GEODELTA

GDMC

Working Towards Oblique Aerial Adjustment through the Creation of Synthetic Test Cases

Ing. W.H.J. Kahn

P5 Presentation 26/06/2025

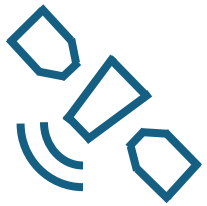
1st supervisor: Edward Verbree
2nd Supervisor: Martijn Meijers
C-Supervisor: Annemieke Verbraeck
Co-reader: Sandra Verhagen
Delegate: Hugo Ledoux

Aerial Photography

- Plane based
- High resolution
- Collected during spring
- Used in mapping
- Pose captured using GNSS-IMU

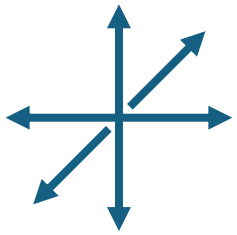
GNSS-IMU

Global Navigation Satellite System

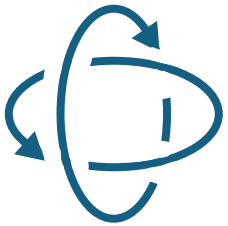


Ephemeris Data

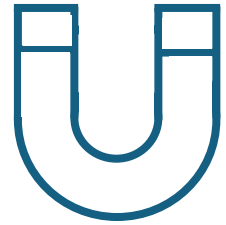
Inertial Motion Unit



3-axis acceleration



3-axis Rotation



3-axis Magnetism

Combination gives:

- Position
- Velocity
- Attitude

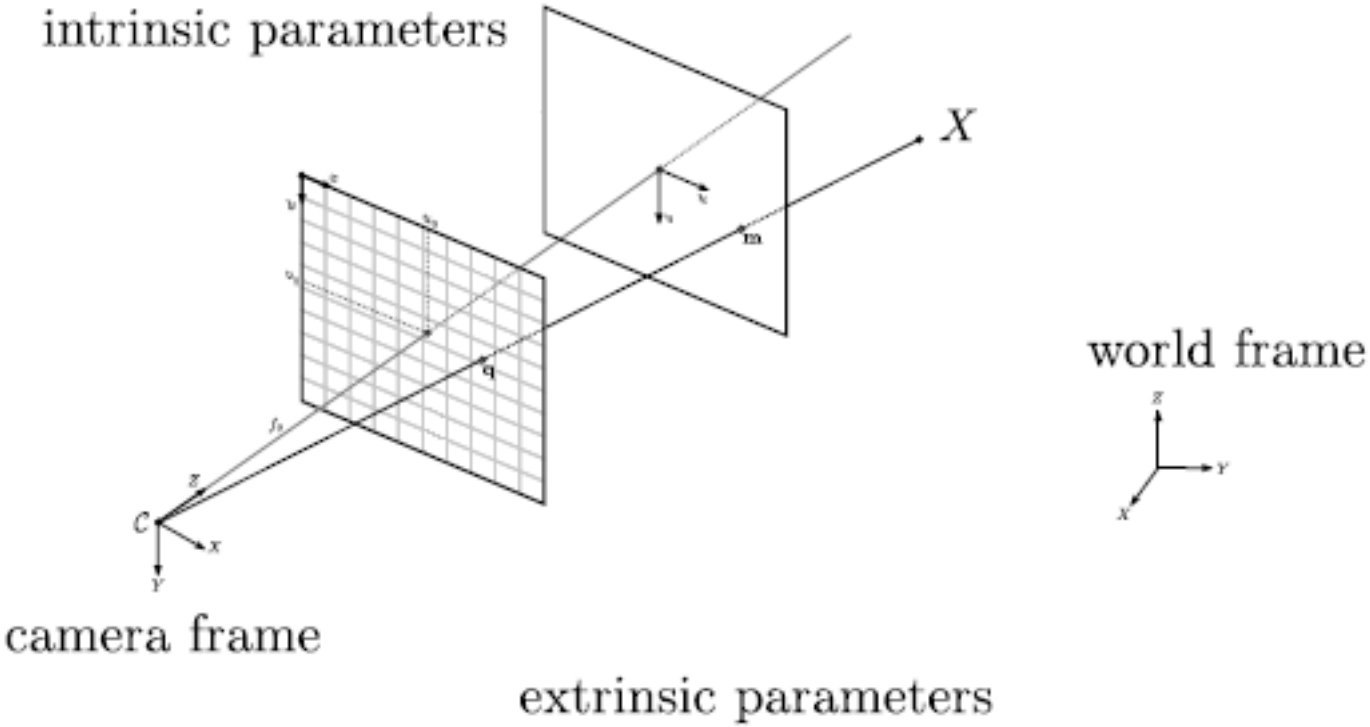
Camera Model

Intrinsic Parameters

- Sensor width and height
- Pixel width and height
- Focal distance
- Principle Point Average

Extrinsic Parameters

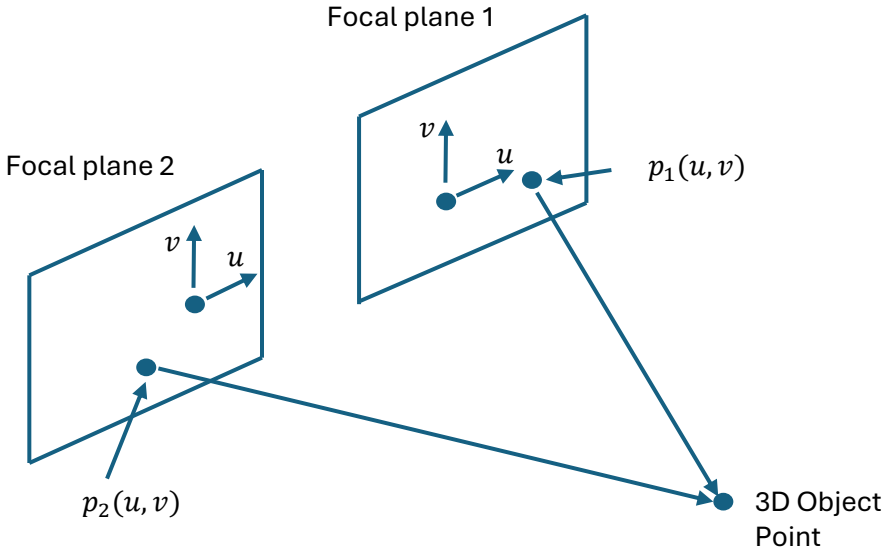
- C_{XYZ}
- $R_{\omega\phi\kappa}$



Object and Control Points

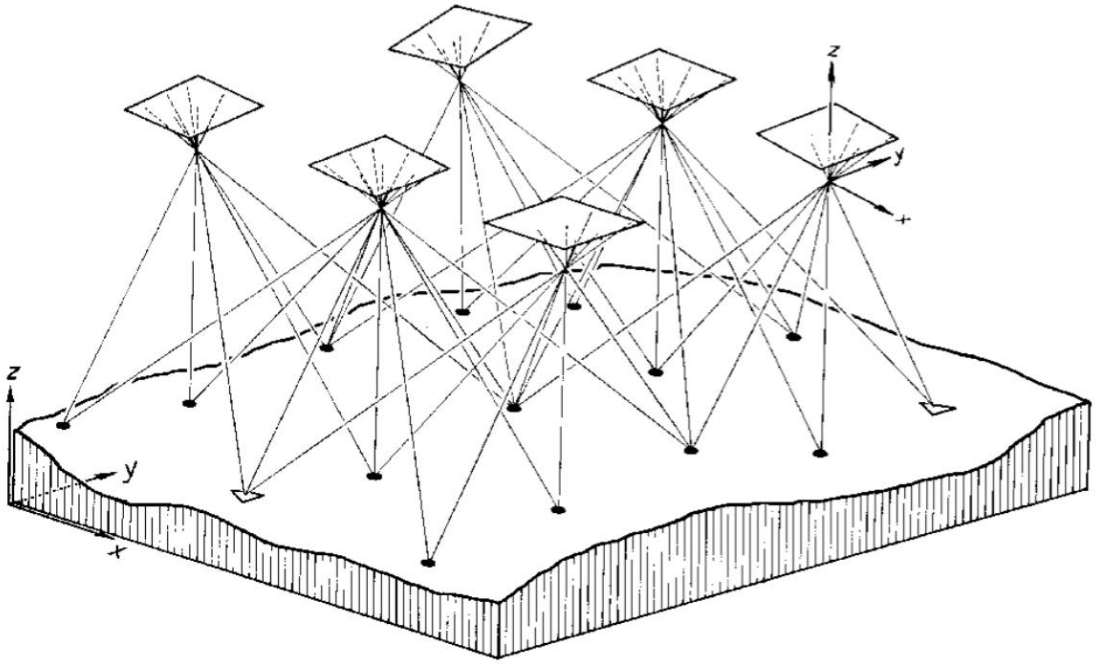
Object Points

- 2D Image points
- p_{uv}
- 3D intersected point
- p_{xyz}
- Link images



Control Points

- 3D Terrestrially measured
- P_{XYZ}
- Link system to real-world



Adjustment Theory

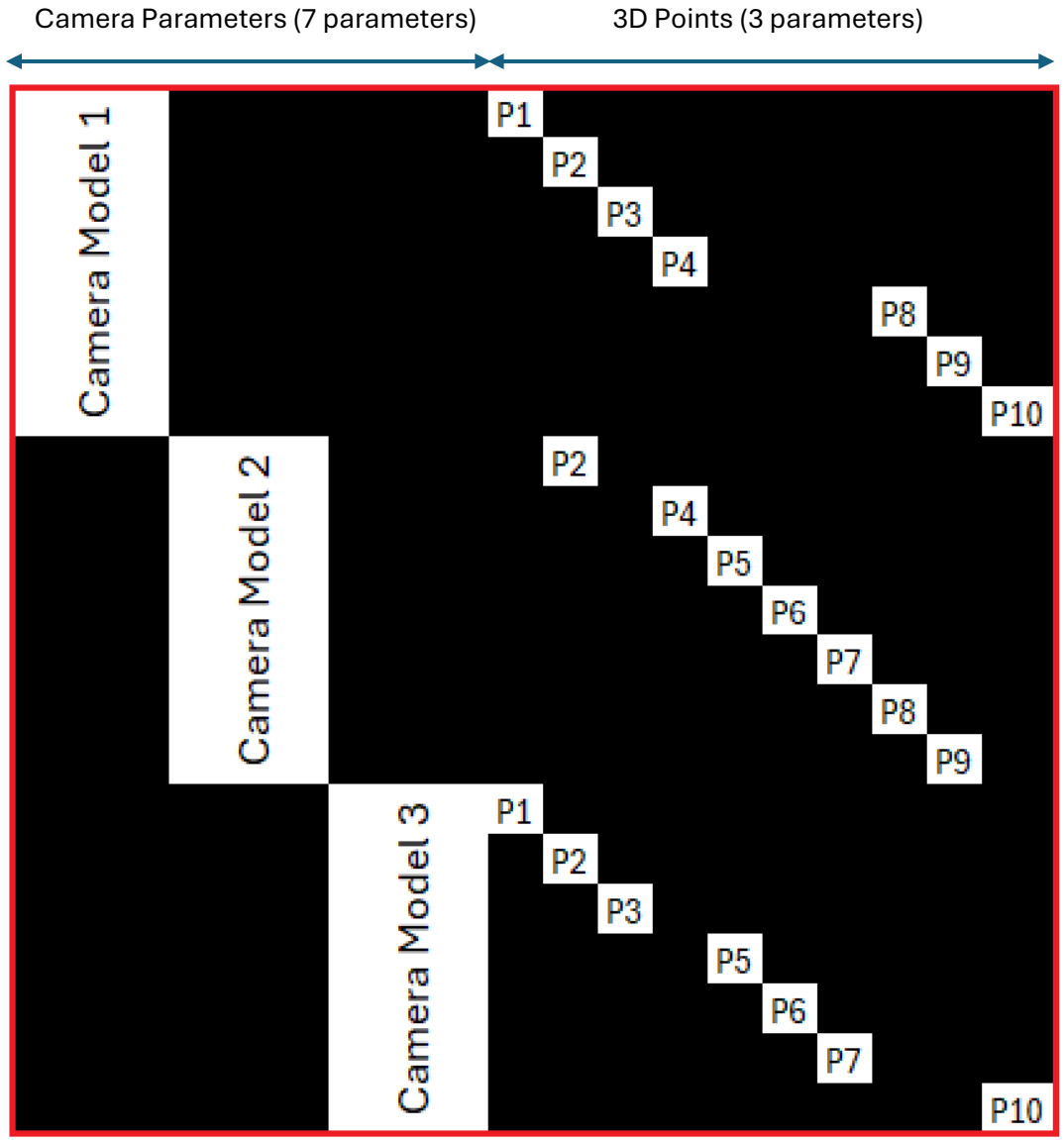
- Iteratively reduce noise

$$\min_{r,t,f,d,P} \sum_{i \in I} \sum_{j \in J} \left| x_{ij} - \pi(P_i, C_j) \right|^2$$

- Free network (1st phase)
- Constrained network (2nd phase)

- F-test (General Model Test)

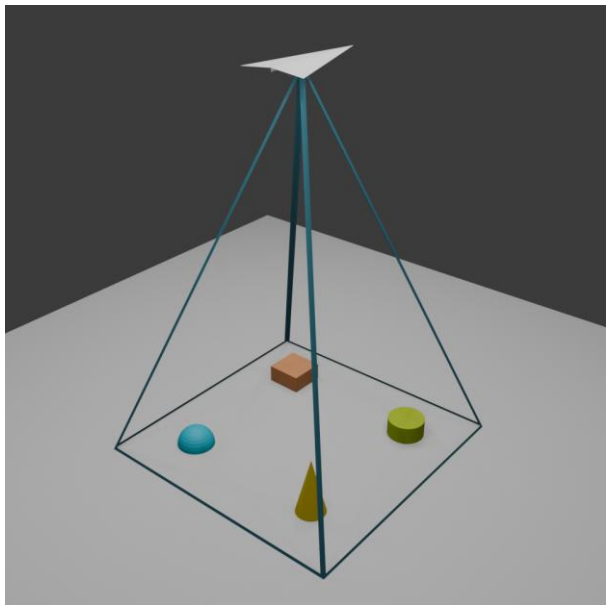
$J =$

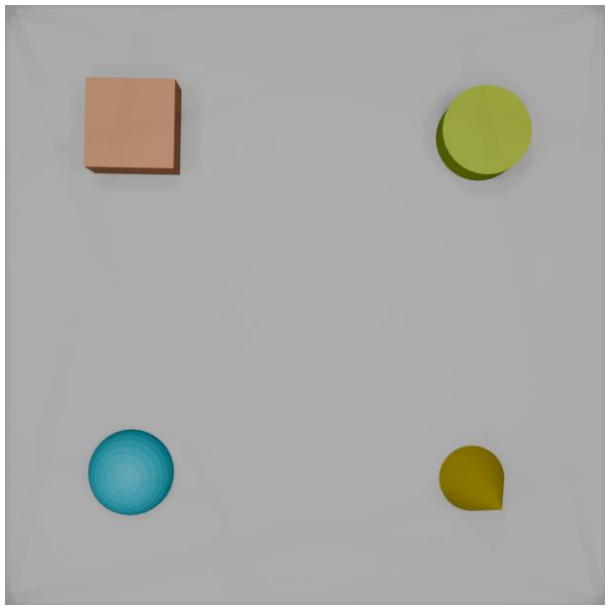


Aerial Collection Pipeline

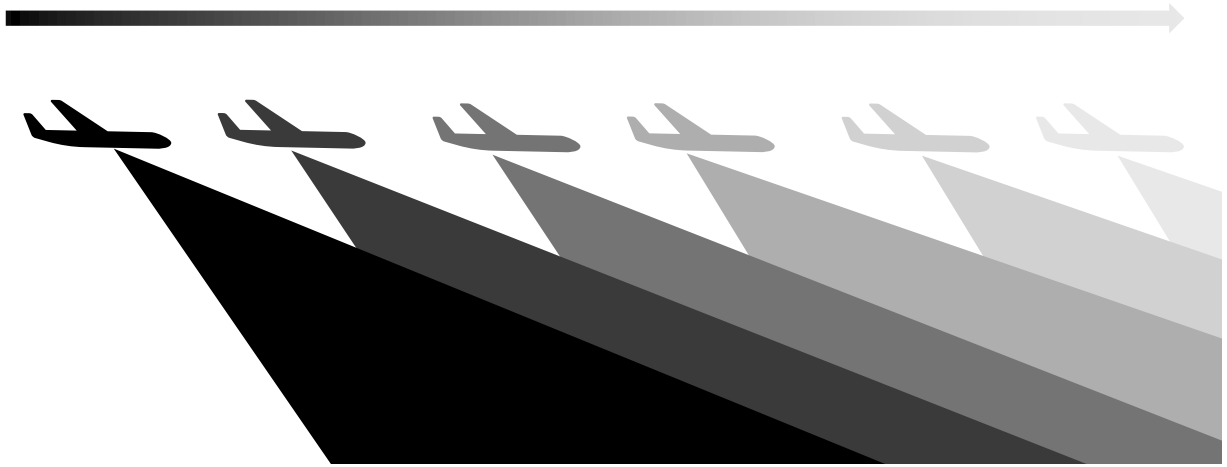
- Signal plan
- Flight plan
- Image capture
- Object Point Detection and matching
- Adjustment
- Quality Inspection
- Mapping

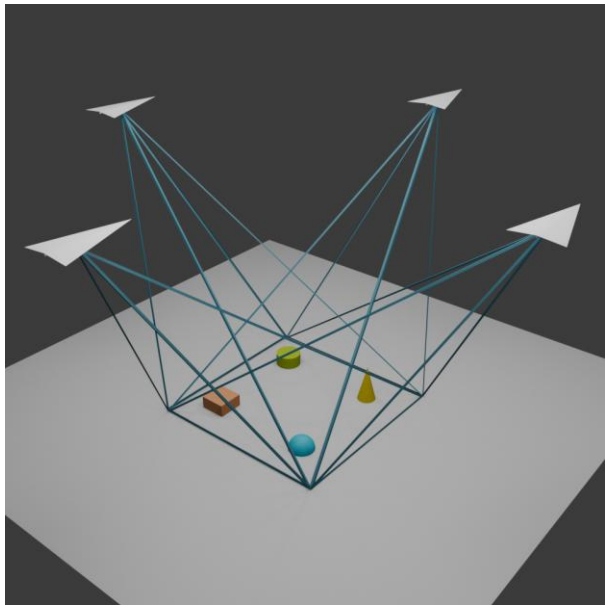
Nadir Imagery

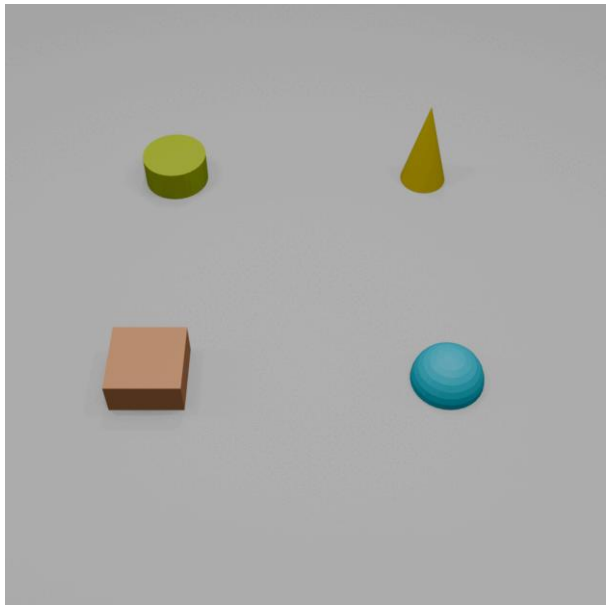




Oblique Imagery







Goal: Oblique Framework

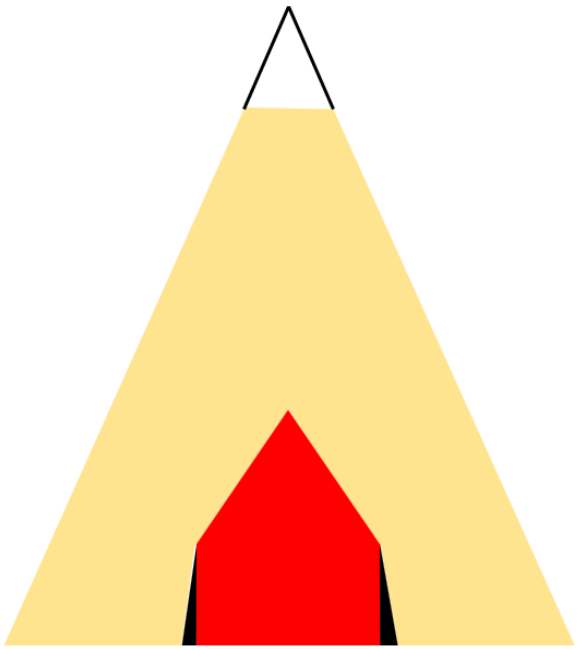
- Signal plan
- Flight plan
- Image Capture
- Object Point Detection and matching
- Adjustment
- Quality Inspection
- Mapping

Occlusion

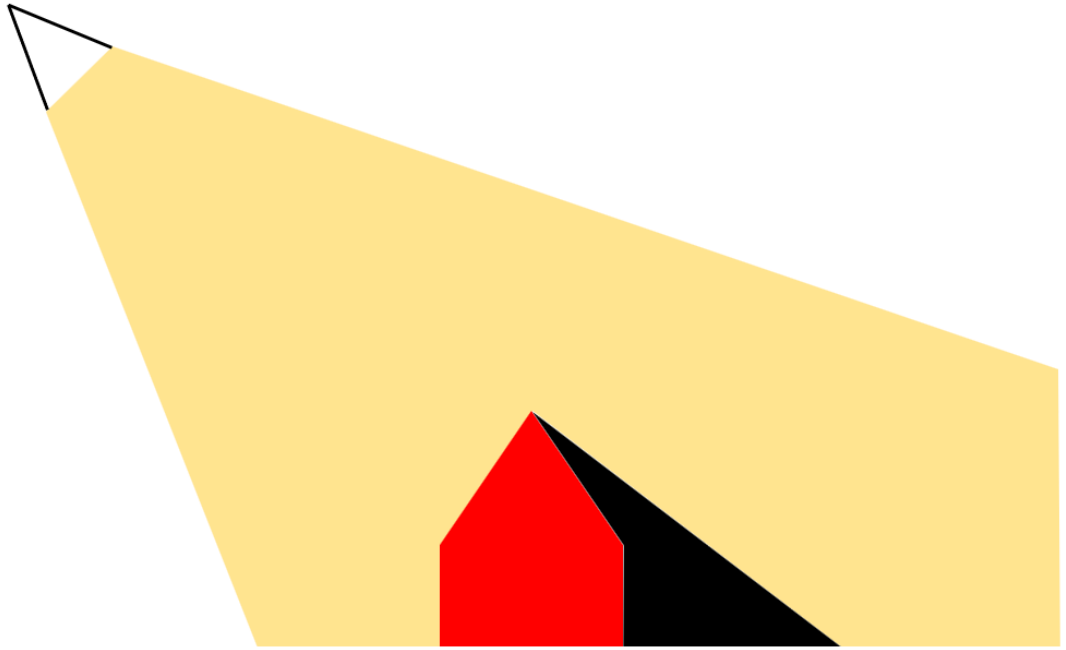
Built Environment Object

Occluded Space

Visible Space

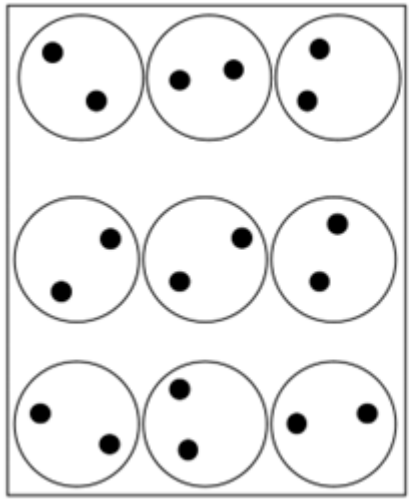


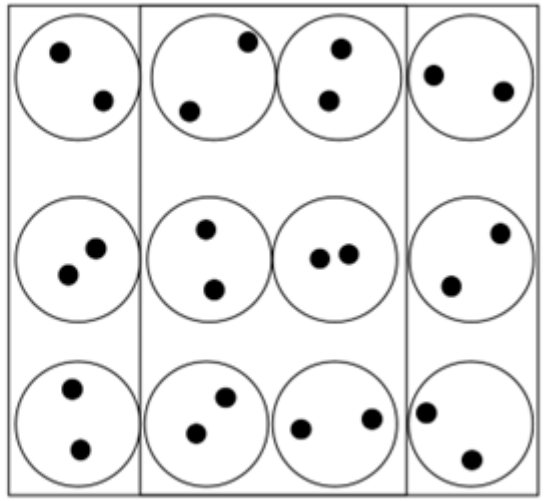
Nadir Occlusion



Oblique Occlusion

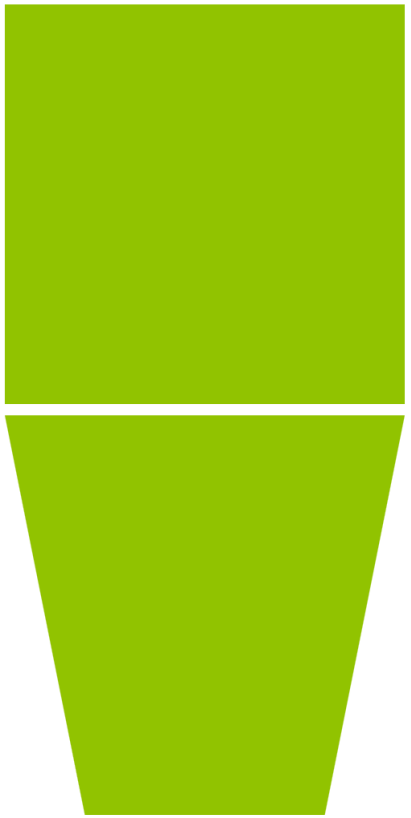
Point Distribution Von Gruber squares

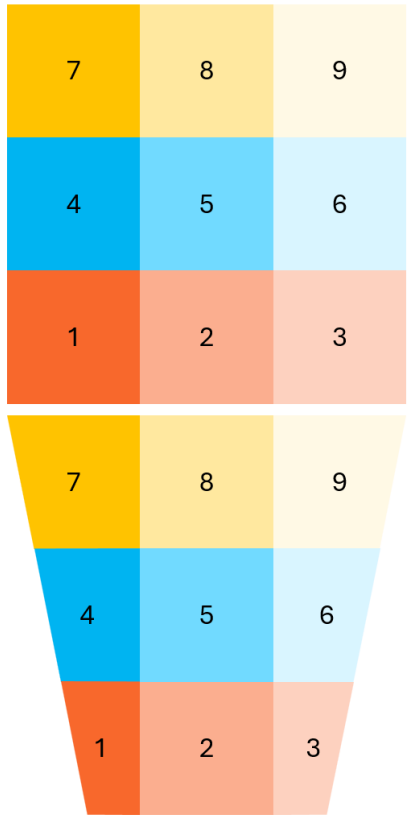




Nadir Footprint

Oblique Footprint

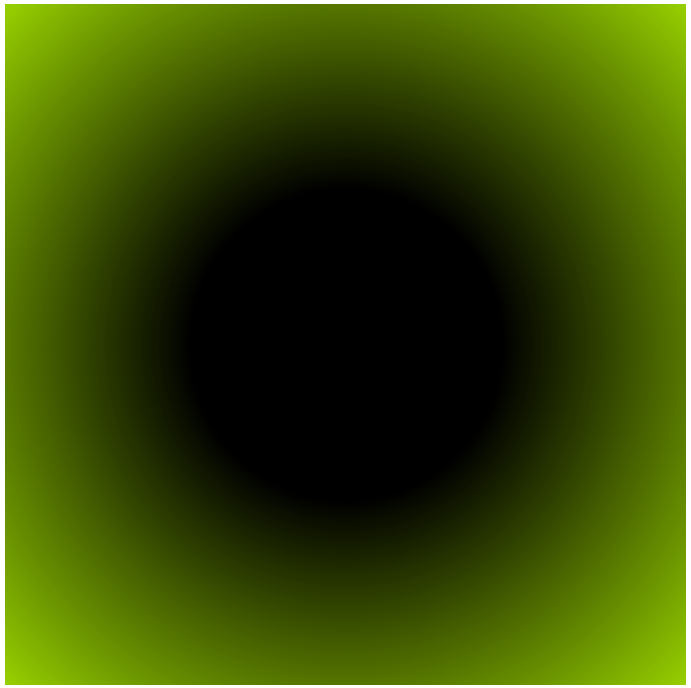




Nadir Von Gruber Squares

Oblique Von Gruber Squares

Ground Sampling Size

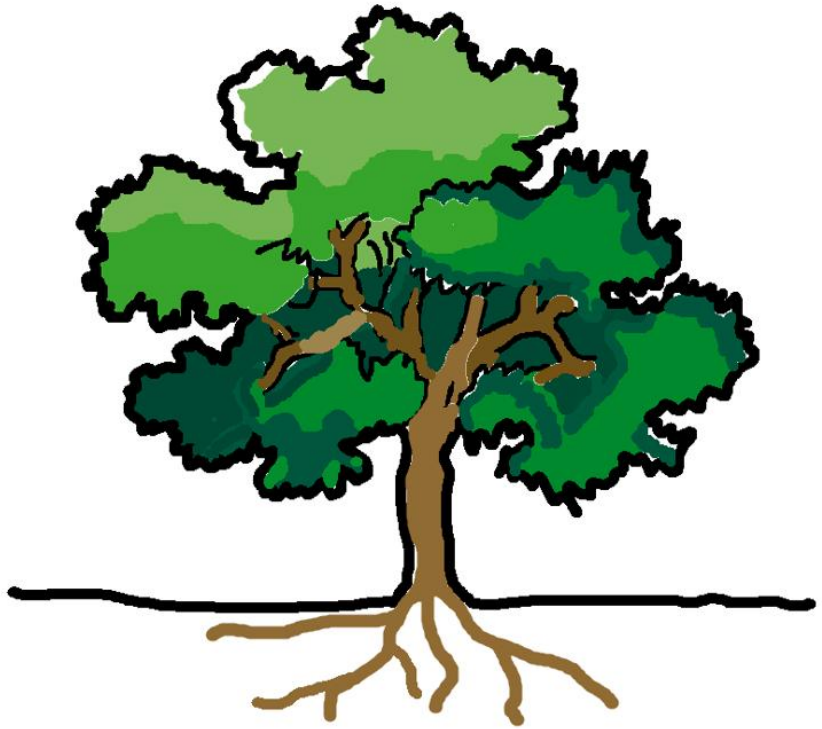


Nadir Footprint

Oblique Footprint

Pixel size

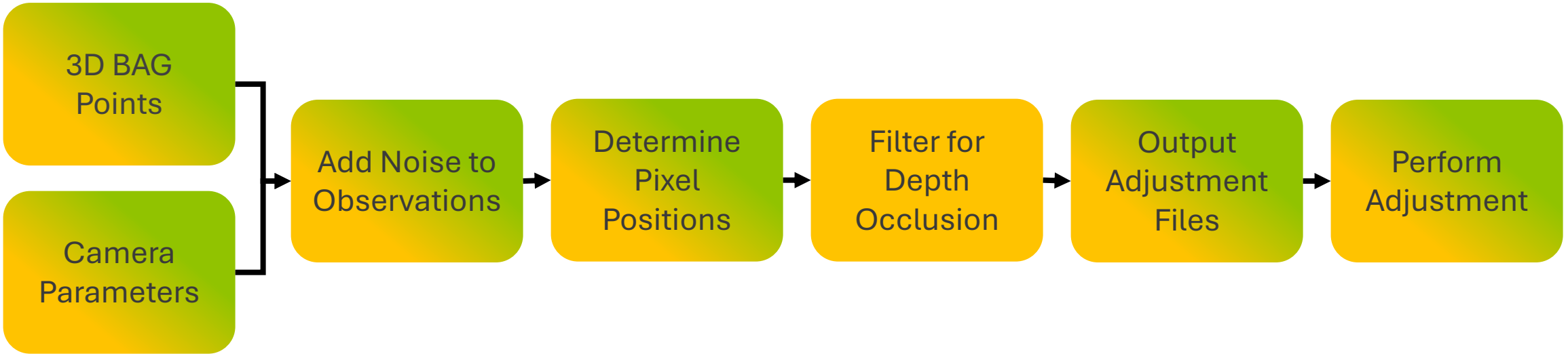
Synthetic Data

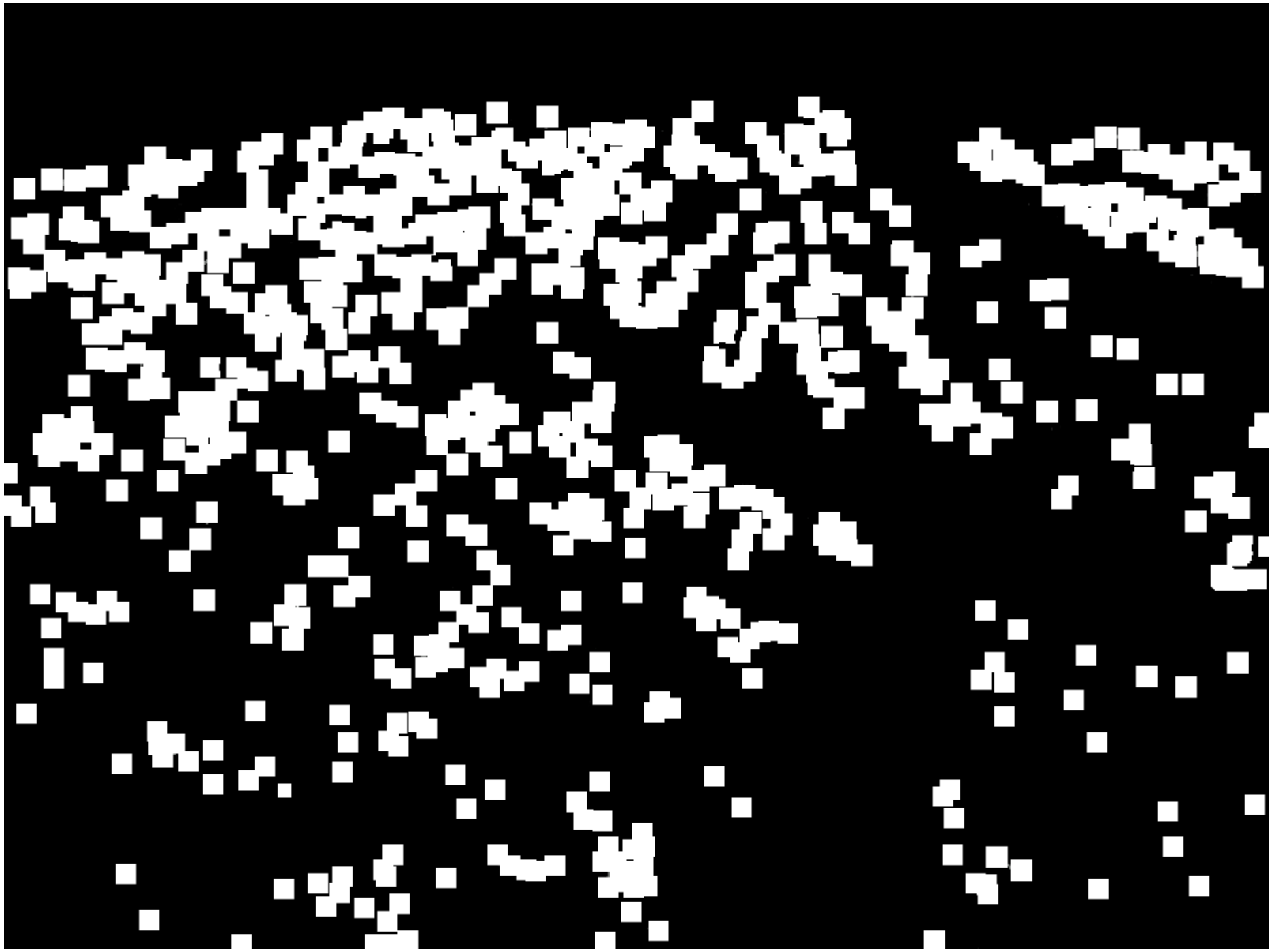


Main Question

What **parameters** are key in the reconstruction accuracy of **adjustment** theory applied to RGB aerial images using **synthetic test cases**?

Phase I: Non-Obstructed Synthetic Adjustment & Depth Map-Based Occlusion for Synthetic Adjustment





3D BAG Points

2D projection

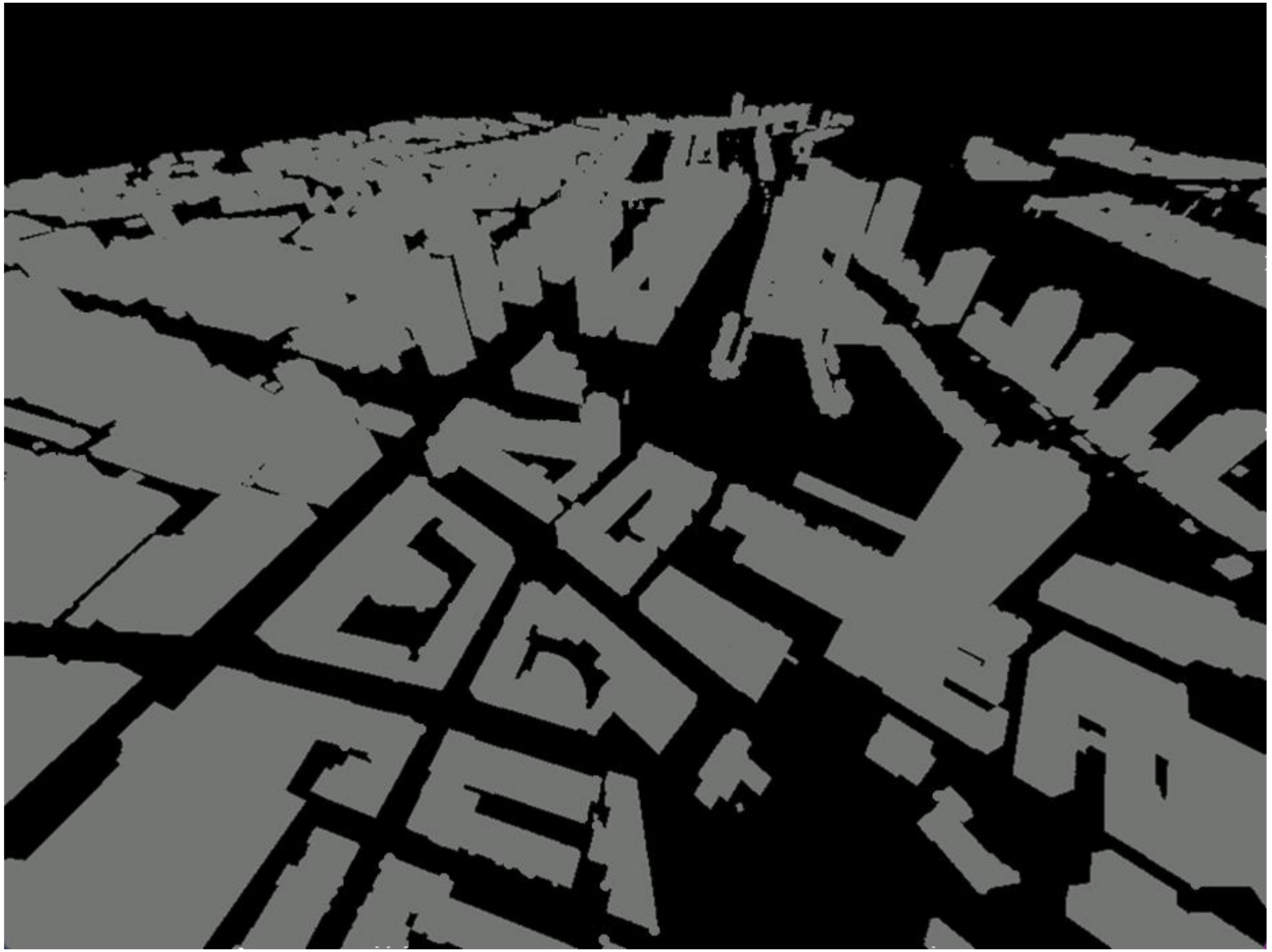
$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = C_{int} C_{ext} \begin{bmatrix} P_X \\ P_Y \\ P_Z \\ 1 \end{bmatrix}$$

$$C_{int} = \begin{bmatrix} f & \rho & c_x + ppa_u \\ 0 & f & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$C_{ext} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix}$$

$$u = \frac{f \cdot x}{z}$$

$$v = \frac{f \cdot y}{z}$$



3D BAG Meshes

3D BAG Object files

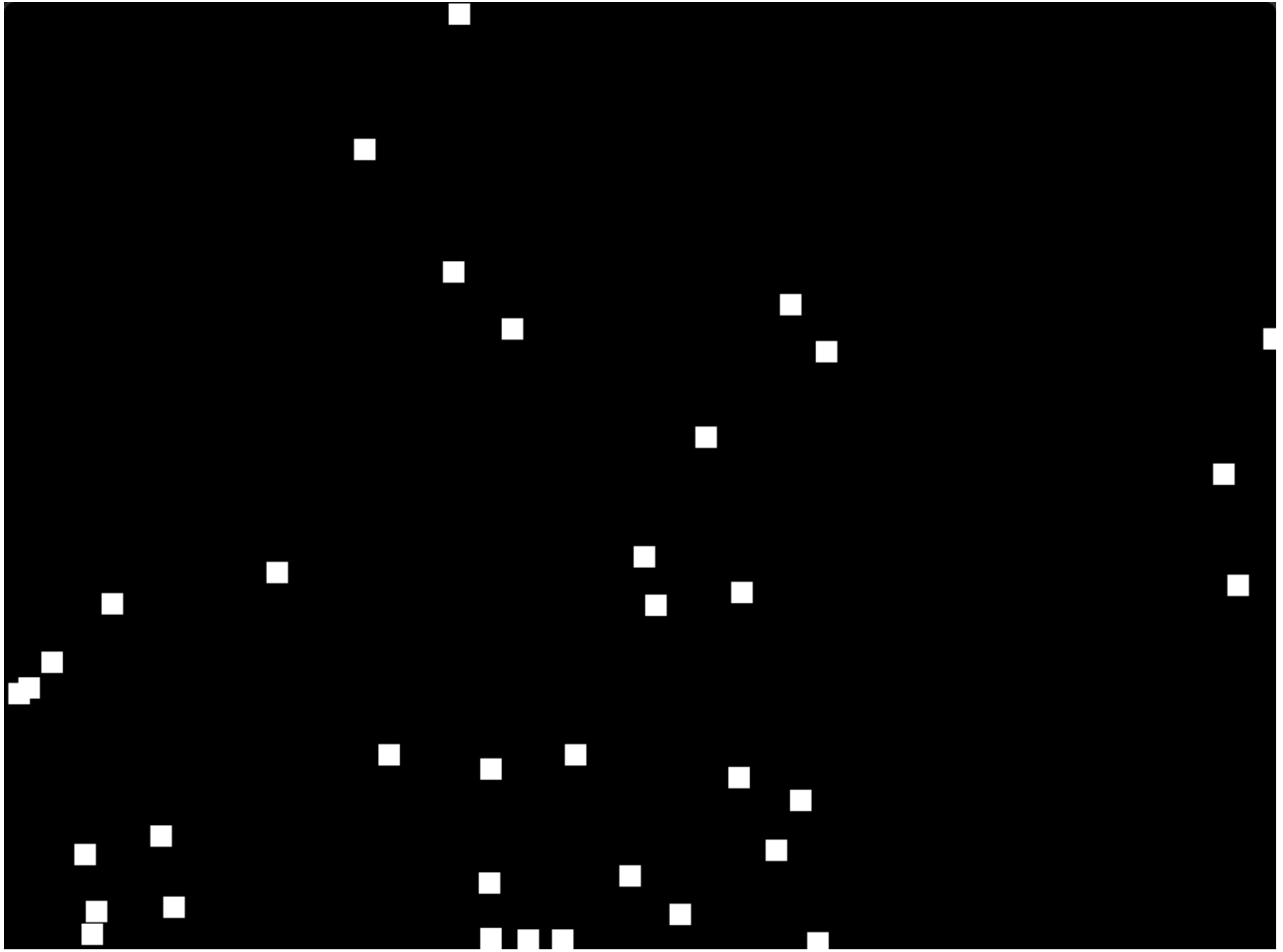
Split on a building level

Depth map

OpenGL a C++ Library

Rendered from camera perspective overlaid on mesh using GLSL vertex shader

Distance



Filtered points

Number of points is reduced

Introduces Adjustment Complexity

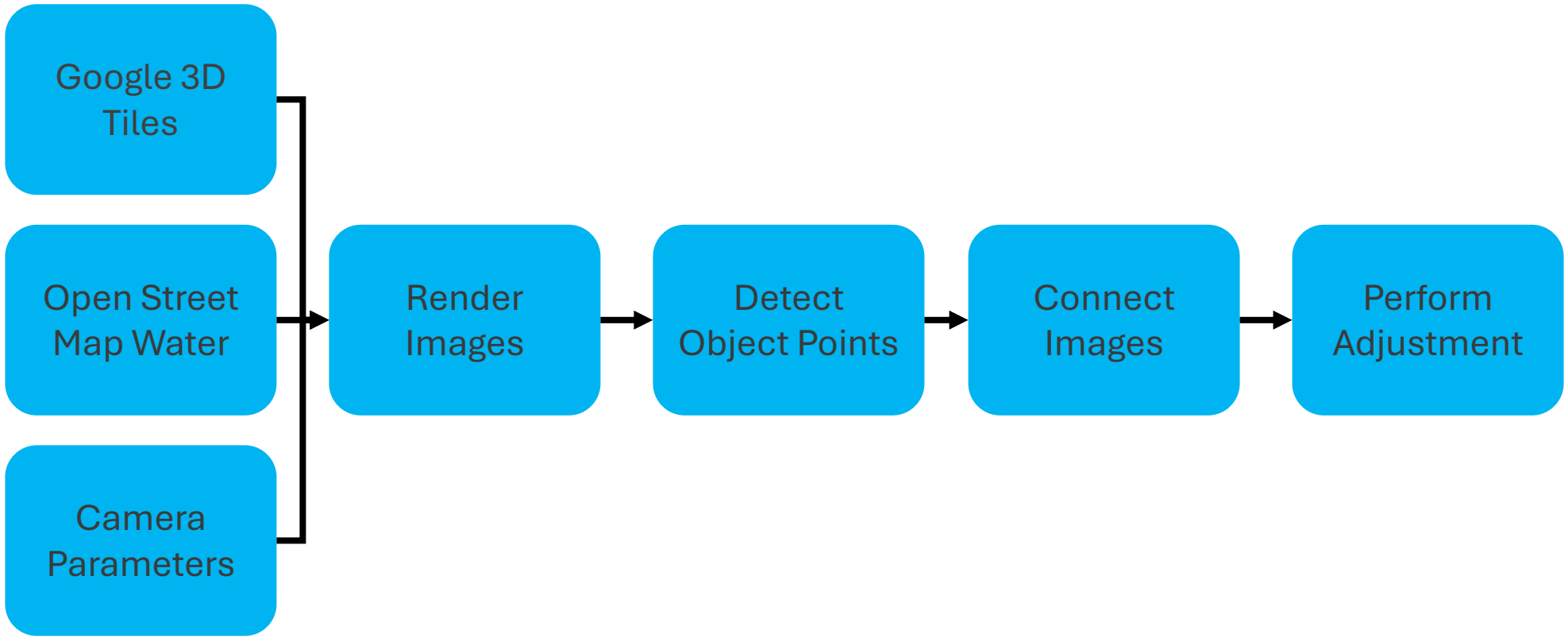
Total number of points needed to doubled

Image Types	Adjustment Types	CaseTypes
146 Nadir & 552 Oblique	Free Network & Constrained Network	NoneNoise
		XNoise
		YNoise
		ZNoise
		OmegaNoise
		PhiNoise
		KappaNoise
		PPAuNoise
		PPAvNoise
		FocalNoise
		VonGruber123Noise
		VonGruber456Noise
		VonGruber789Noise

	CaseType	Avg. F-test 1st Phase Nadir	Avg. F-test 2nd Phase Nadir	Avg. F-test 1st Phase Oblique	Avg. F-test 2nd Phase Oblique
Phase IA: **Non-Obstructed Synthetic Adjustment**	NoneNoise	0.000	0.000	0.000	0.000
	XNoise	0.010	0.009	0.008	0.008
	YNoise	0.010	0.010	0.010	0.008
	ZNoise	0.011	0.009	0.005	0.005
	OmegaNoise	2.407	2.356	2.117	2.270
	PhiNoise	2.107	1.764	5.514	2.474
	KappaNoise	1.053	1.339	1.080	0.845
	PPAuNoise	282.099	280.432	73.582	74.639
	PPAvNoise	308.276	306.053	75.890	72.480
	FocalNoise	1.278	1.239	0.0676	0.650
	Gruber123Noise	0.000	0.000	0.000	Failed
	Gruber456Noise	0.000	0.000	0.000	Failed
	Gruber789Noise	0.000	0.000	0.000	Failed

	CaseType	Avg. F-test 1st Phase Nadir	Avg. F-test 2nd Phase Nadir	Avg. F-test 1st Phase Oblique	Avg. F-test 2nd Phase Oblique
Phase IB: **Depth Map-Based Occlusion for Synthetic Adjustment**	NoneNoise	0.000	0.000	0.000	0.000
	XNoise	0.034	0.033	0.011	0.015
	YNoise	0.044	0.039	0.015	0.013
	ZNoise	0.011	0.011	0.008	0.008
	OmegaNoise	6.513	9.113	2.744	3.064
	PhiNoise	6.665	6.220	3.732	3.421
	KappaNoise	1.310	1.735	1.119	1.229
	PPAuNoise	175.109	161.095	285.268	286.778
	PPAvNoise	366.599	341.614	296.492	297.105
	FocalNoise	0.992	1.216	0.627	0.572
	Gruber123Noise	0.000	0.000	0.000	0.000
	Gruber456Noise	0.000	0.000	0.000	0.000
	Gruber789Noise	0.000	0.000	0.000	0.000

Phase II: Synthetic Computer Vision-Based Object Point Detection

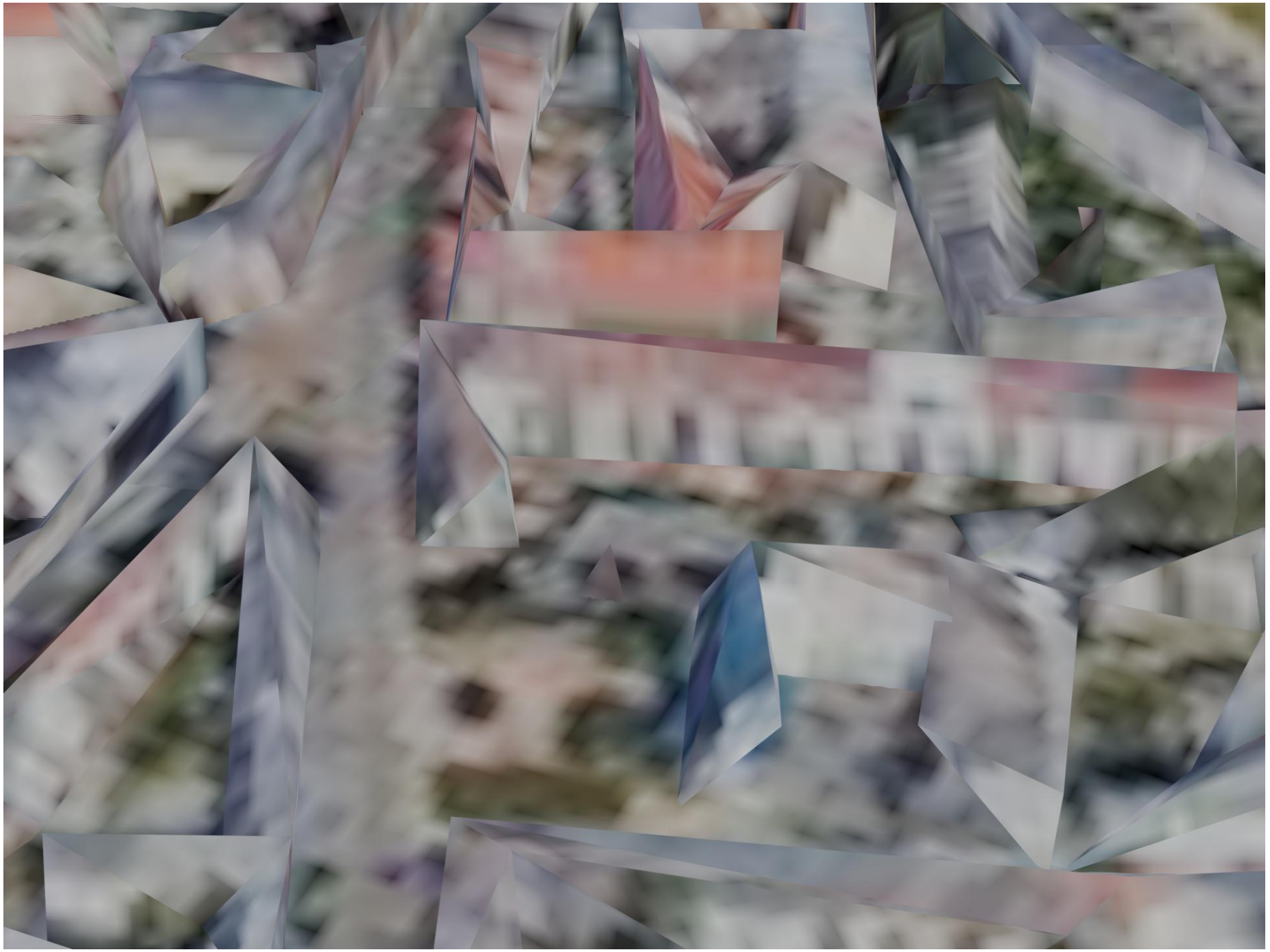


Oblique

Quality level:

Whole City

Resolution 4800 x 6400
Focal Distance 112 mm
Principle Point Average 0 mm



Oblique

Quality level:

Districts

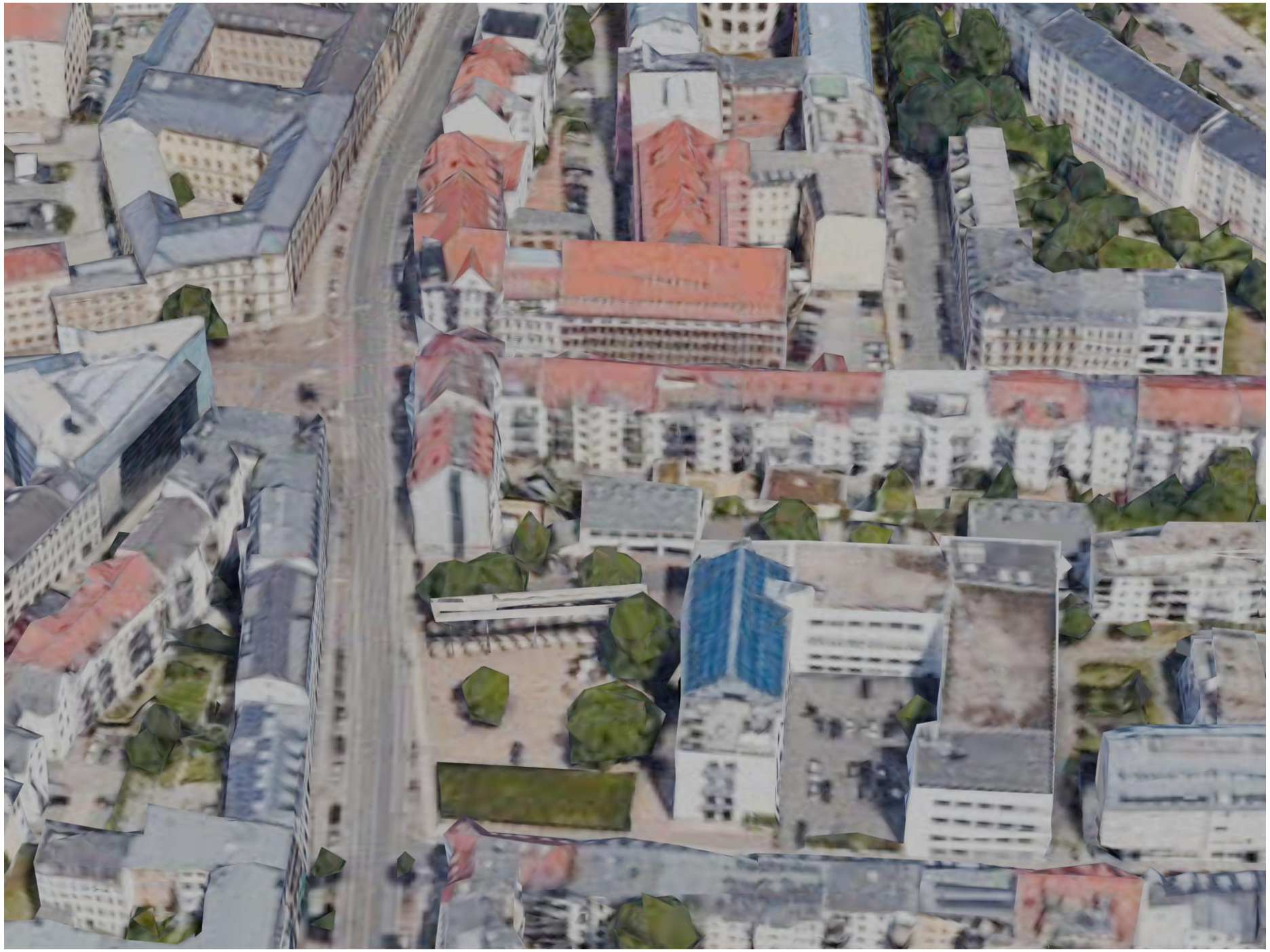
Resolution 4800 x 6400
Focal Distance 112 mm
Principle Point Average 0 mm

Oblique

Quality level:

Groups of Buildings

Resolution 4800 x 6400
Focal Distance 112 mm
Principle Point Average 0 mm



Oblique

Quality level:

Separate Buildings

Resolution 4800 x 6400
Focal Distance 112 mm
Principle Point Average 0 mm

Oblique

Quality level:

Buildings with Details

Resolution 4800 x 6400
Focal Distance 112 mm
Principle Point Average 0 mm

Oblique

Quality level:

Buildings with more Details

Resolution 4800 x 6400
Focal Distance 112 mm
Principle Point Average 0 mm

Oblique

Quality level:

Buildings with more detail

Rotterdam Stadsdriehoek

One Problem:

Water

Oblique

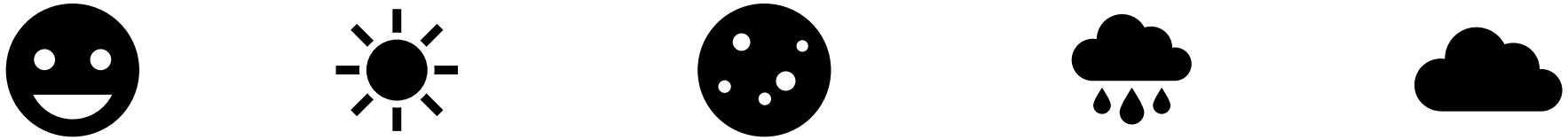
Quality level:

Buildings with more detail

Rotterdam Stadsdriehoek

With OSM-water 3D Tiles
Retrieved through BLOSM

Exogenous effects as CaseTypes



Normal Bright Shadow Rain Clouds

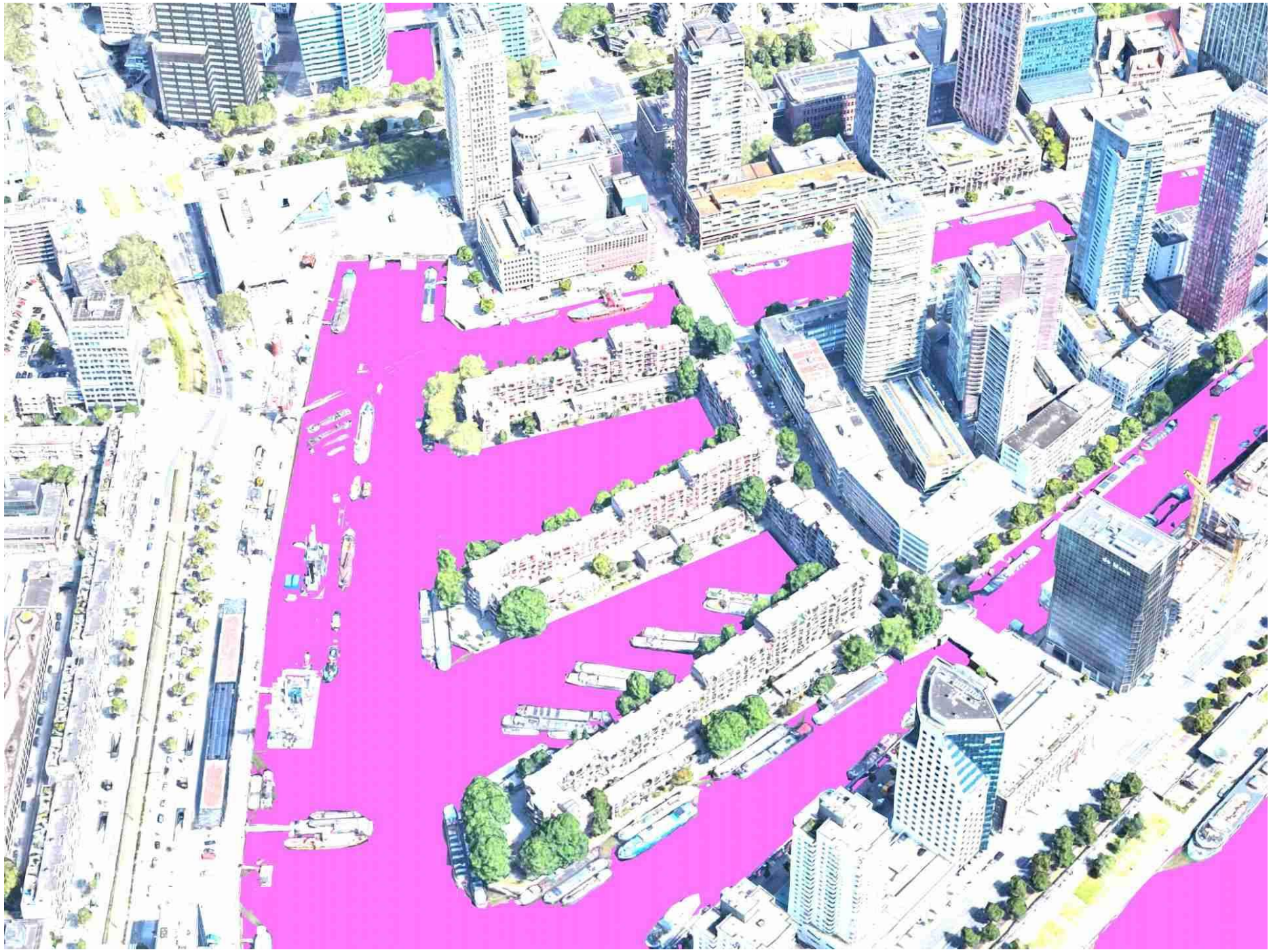
Two methods of detection

- SIFT (Classical image processing techniques)
- DISK (CNN-based Detector)

Oblique

Effect:

Normal



Oblique

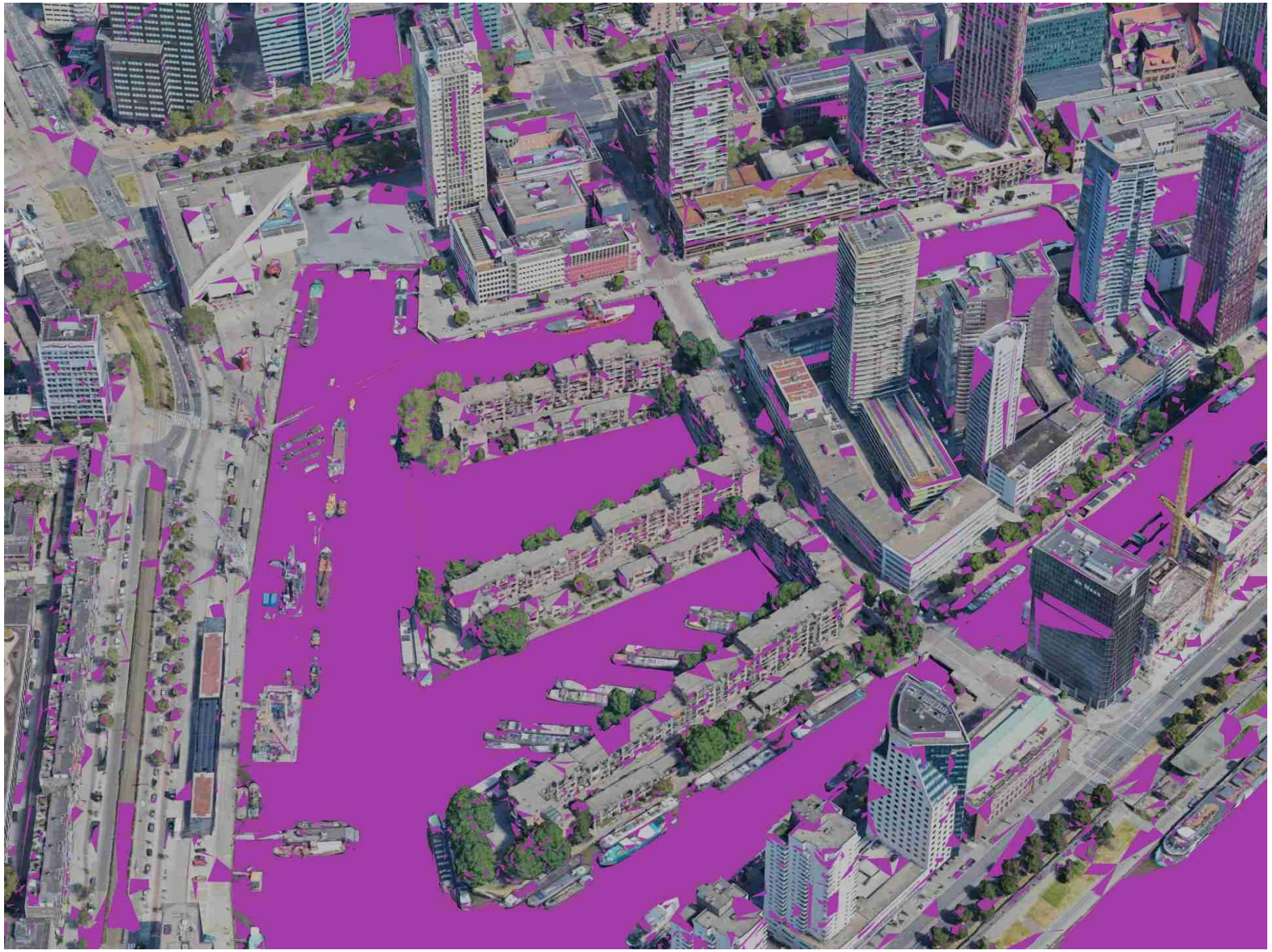
Effect:

Bright

Oblique

Effect:

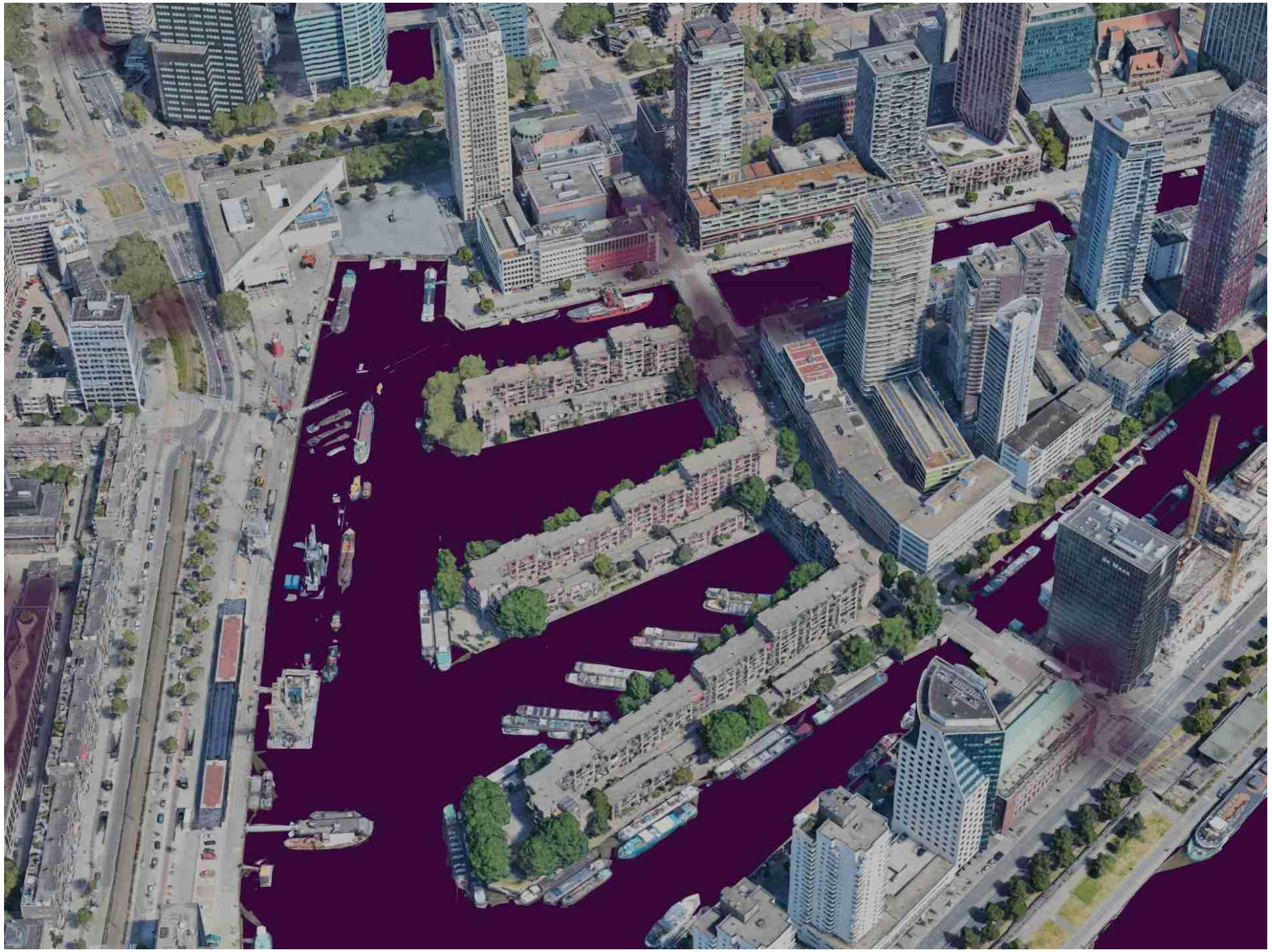
Shadow



Oblique

Effect:

Rain



Oblique

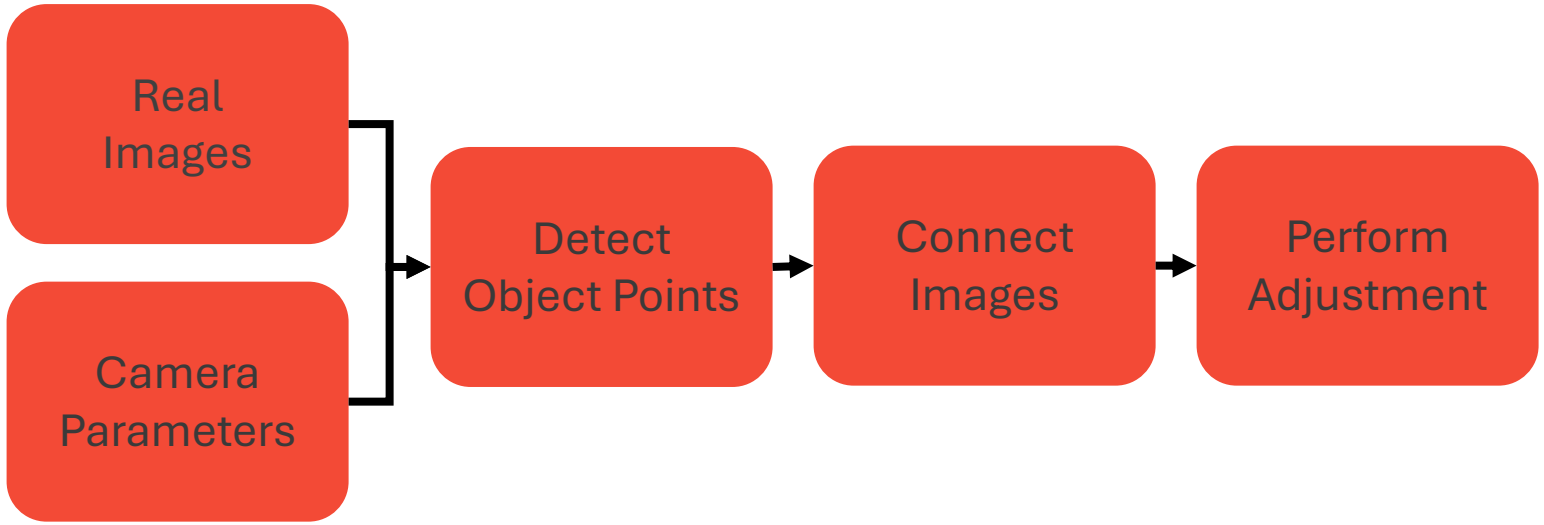
Effect:

Clouds

	Number of Images	Detection (S/F) Matching (S/F) Adjustment (S/F) Nadir	F-tests Results Nadir	Detection (S/F) Matching (S/F) Adjustment (S/F) Oblique	F-tests Results Oblique
DISK Normal	146 Nadir Or 552 Oblique Images	S/F/-	-	S/F/-	-
SIFT Normal		S/S/S	0.429	S/S/S	0.830
DISK Bright		S/F/-	-	S/F/-	-
SIFT Bright		S/S/S	0.432	S/S/S	0.835
DISK Shadow		S/F/-	-	S/F/-	-
SIFT Shadow		S/S/S	0.434	S/S/S	0.838
DISK Snow		S/F/-	-	S/F/-	-
SIFT Snow		S/S/S	0.435	S/S/S	0.839
DISK Clouds		S/F/-	-	S/F/-	-
SIFT Clouds		S/S/S	0.447	S/S/S	1.103

Image Quality

Phase III: Application to Real-World Data



Oblique

Real Images

	Numbers of Images	Detection (S/F) Matching (S/F) Adjustment (S/F) Nadir	F-test Results Nadir	Detection (S/F) Matching (S/F) Adjustment (S/F) Oblique	F-test Results Oblique
DISK Real Data	146 Nadir Images Or 552Oblique Images	S/S/S	0.450	S/S/S	0.659
SIFT Real Data		S/S/S	0.460	S/S/S	0.830

Conclusion

What parameters are key in the reconstruction accuracy of adjustment theory applied to RGB aerial images using synthetic test cases?

- Number of Points
- Image Rotation
- Intrinsic Parameters

Conclusions Synthetic Framework Steps

- Image Capture
- Object Point Detection and matching
- Adjustment

Contribution and Limitations

Single Variable

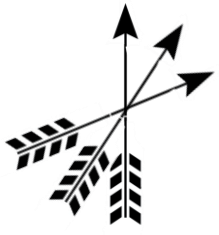
$N(\mu, \sigma)$

Single Standard Deviation

$N(0, \sigma)$

Mean of Zero

Restricted Focus Area



Bundle Extension

Other Frameworks

Showed Limitations of Detection

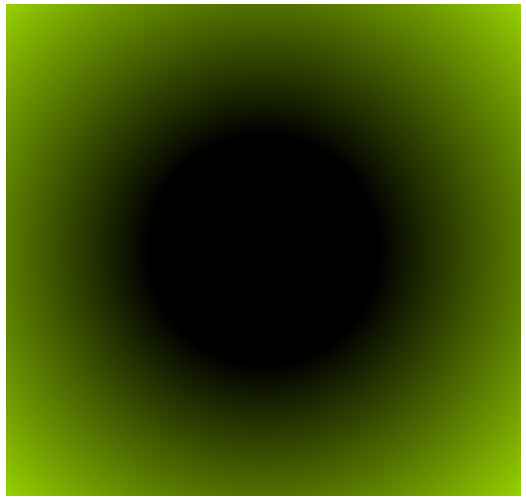
Future Work

- Gaussian splatting

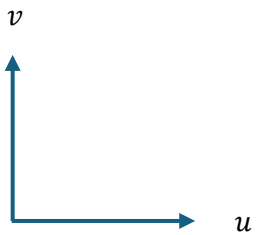
Future Work

- Gaussian splatting
- Distance based oblique weighting

Oblique Footprint

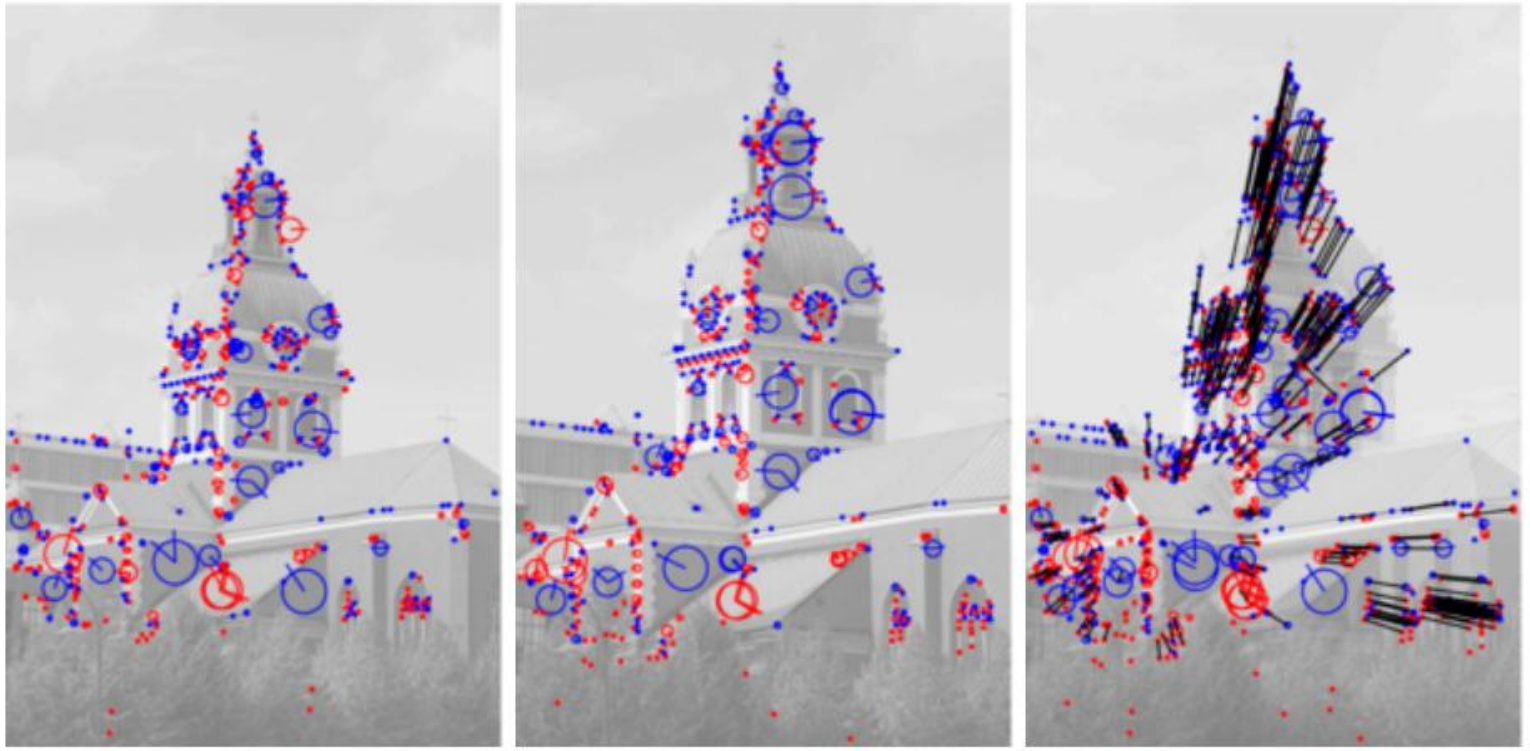


Nadir Footprint



Future Work

- Gaussian splatting
- Distance based oblique weighting
- Dutch ground truth data



GEODELTA

GDMC

Questions?

Ing. W.H.J. Kahn

P5 Presentation 26/06/2025

1st supervisor: Edward Verbree
2nd Supervisor: Martijn Meijers
C-Supervisor: Annemieke Verbraeck
Co-reader: Sandra Verhagen
Delegate: Hugo Ledoux