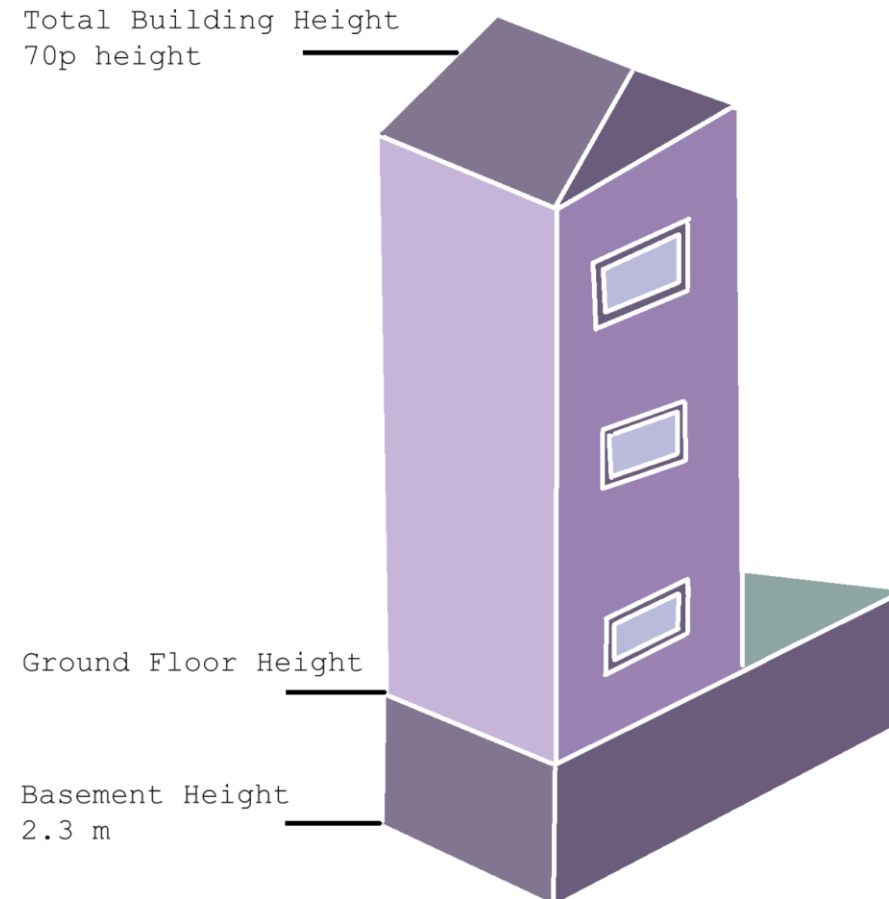
Building ID	$\epsilon=0.2$	0.4	0.6	1.0	1.4	1.8	2.2	Amnt Drawn Storeys
1878/1879	11	6	3	3	2	2	1	4
2359	4	4	4	3	3	3	3	3
3723	28	20	17	9	5	5	1	2*
555/556	8	6	4	4	4	4	3	4

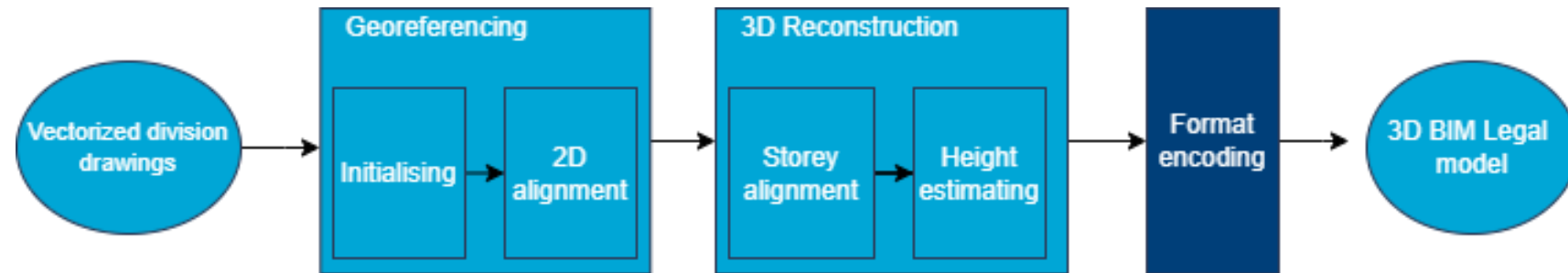
Height estimation

- Use 3DBAG as safety measure
 - Average height per storey
- Keep height between limits

Table 6.4.: Average and total estimated storey heights using Section and 3DBAG methods.

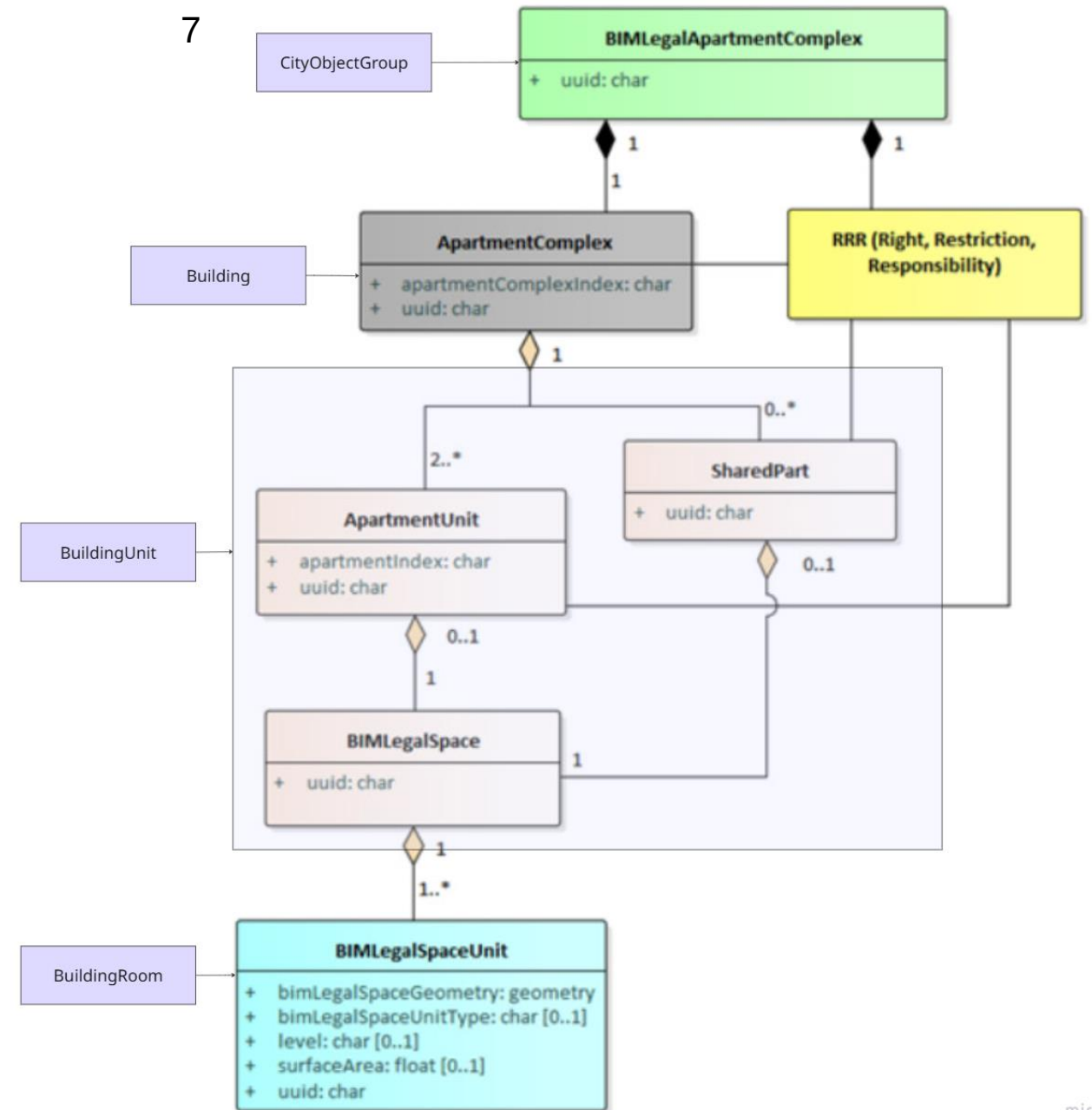
Building ID	Sec. Total	Sec. Avr Storey	3DBAG Total	3DBAG Avr Storey	Notes
1878/1879	6.88	1.72	9.72	3.24	Multiple sections
1882	-	-	9.40	3.13	
2359	9.46	3.15	9.21, 9.19	3.07, 3.06	2 BAG
2643	-	-	10.40	2.60	
2848	-	-	11.91	2.98	
3211	-	-	5.86	2.93	
3723	21.82	10.91	11.59	11.59	Faulty input
4216	-	-	13.43	3.36	
555/556	12.40	3.10	10.94, 10.47	3.65, 3.49	2 BAG
9252	43.61	43.61	8.69	8.69	





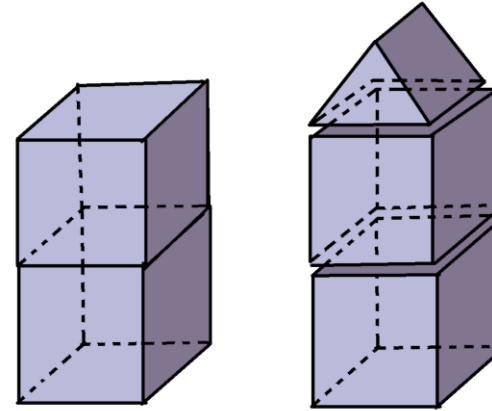
BIM Legal - Format

- CityJSON
 - 3D support
 - Semantic hierarchy
 - GIS tools
 - Georeferencing

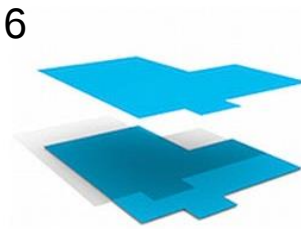


BIM Legal – 3D modeling

- Extrude footprints
- Interior Level of Detail

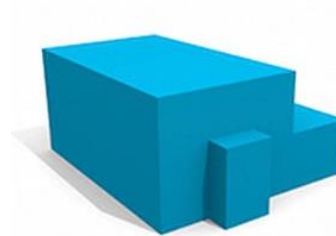


6



Level of detail

0



Level of detail

1



Level of detail

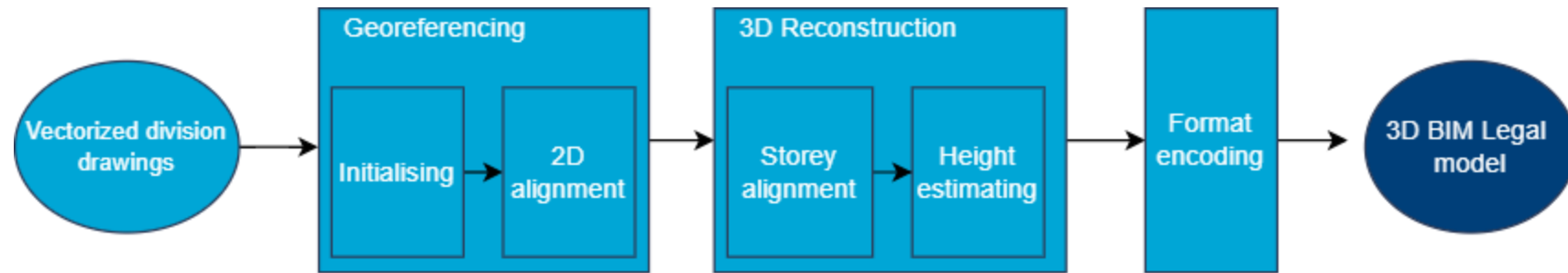
2



Level of detail

3

Final models!

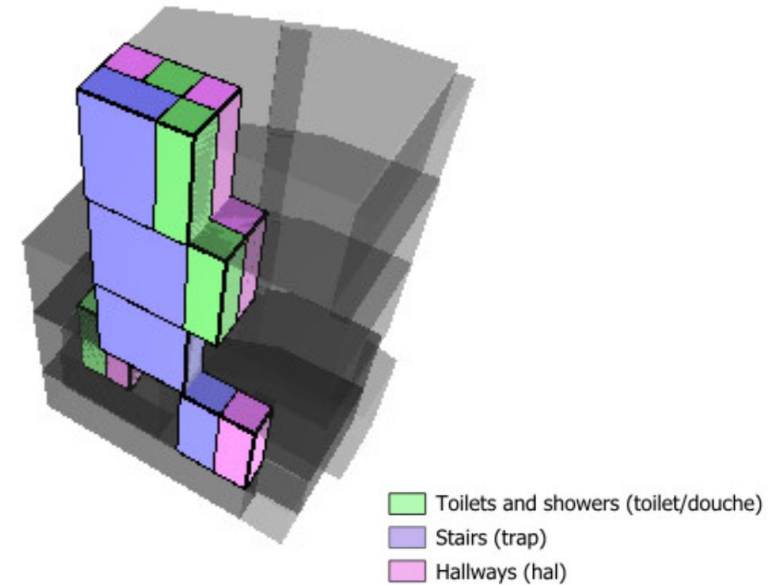


BIM Legal - Visualization

- Apartment index

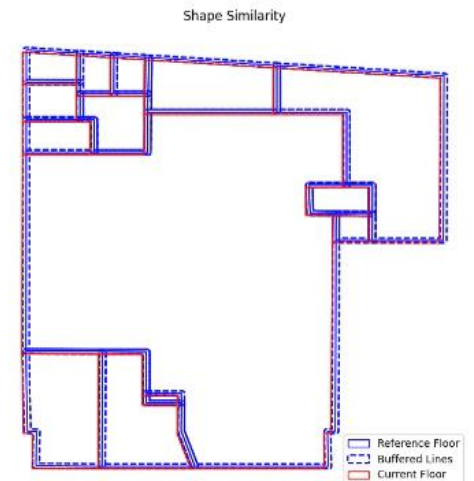
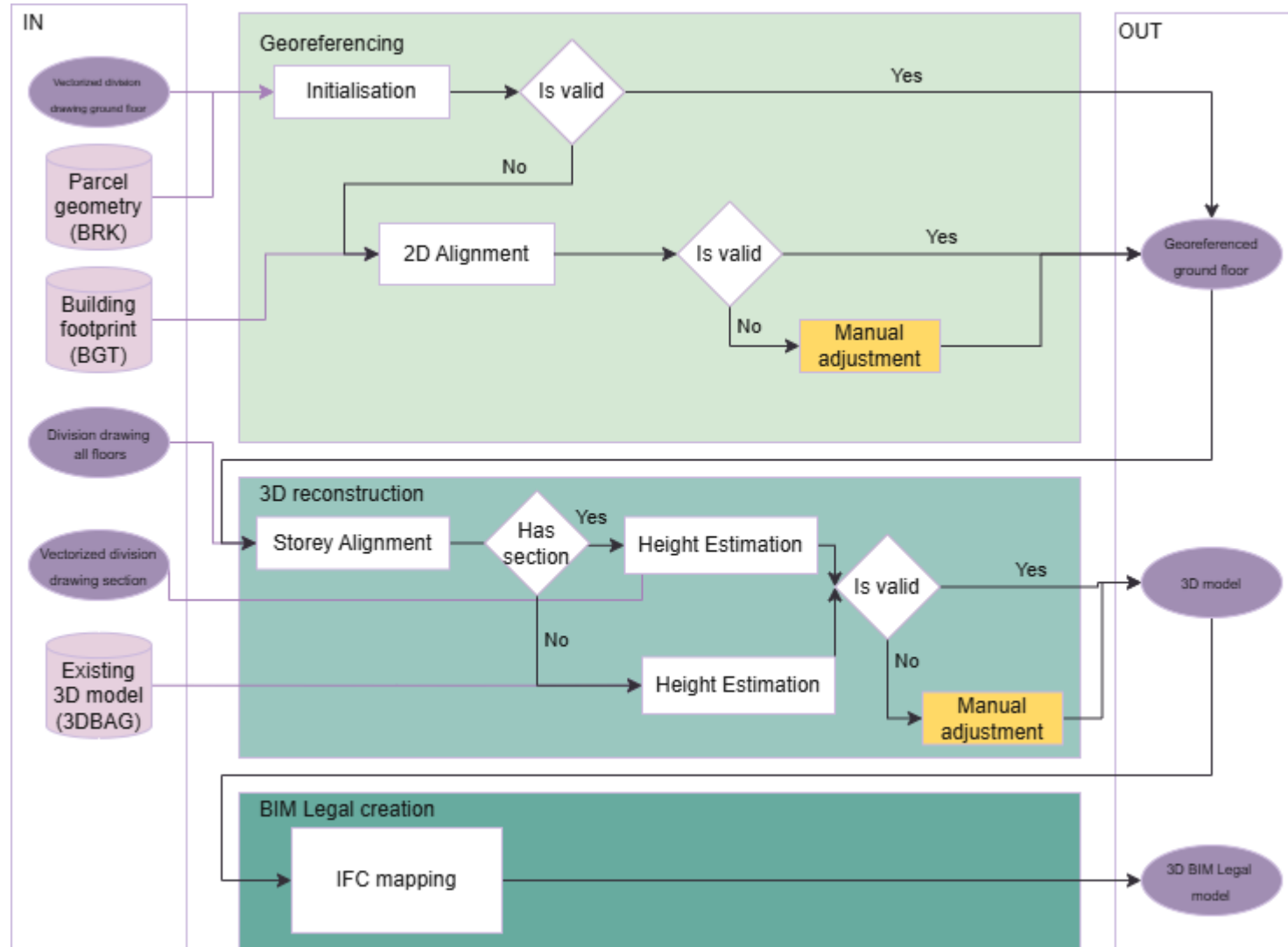


- Functional spaces



- Shared spaces

Pipeline overview



Limitations

- Test with more buildings
 - Outside spaces – parcel geometry instead of BGT
 - Low similarity floor alignment – layout usage
 - Detail level LoD1+
-
- Future research
 - Also visualization use cases

Conclusions

- Mostly automatic pipeline
- Accurate georeferencing under certain conditions (95.2%)
- Improvement to vectorization -> better 3D reconstruction
 - North arrow, scale
 - Cross sections
- Proof of concept CityJSON for BIM Legal

ID	Final BIM Legal model
9252*	
555/556	
1878/1879	
1882	
2359	

ID	Final BIM Legal model
2643	
2848	
3211	
3723*	
4216	



Thanks for your attention!

Thesis final presentation| Lotte de Niet

18-6-2025

Figure sources

1. *Integraal ontwerpen en samenwerken met BIM · BDG Architecten*. (n.d.). BDG Architecten. Retrieved May 9, 2025, from <http://www.bdgarchitecten.nl/bureau/thema/bim>
2. Atazadeh, B., Kalantari, M., Rajabifard, A., Ho, S., & Ngo, T. (2017). Building Information Modelling for High-rise Land Administration. *Transactions in GIS*, 21(1), 91–113. <https://doi.org/10.1111/tgis.12199>
3. J. Stoter, P. V. Oosterom, and H. Ploeger. The phased 3d cadastre implementation in the netherlands. 2012
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