



GEO DELTA



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

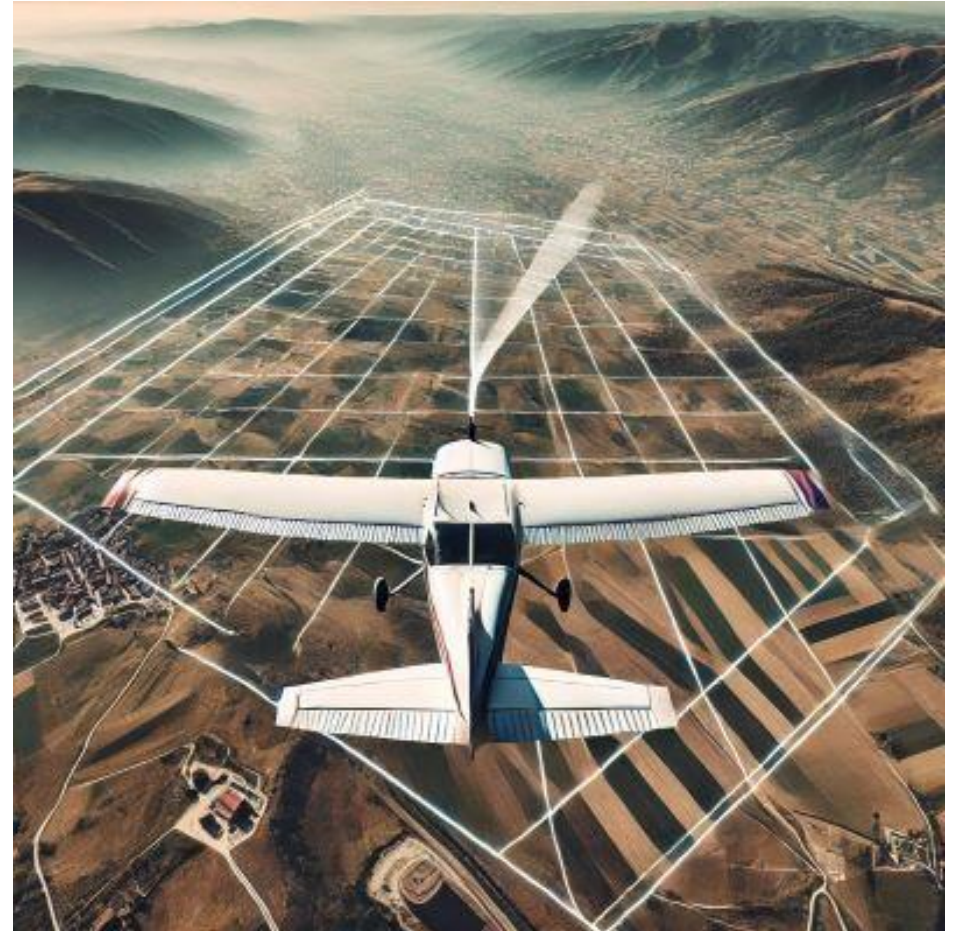
C-Supervisor: Annemieke Verbraeck

Co-reader: Sandra Verhagen

Delegate: Hugo Ledoux

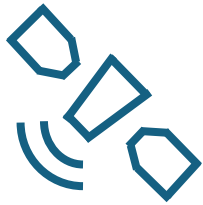
Aerial Photography

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



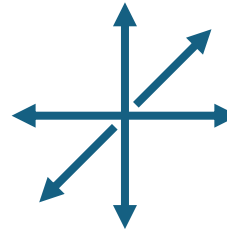
GNSS - IMU

Global Navigation Satellite System

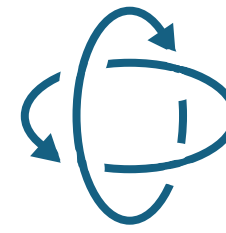


Ephemeris Data

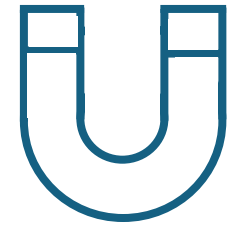
Inertial Motion Unit



3-axis acceleration



3-axis Rotation



3-axis Magnetism

Combination gives:

- Position
- Velocity
- Attitude

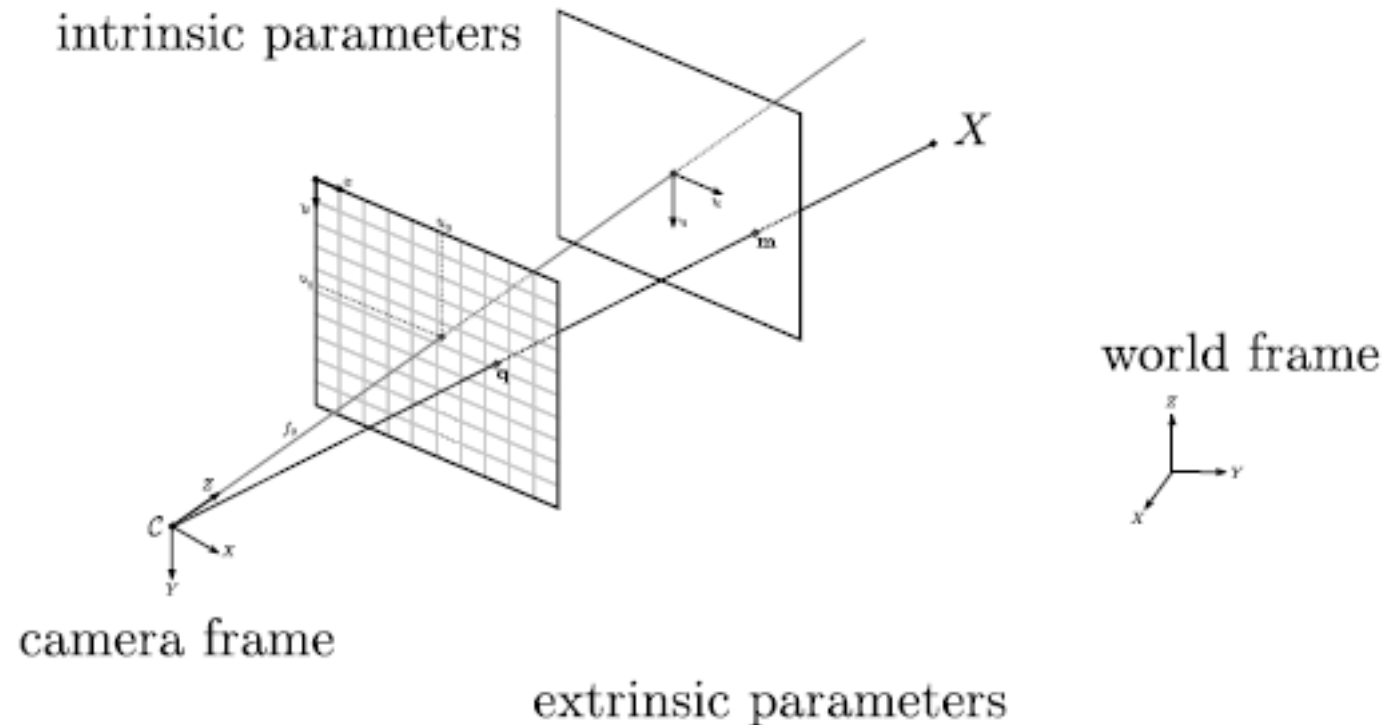
Camera Model

Intrinsic Parameters

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

Extrinsic Parameters

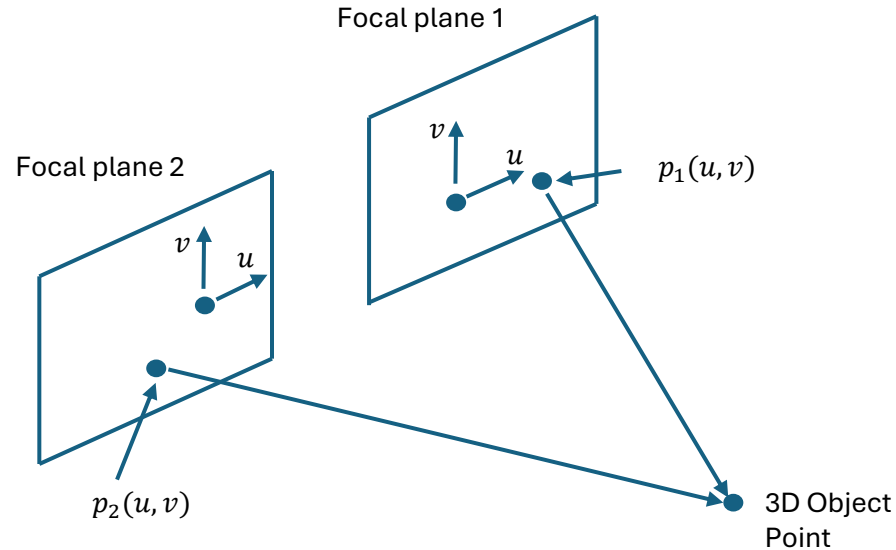
- C_{XYZ}
- $R_{\omega\phi\kappa}$



Object and Control Points

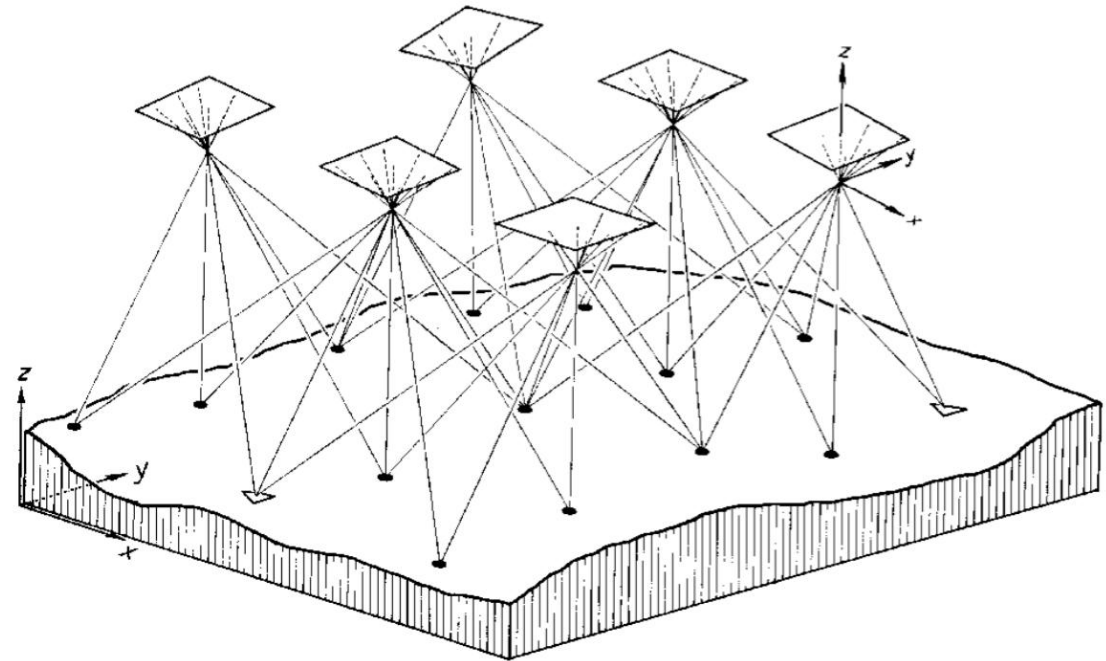
Object Points

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



Control Points

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



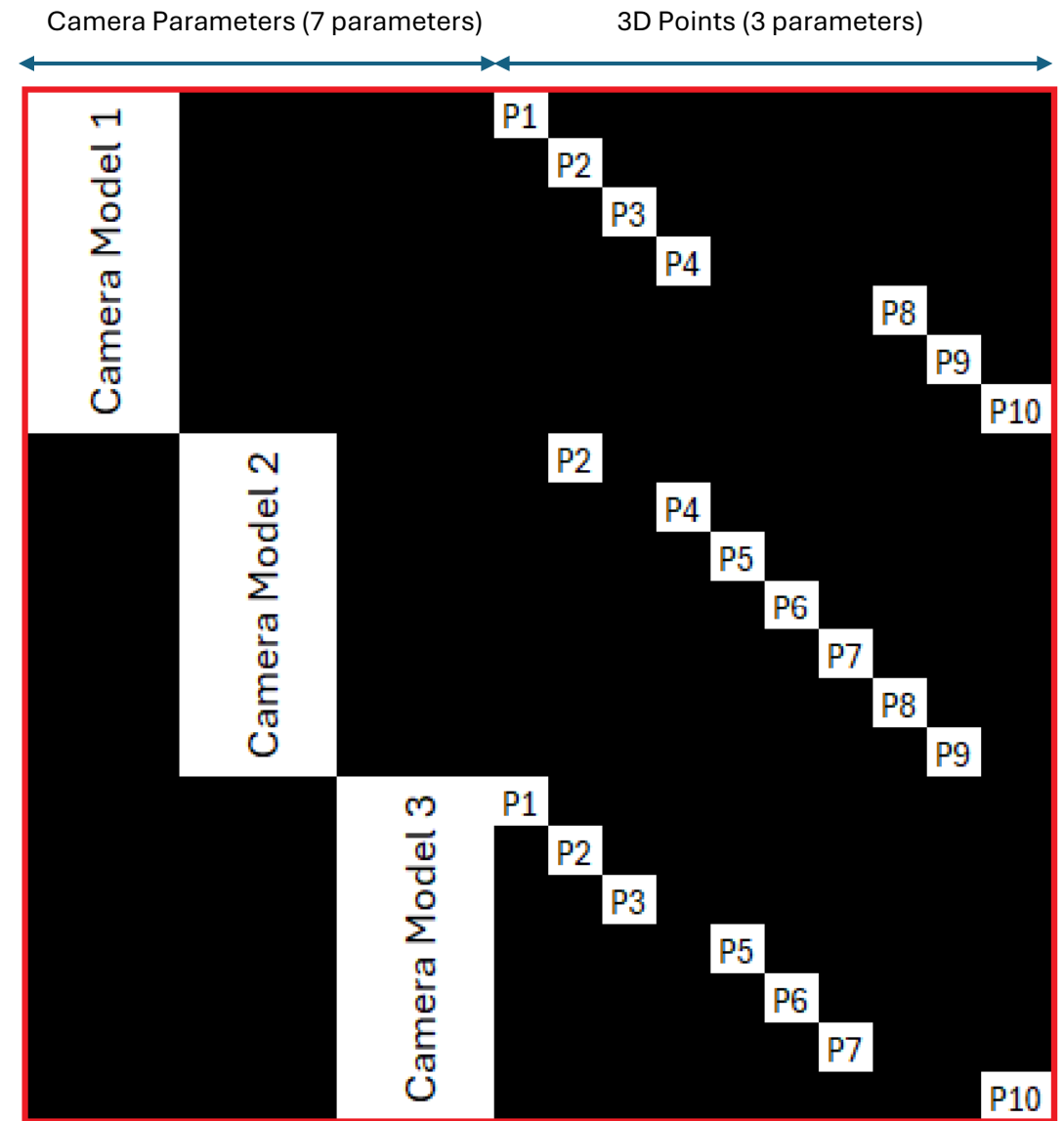
Adjustment Theory

- Iteratively reduce noise

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

- Free network (1st phase)
- Constrained network (2nd phase)
- F-test (General Model Test)

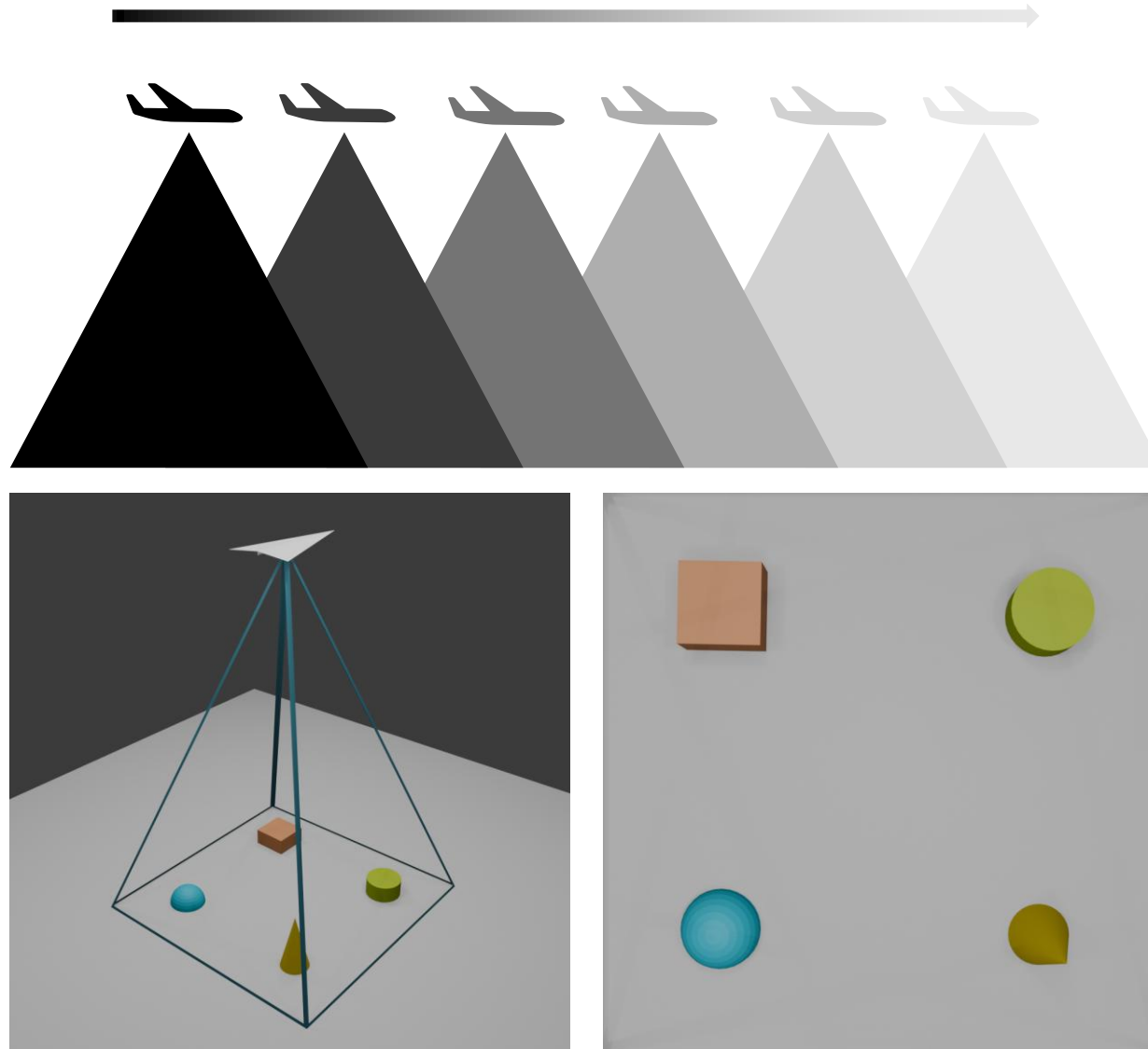
$J =$



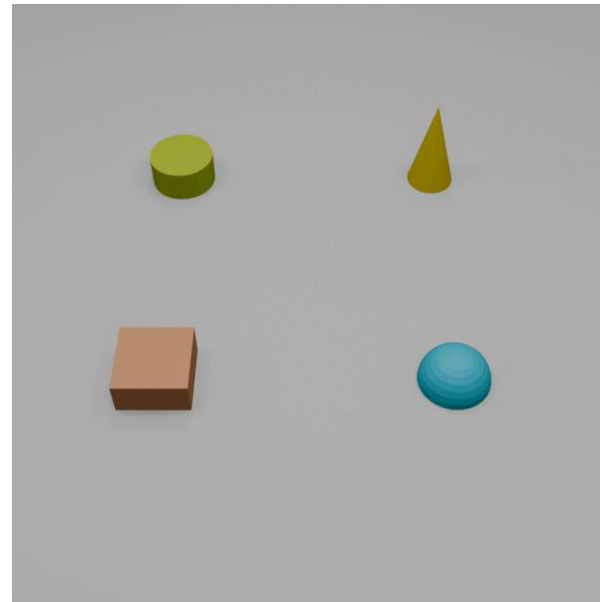
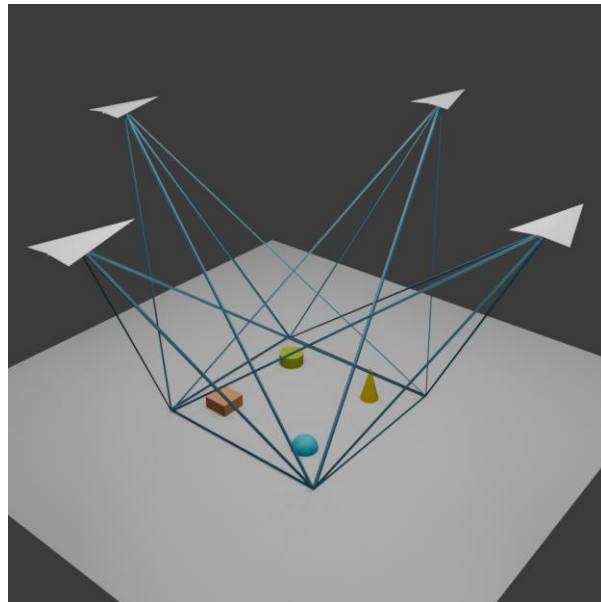
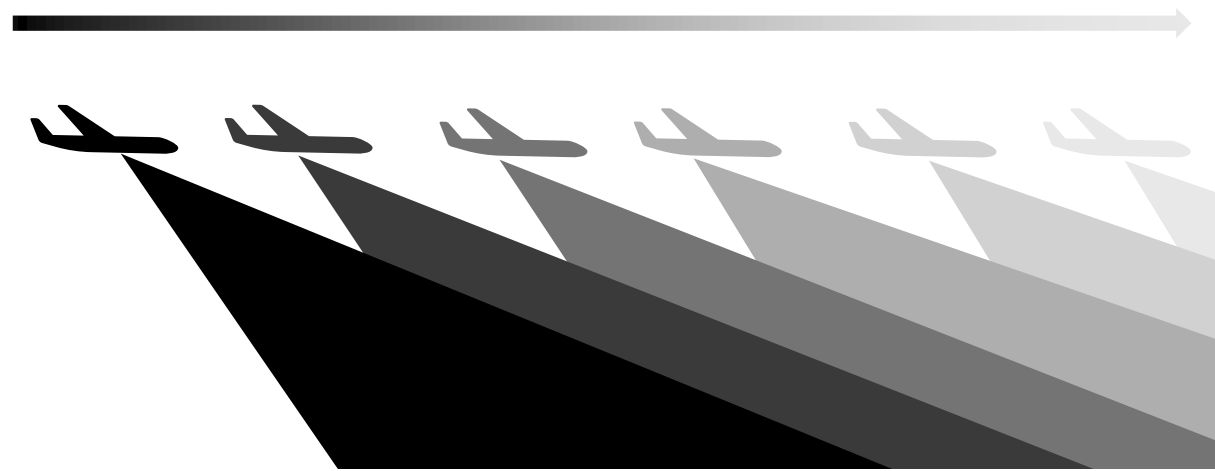
Aerial Collection Pipeline

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

Nadir Imagery



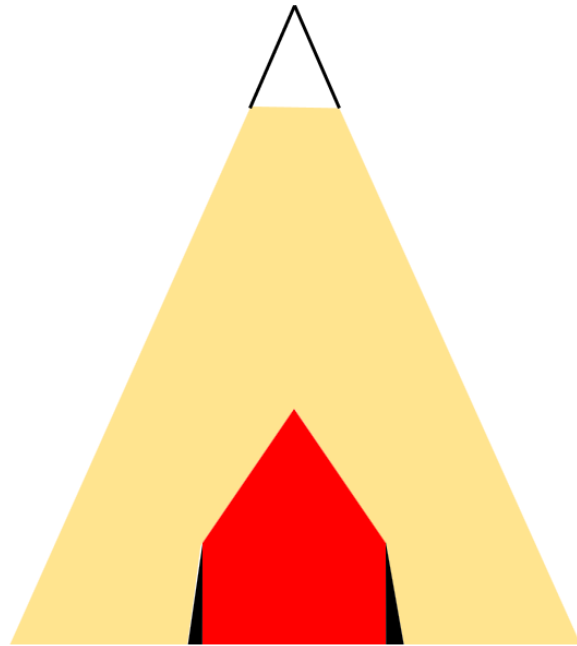
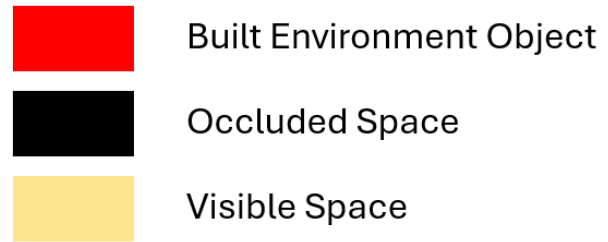
Oblique Imagery



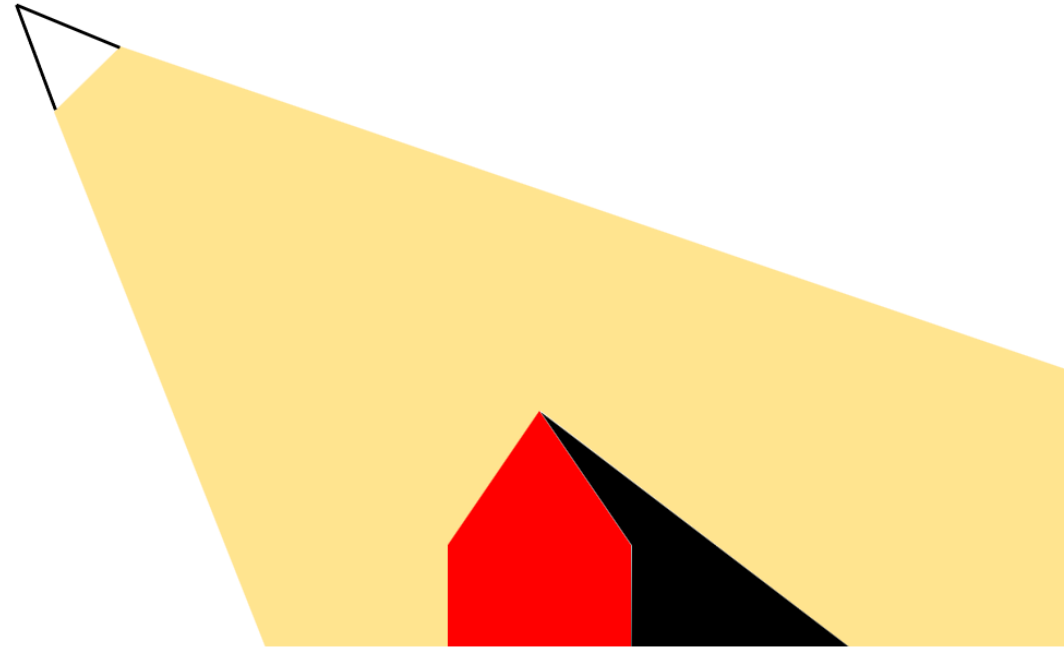
Goal: Oblique Framework

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

Occlusion

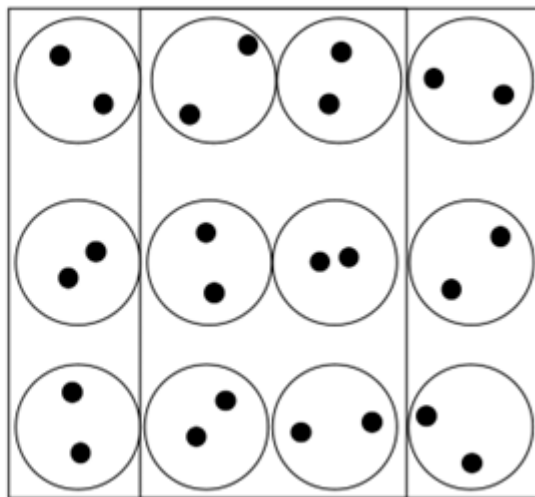
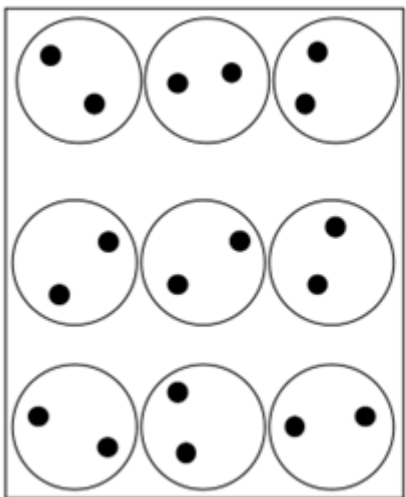


Nadir Occlusion



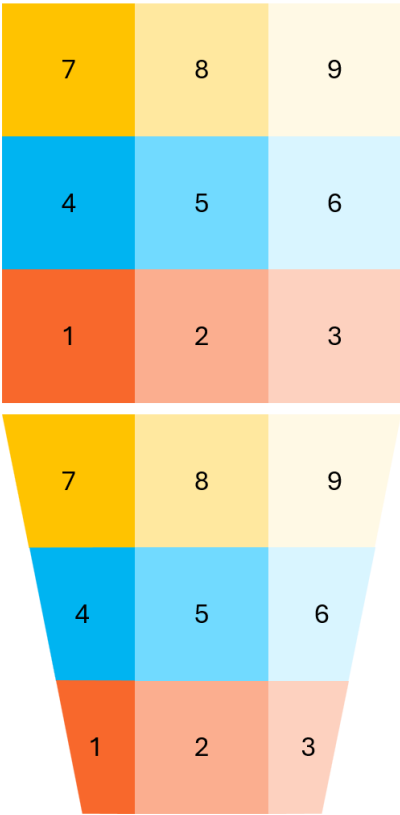
Oblique Occlusion

Point Distribution Von Gruber squares



Nadir Footprint

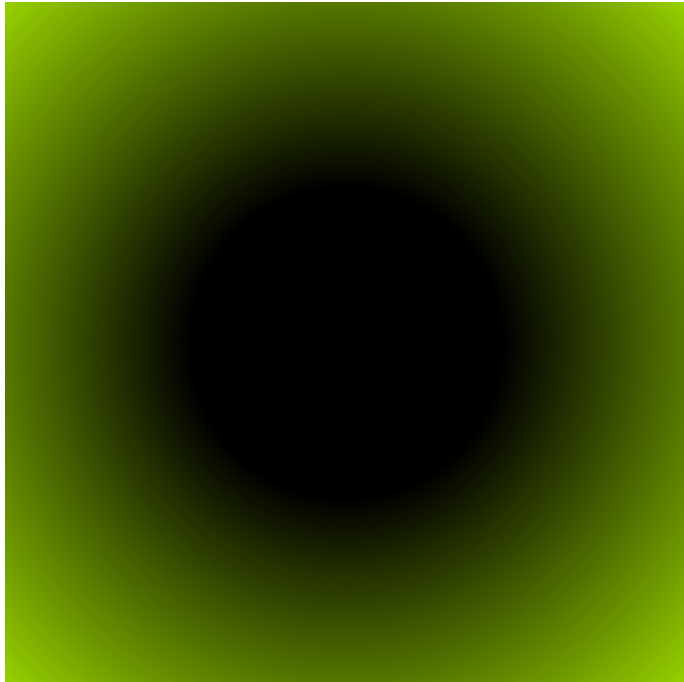
Oblique Footprint



Nadir Von Gruber Squares

Oblique Von Gruber Squares

Ground Sampling Size



Nadir Footprint

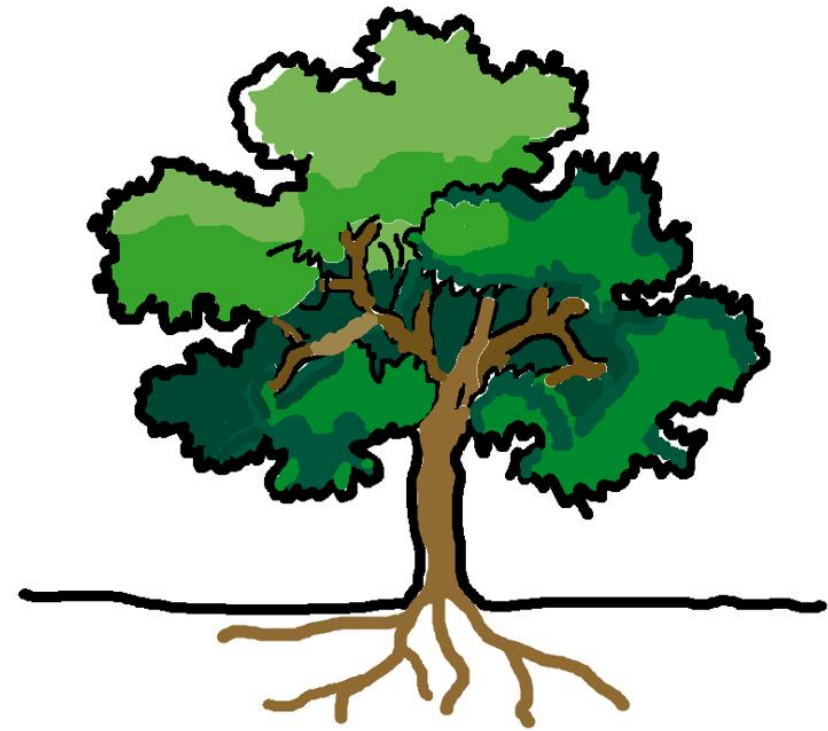


Oblique Footprint



Pixel size

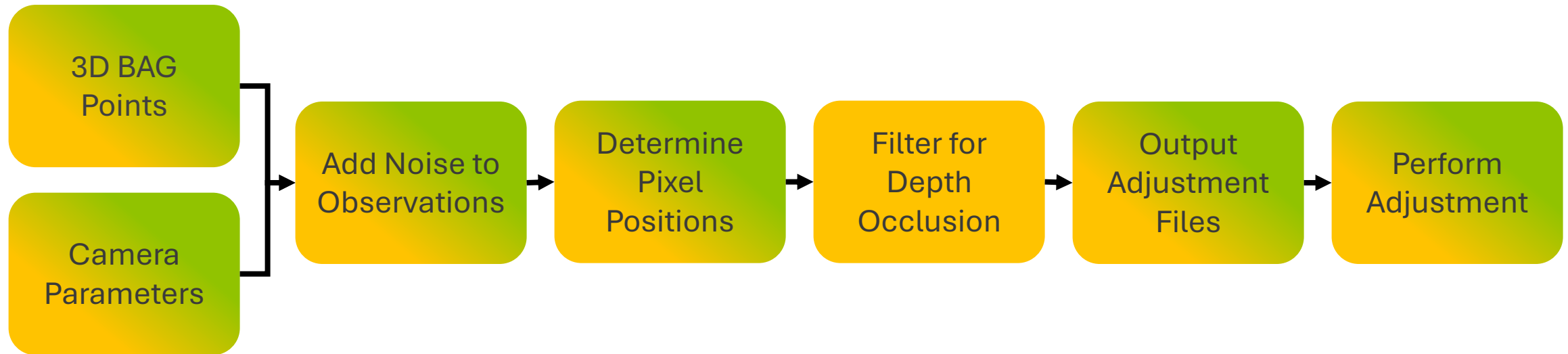
Synthetic Data



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

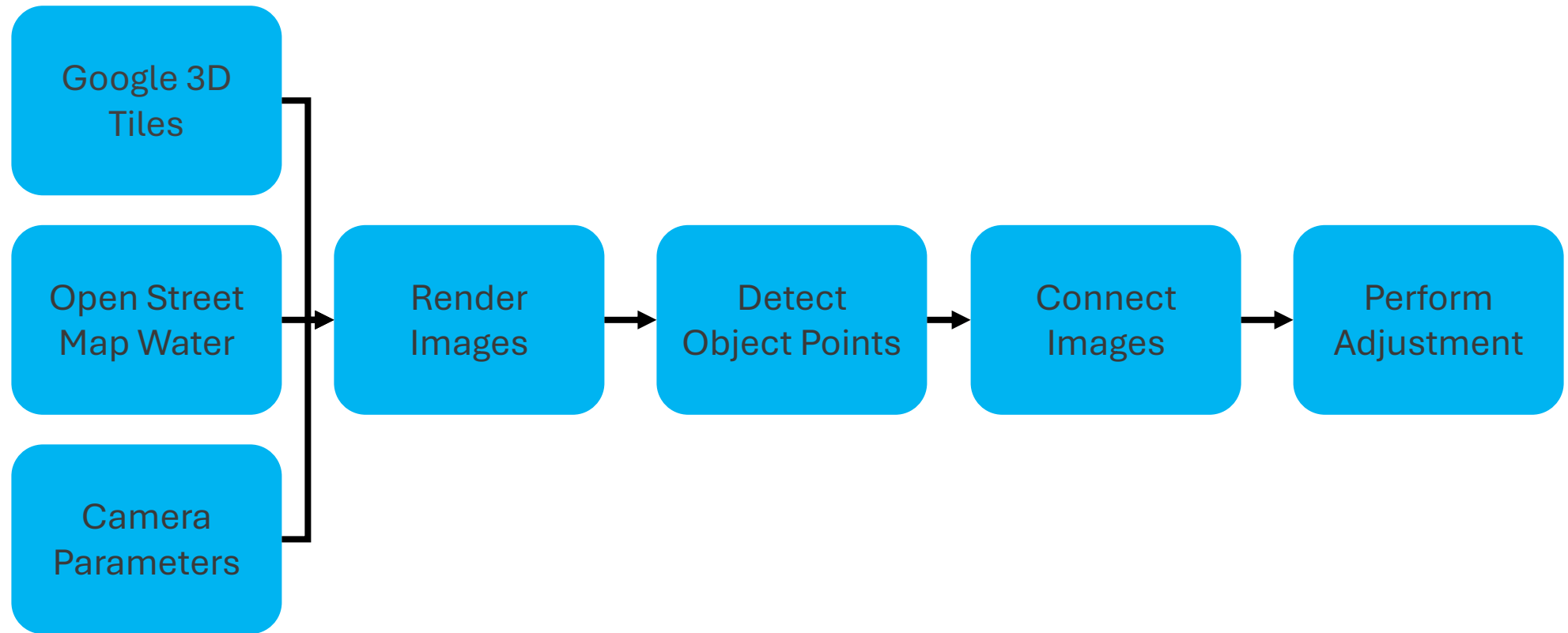
Total number of points
needed to doubled

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 1 st Phase Nadir	Avg. F-test 2 nd Phase Nadir	Avg. F-test 1 st Phase Oblique	Avg. F-test 2 nd 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 1 st Phase Nadir	Avg. F-test 2 nd Phase Nadir	Avg. F-test 1 st Phase Oblique	Avg. F-test 2 nd 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

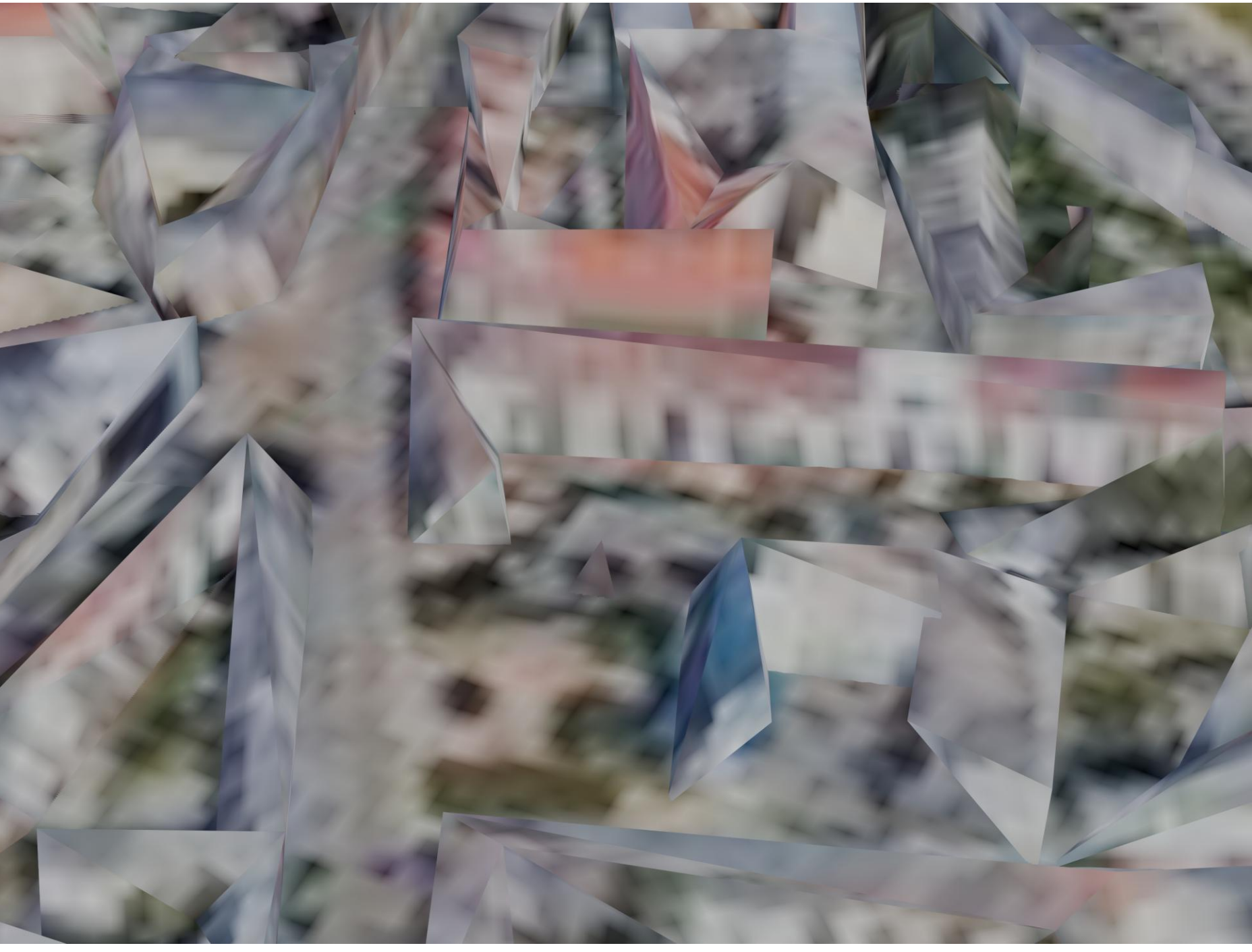
Quality level:

Whole City

Resolution 4800 x 6400

Focal Distance 112 mm

Principle Point Average 0 mm



Oblique

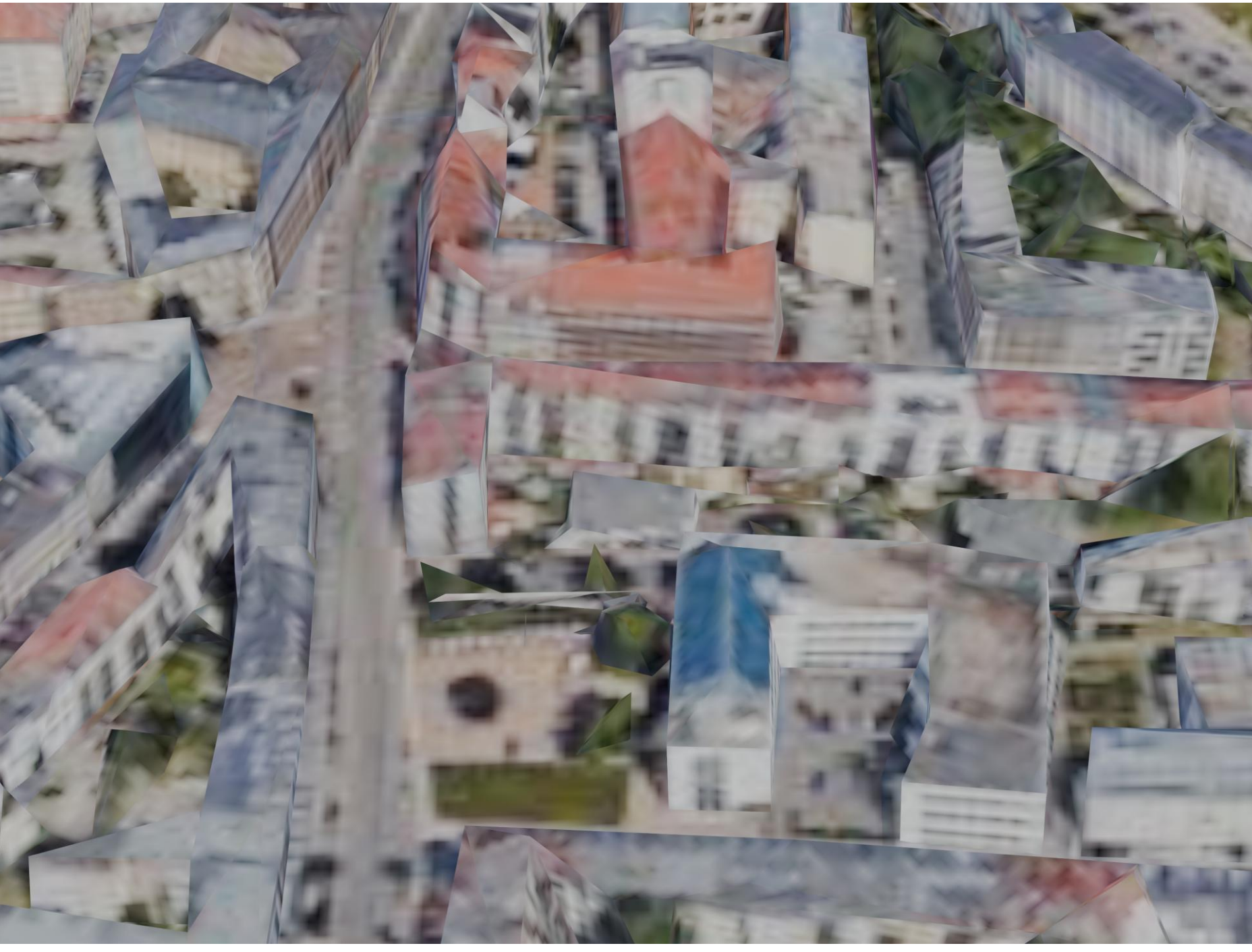
Quality level:

Districts

Resolution 4800 x 6400

Focal Distance 112 mm

Principle Point Average 0 mm

An aerial photograph of a city street grid with numerous 3D building models overlaid. The models are semi-transparent, showing the underlying street layout and other buildings. The models vary in height and color, with some having red roofs and others grey or blue. The perspective is from an oblique angle, looking down at the city.

Oblique

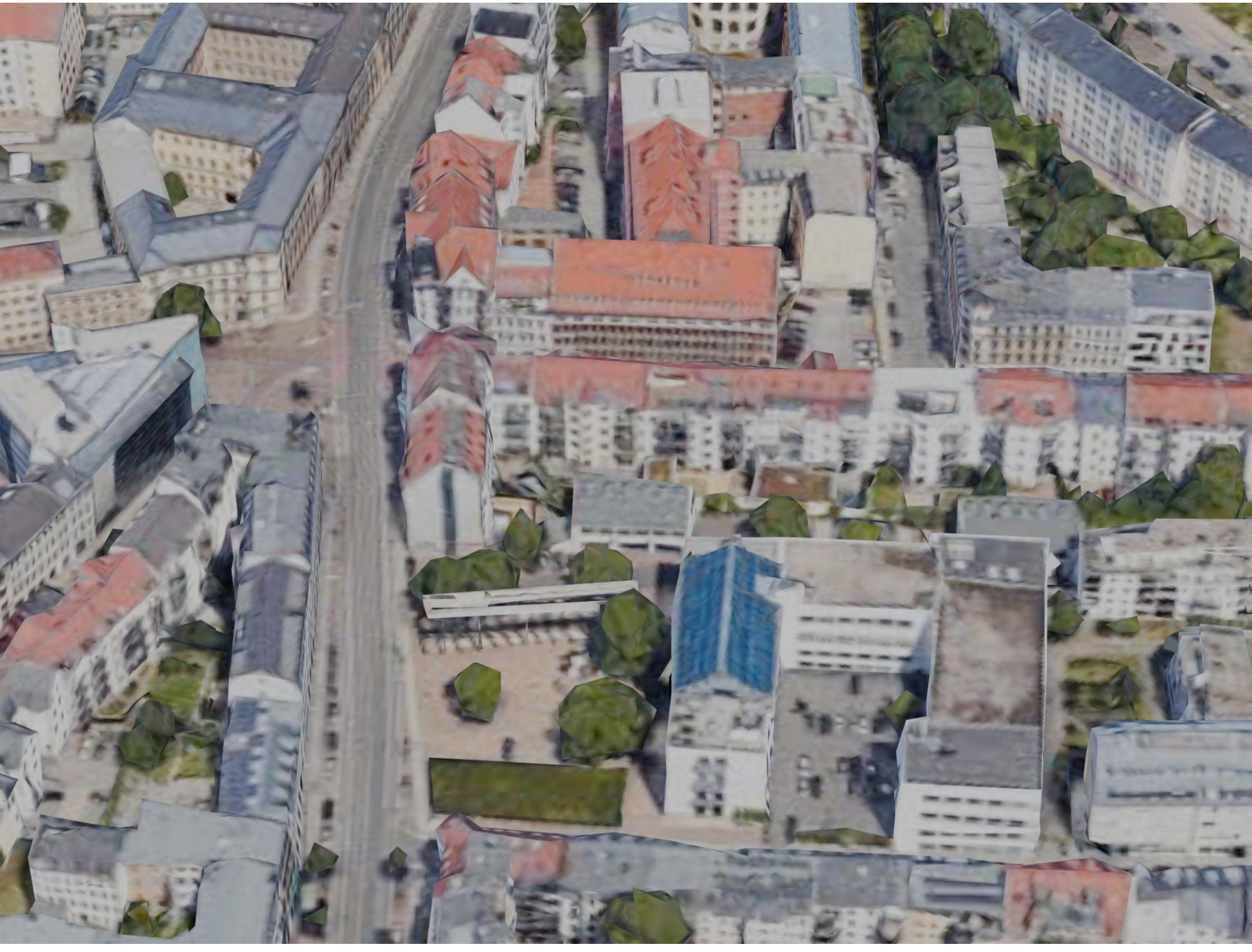
Quality level:

Groups of Buildings

Resolution 4800 x 6400

Focal Distance 112 mm

Principle Point Average 0 mm

An aerial oblique photograph of a city street scene. The image shows a dense urban environment with various buildings, including residential houses with red and grey roofs, and larger commercial or institutional buildings. A wide road runs vertically through the center of the image. The 3D models of the buildings are semi-transparent, allowing the underlying aerial photograph to be visible through them. The models are colored in shades of grey, blue, and red, matching the colors of the buildings in the photograph. The perspective is from an elevated angle, looking down at the city.

Oblique

Quality level:

Separate Buildings

Resolution 4800 x 6400

Focal Distance 112 mm

Principle Point Average 0 mm

An oblique aerial photograph of a city street. The street runs vertically through the center of the image. On either side of the street are multi-story buildings with various roof colors, including red, grey, and blue. There are green trees interspersed among the buildings. The perspective is from an elevated angle, looking down at the street and buildings.

Oblique

Quality level:

Buildings with Details

Resolution 4800 x 6400

Focal Distance 112 mm

Principle Point Average 0 mm

An oblique aerial photograph of a city street. The street runs vertically through the center of the image. On the left side of the street, there are several large, multi-story buildings with red-tiled roofs. On the right side, there are more buildings, some with grey roofs and others with red roofs. There are also some trees and green spaces interspersed among the buildings. The overall scene is a dense urban environment.

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

An aerial oblique view of the Rotterdam city center, specifically the Stadsdriehoek area. The image shows a dense urban landscape with numerous buildings of varying heights and styles. The water bodies, including the Nieuwe Maas river and the harbor, are highlighted with a solid pink color, indicating the use of OSM-water 3D Tiles. The perspective is from an elevated angle, looking down at the city.

Oblique

Quality level:

Buildings with more detail

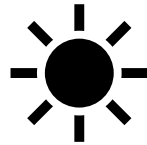
Rotterdam Stadsdriehoek

With OSM-water 3D Tiles
Retrieved through BLOSM

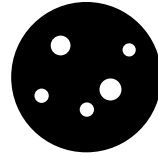
Exogenous effects as CaseTypes



Normal



Bright



Shadow



Rain



Clouds

Two methods of detection

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

Oblique

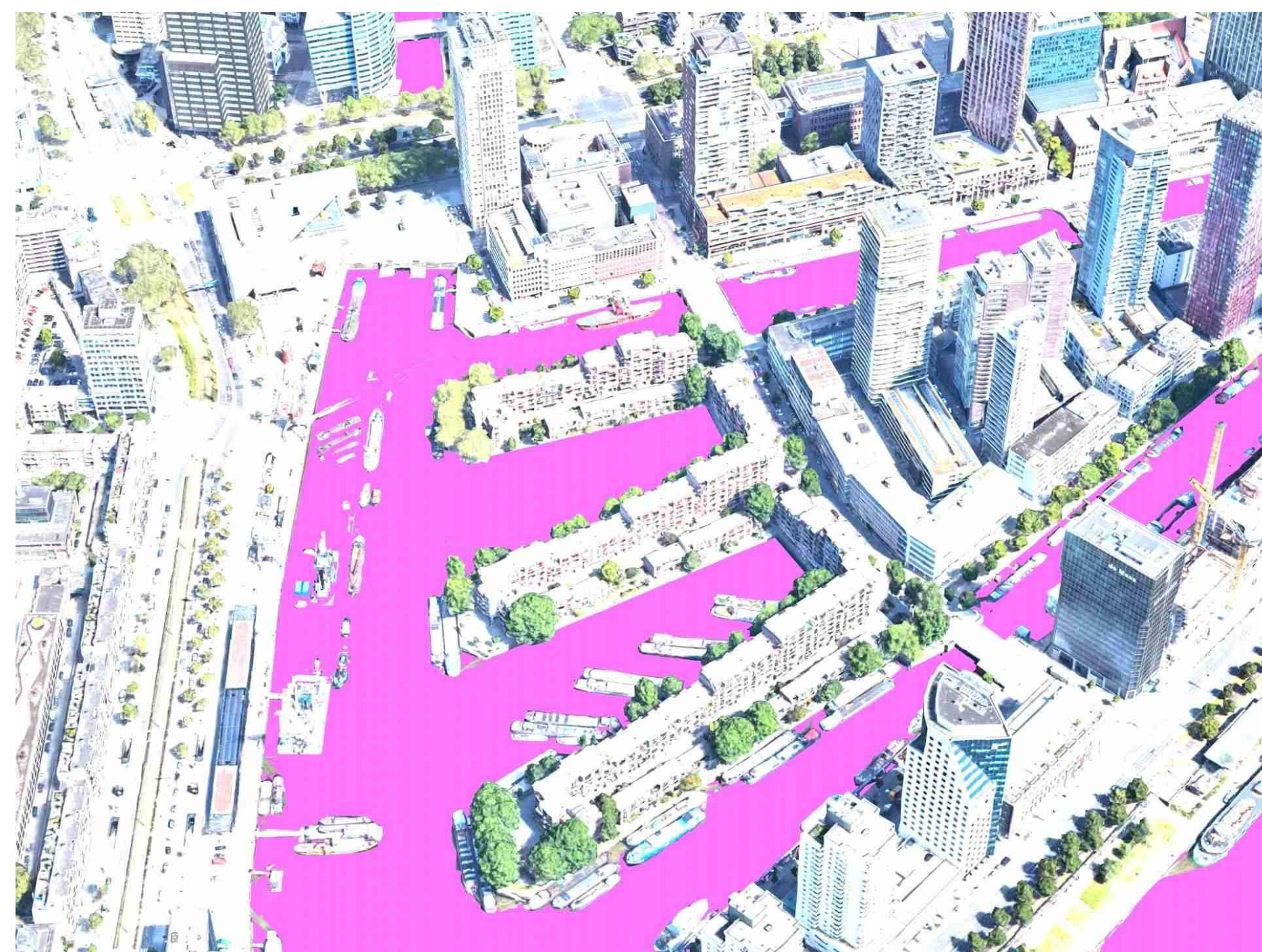
Effect:

Normal

Oblique

Effect:

Bright



Oblique

Effect:

Shadow

Oblique

Effect:

Rain

Oblique

Effect:

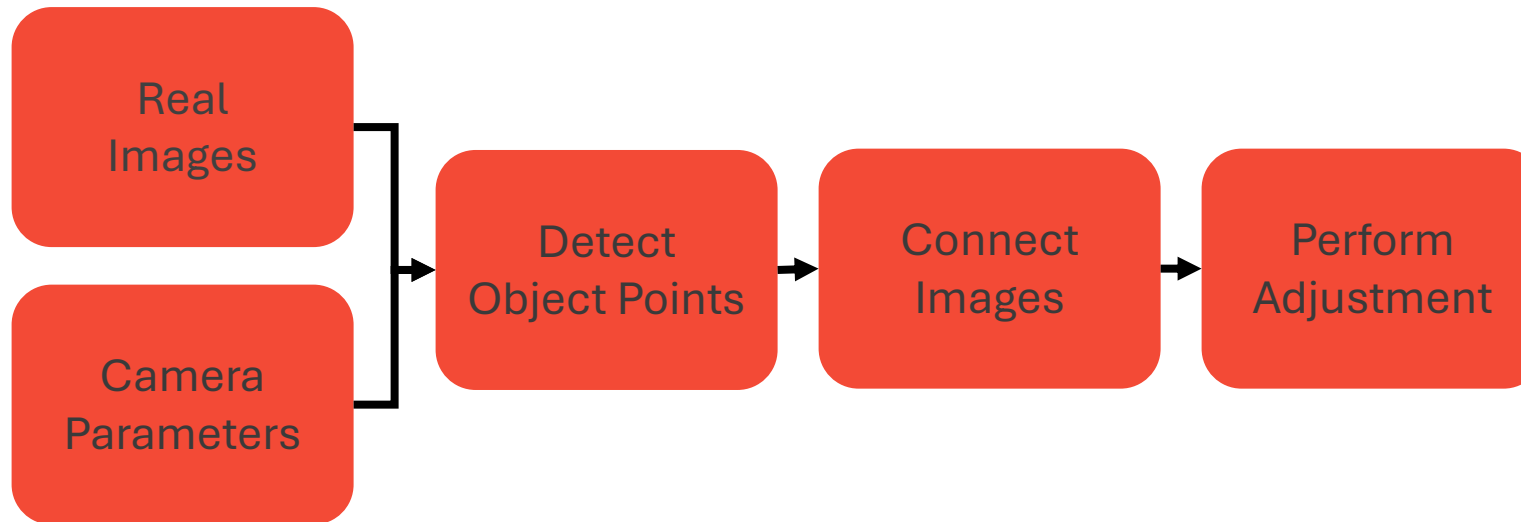
Clouds

	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 552 Oblique 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

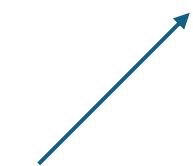
What parameters are key in the reconstruction accuracy of adjustment theory applied to RGB aerial images using synthetic test cases?

- Number of Points
- Image Rotation
- Intrinsic Parameters

Conclusions Synthetic Framework Steps

- Image Capture
- Object Point Detection and matching
- Adjustment

Contribution and Limitations



Single
Variable

$$N(\mu, \sigma)$$

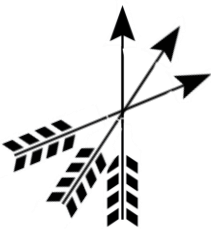
Single
Standard
Deviation

$$N(0, \sigma)$$

Mean of
Zero



Restricted
Focus
Area



Bundle
Extension



Other
Frameworks

Showed
Limitations
of Detection

Future Work

- Gaussian splatting

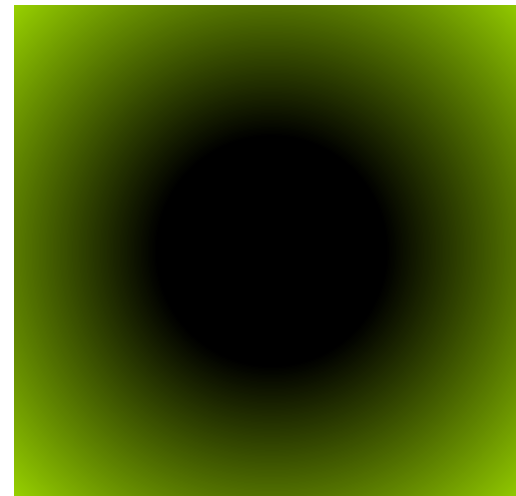


Future Work

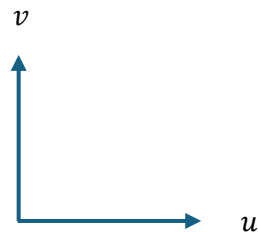
- Gaussian splatting
- Distance based oblique weighting



Oblique Footprint

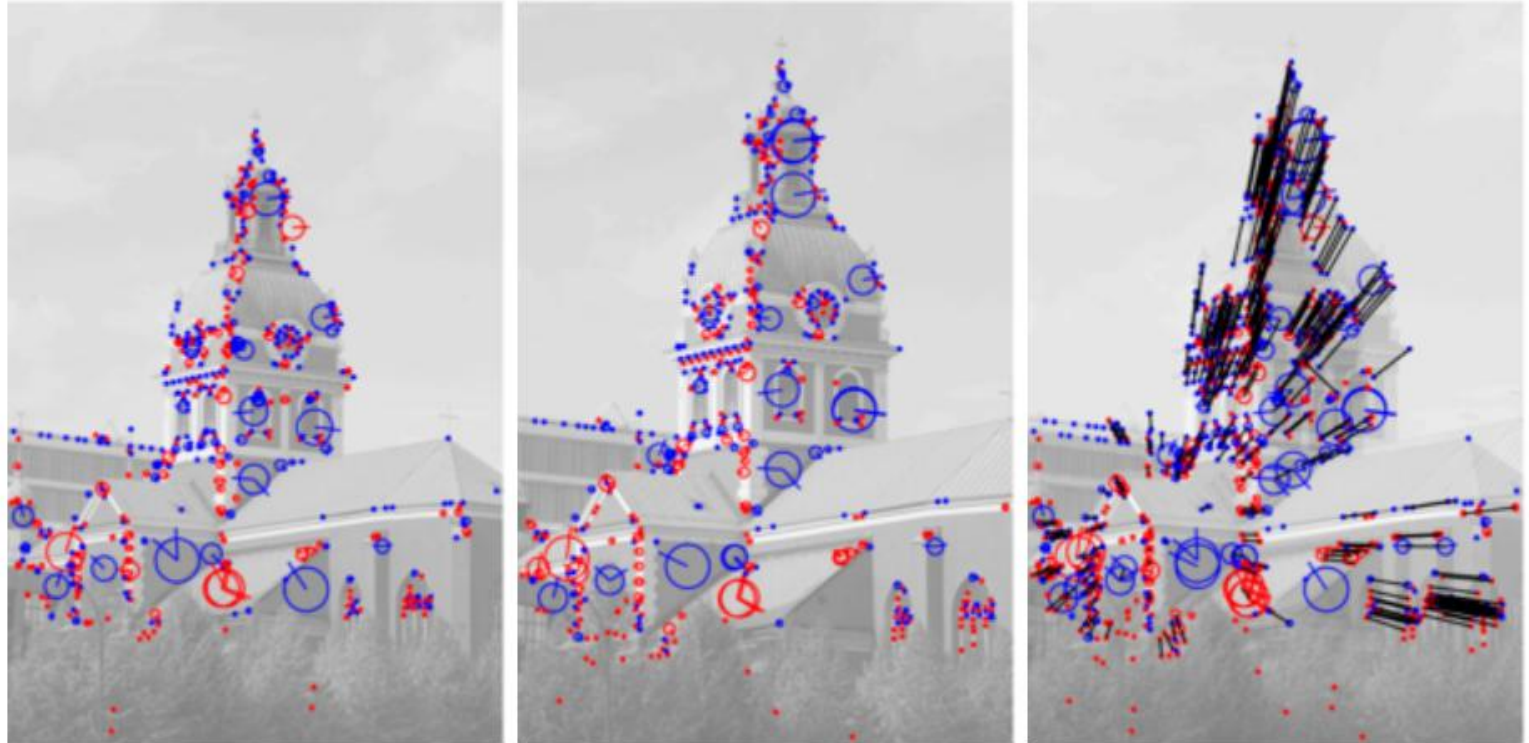


Nadir Footprint



Future Work

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





GEO DELTA



Questions?

Ing. W.H.J. Kahn

P5 Presentation 26/06/2025

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