



Technische
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Visual localization in urban environments employing 3D city models

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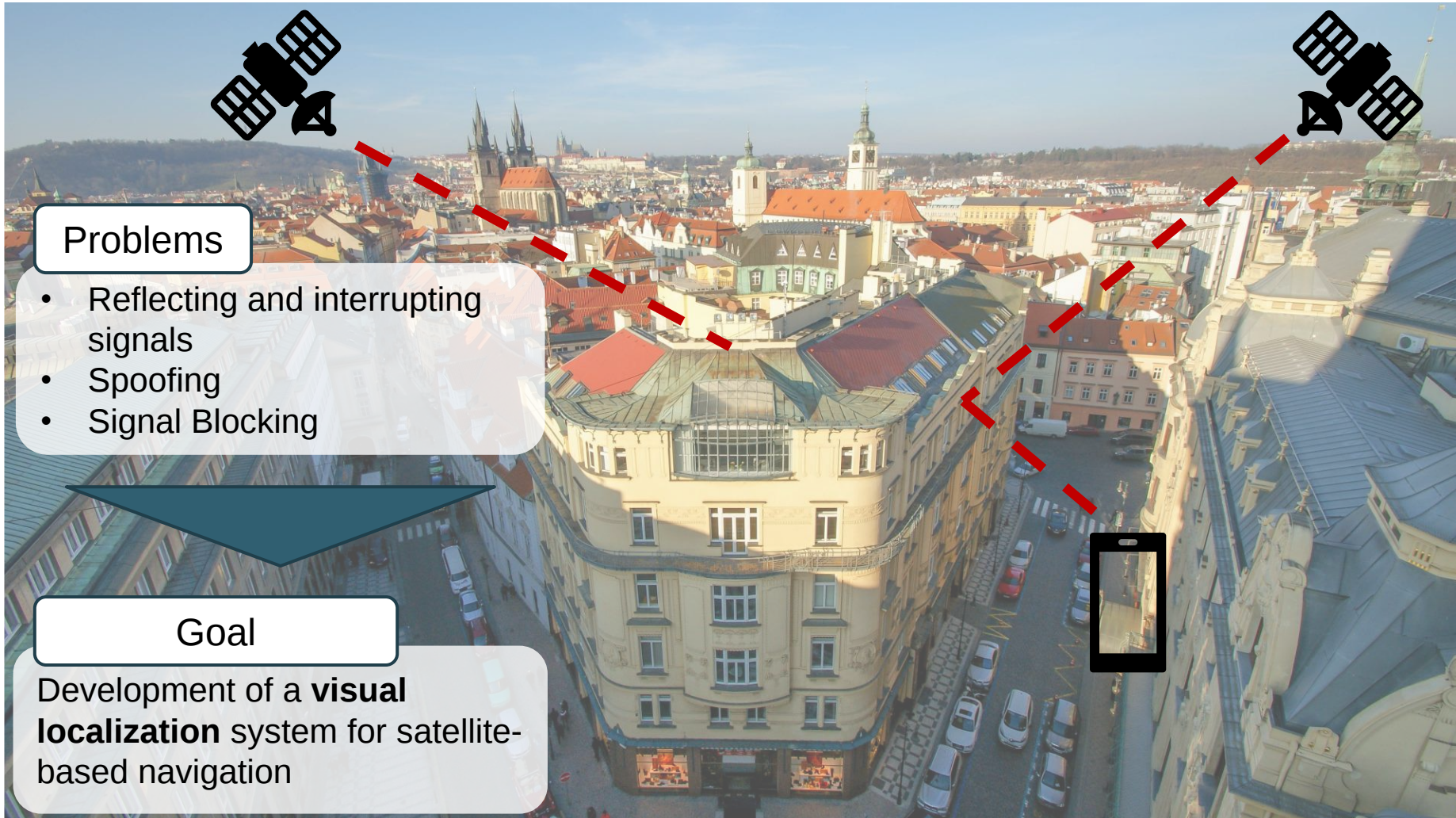
Low-Cost 3D Workshop 2024. Brescia, Italy

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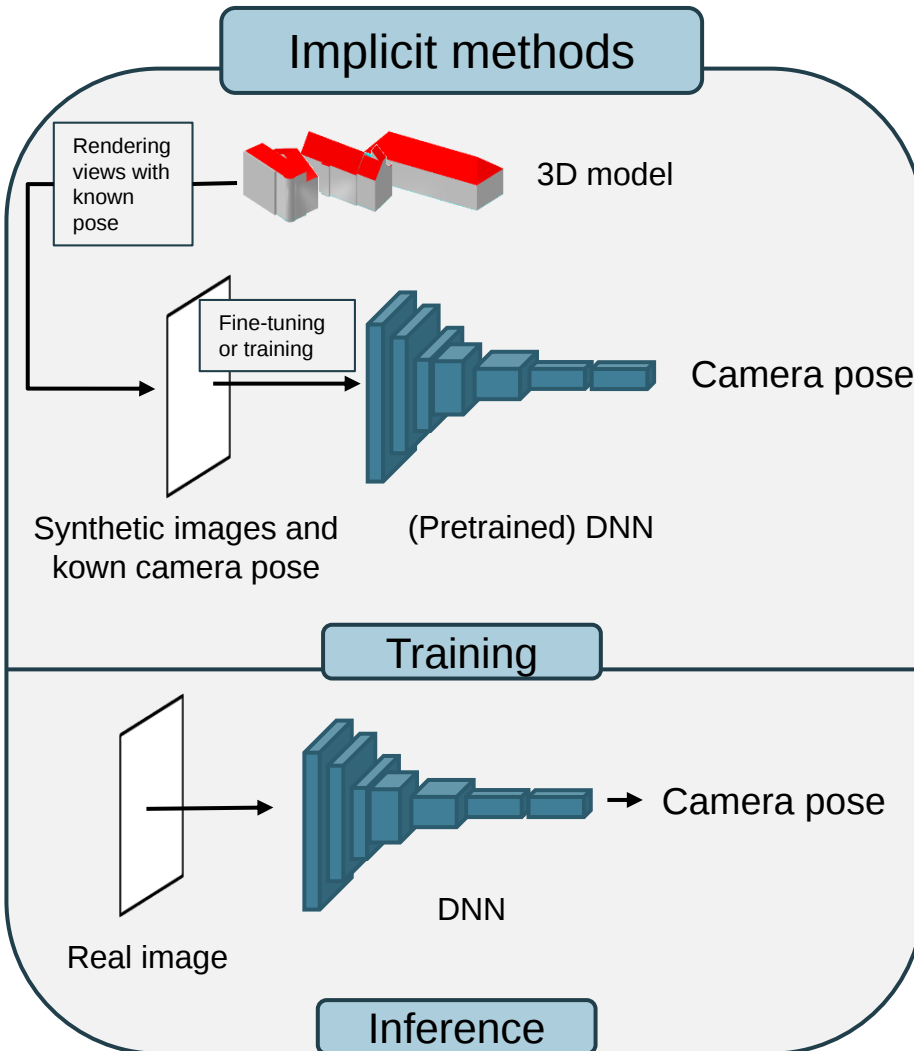
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Unit Assistive and Autonomous Systems,
Center for Vision, Automation and Control

Motivation

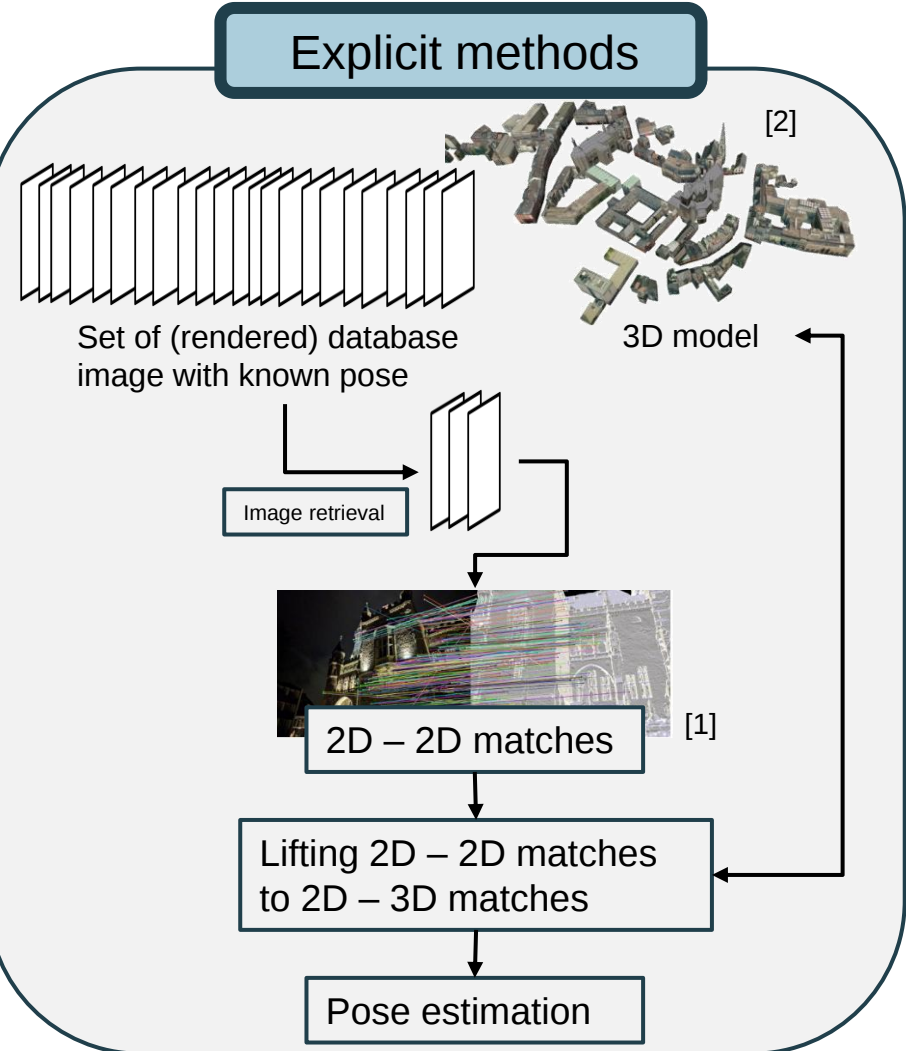


Related Work

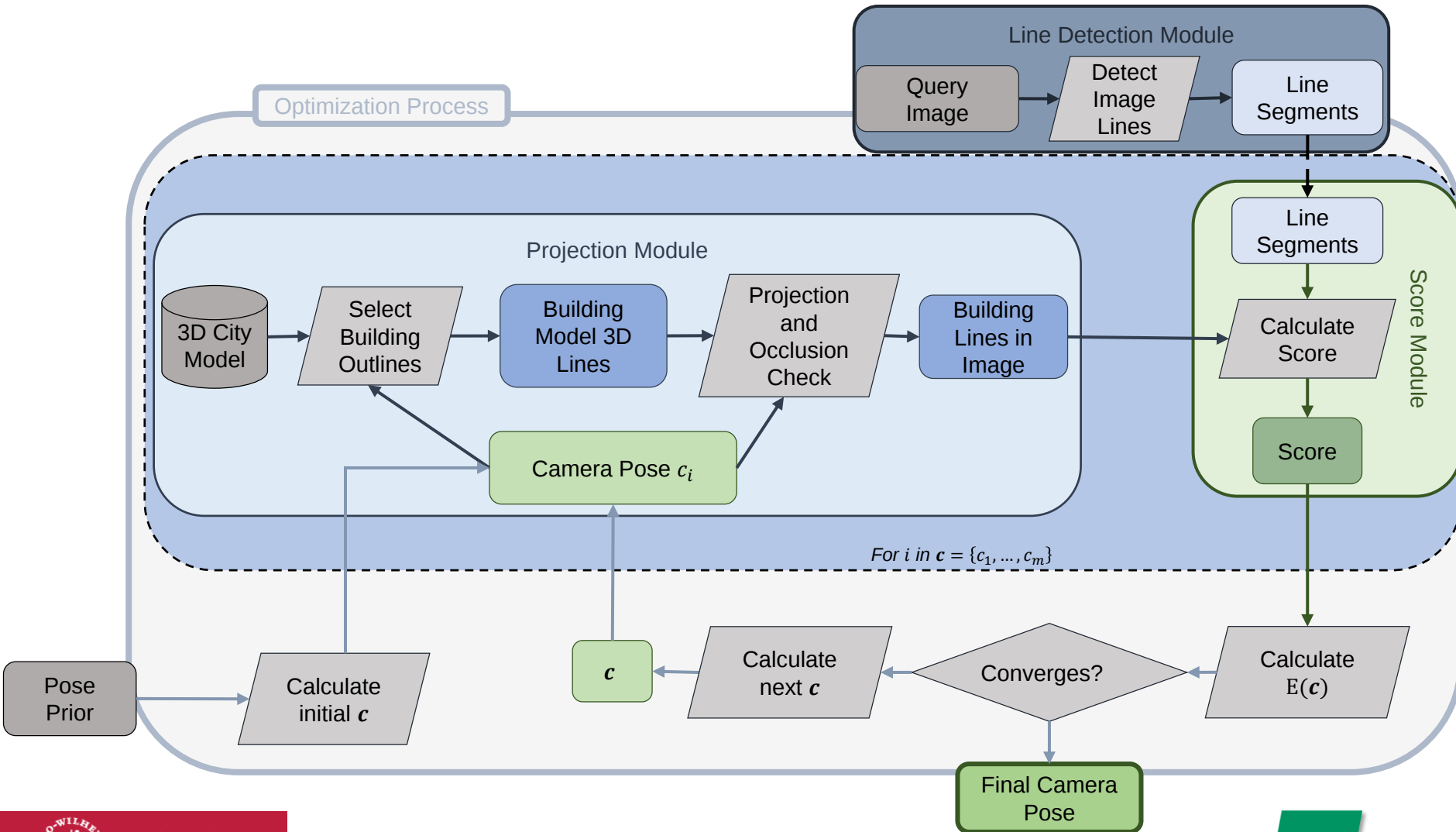
Implicit methods



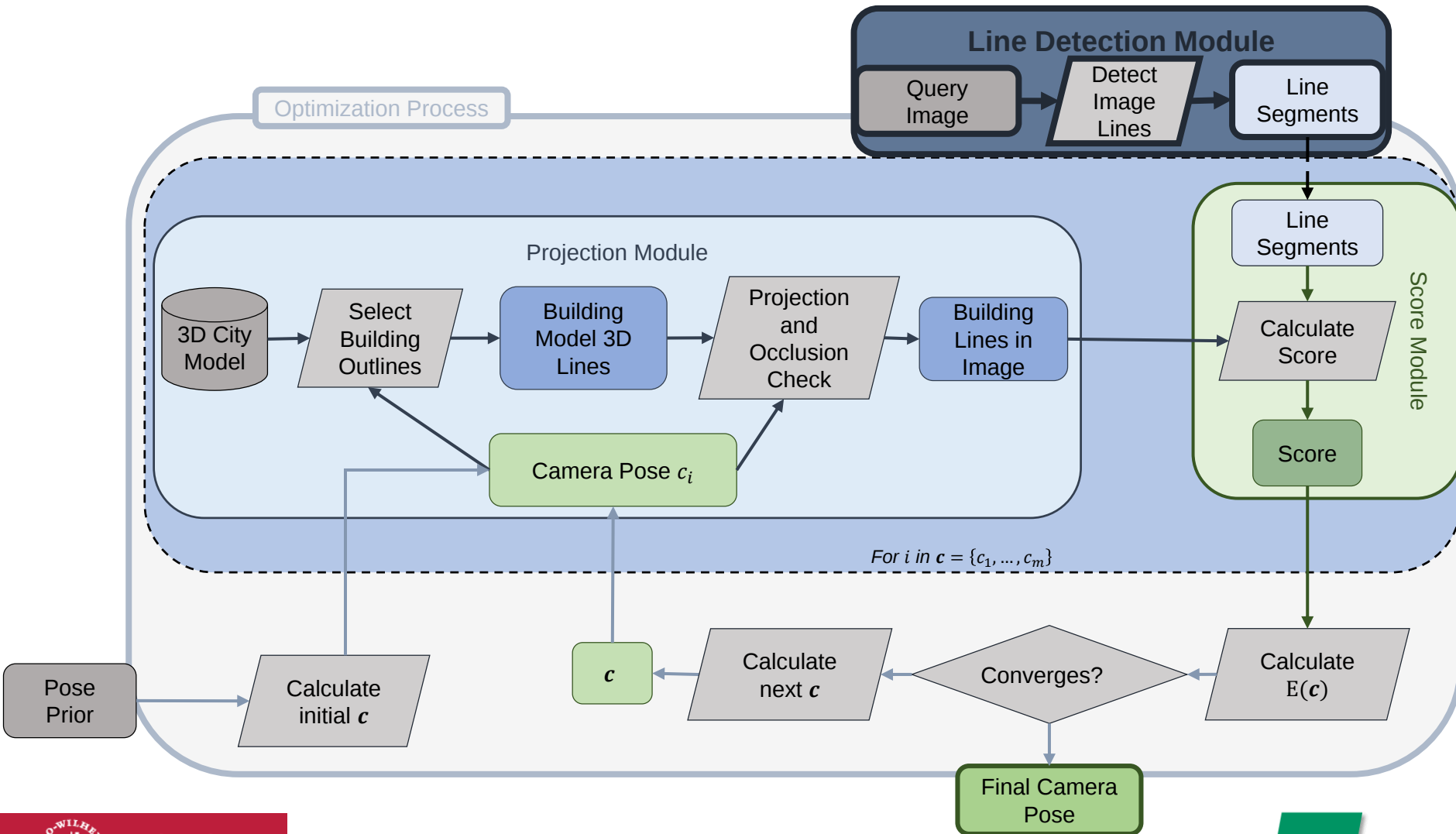
Explicit methods



Object-based Visual Localization Workflow



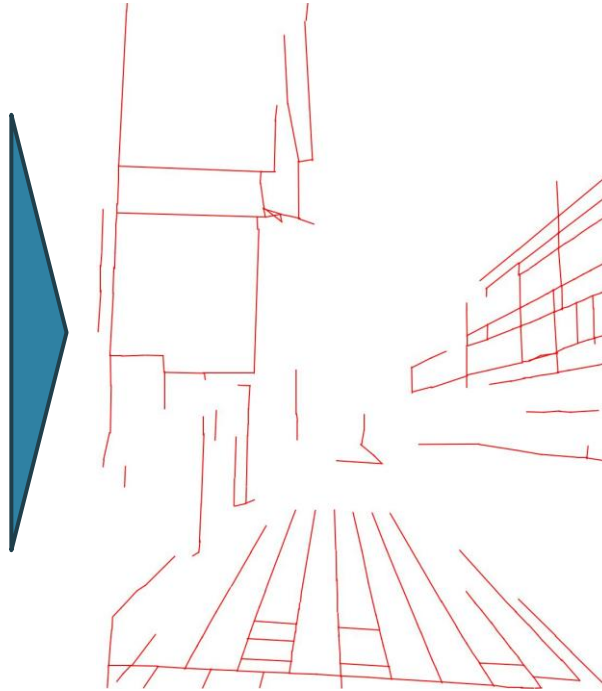
Object-based Visual Localization Workflow



Line Detection Module



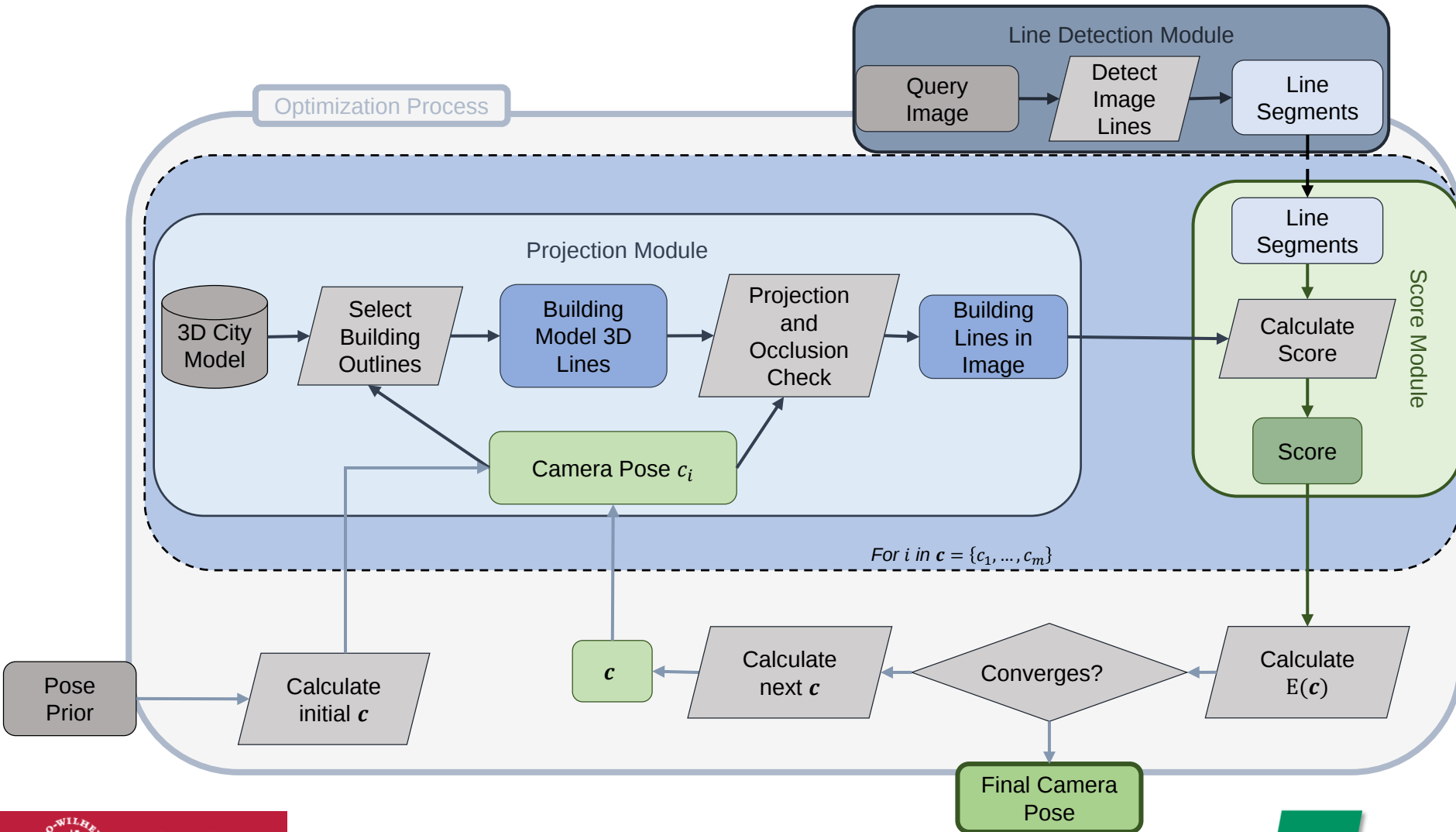
Query image



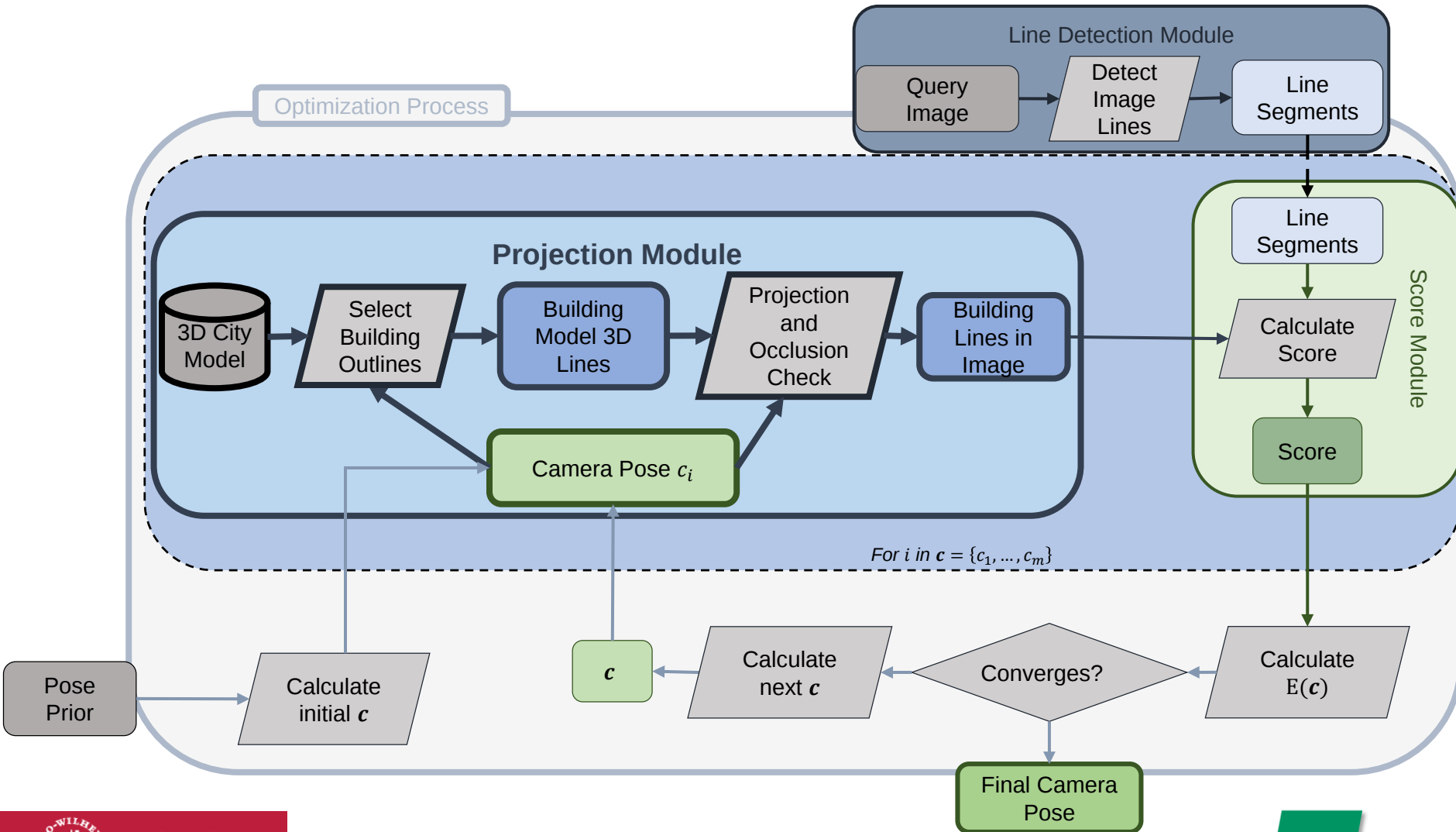
Detected lines in query image

- ▶ Pettrained SOLD2 [3] model
- ▶ Resulting in line segments defined by start- and endpoint

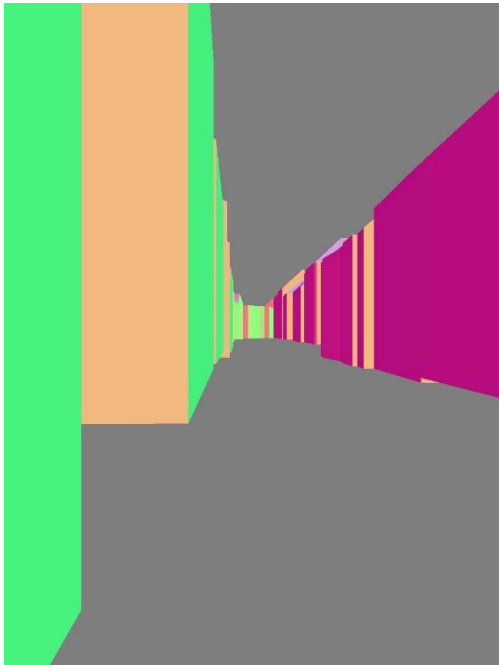
Object-based Visual Localization Workflow



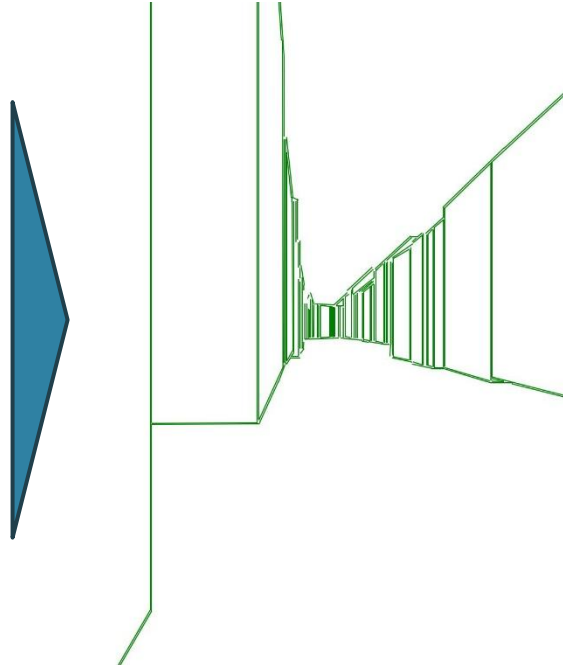
Object-based Visual Localization Workflow



Projection Module



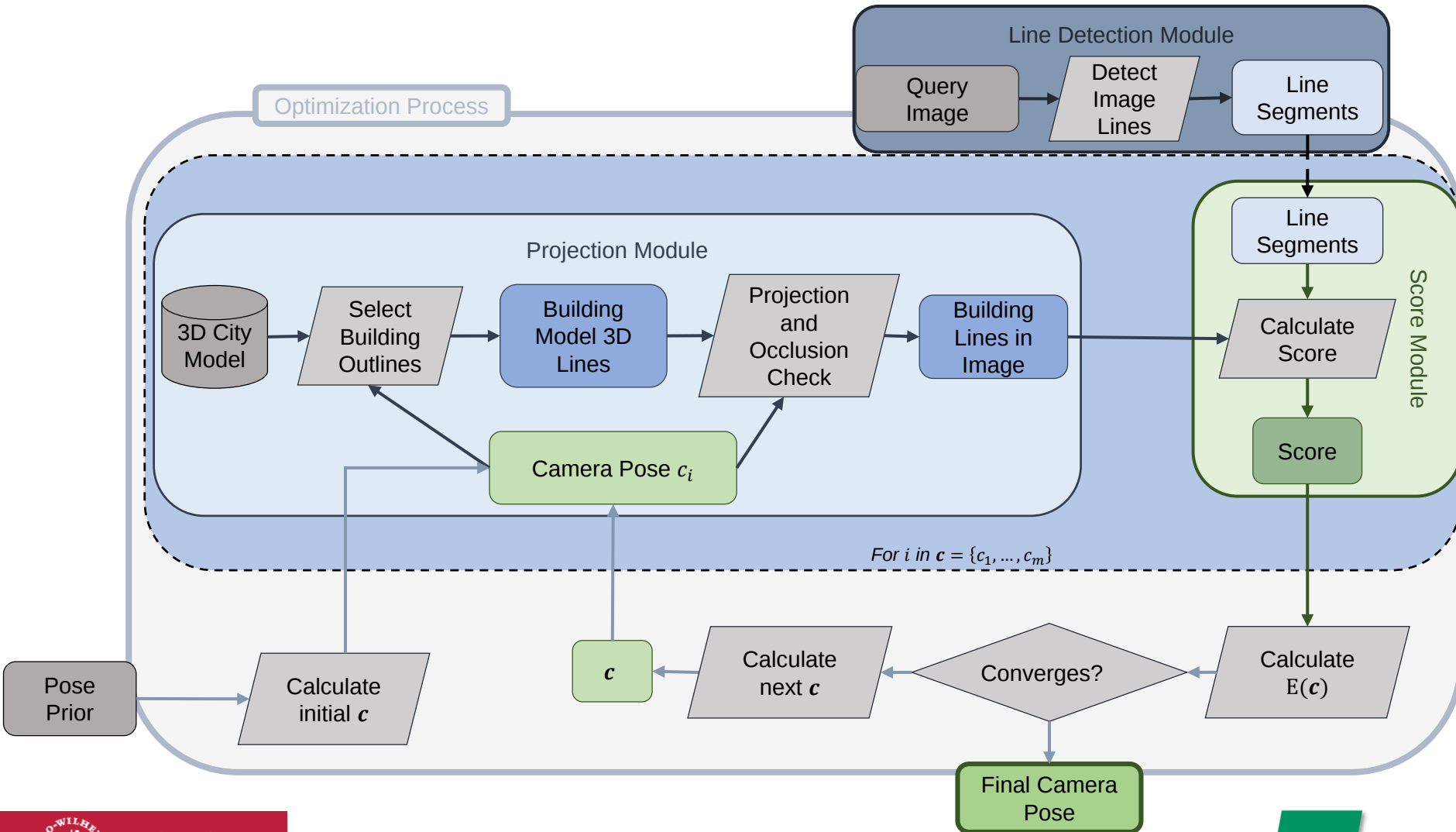
Projection and occlusion check



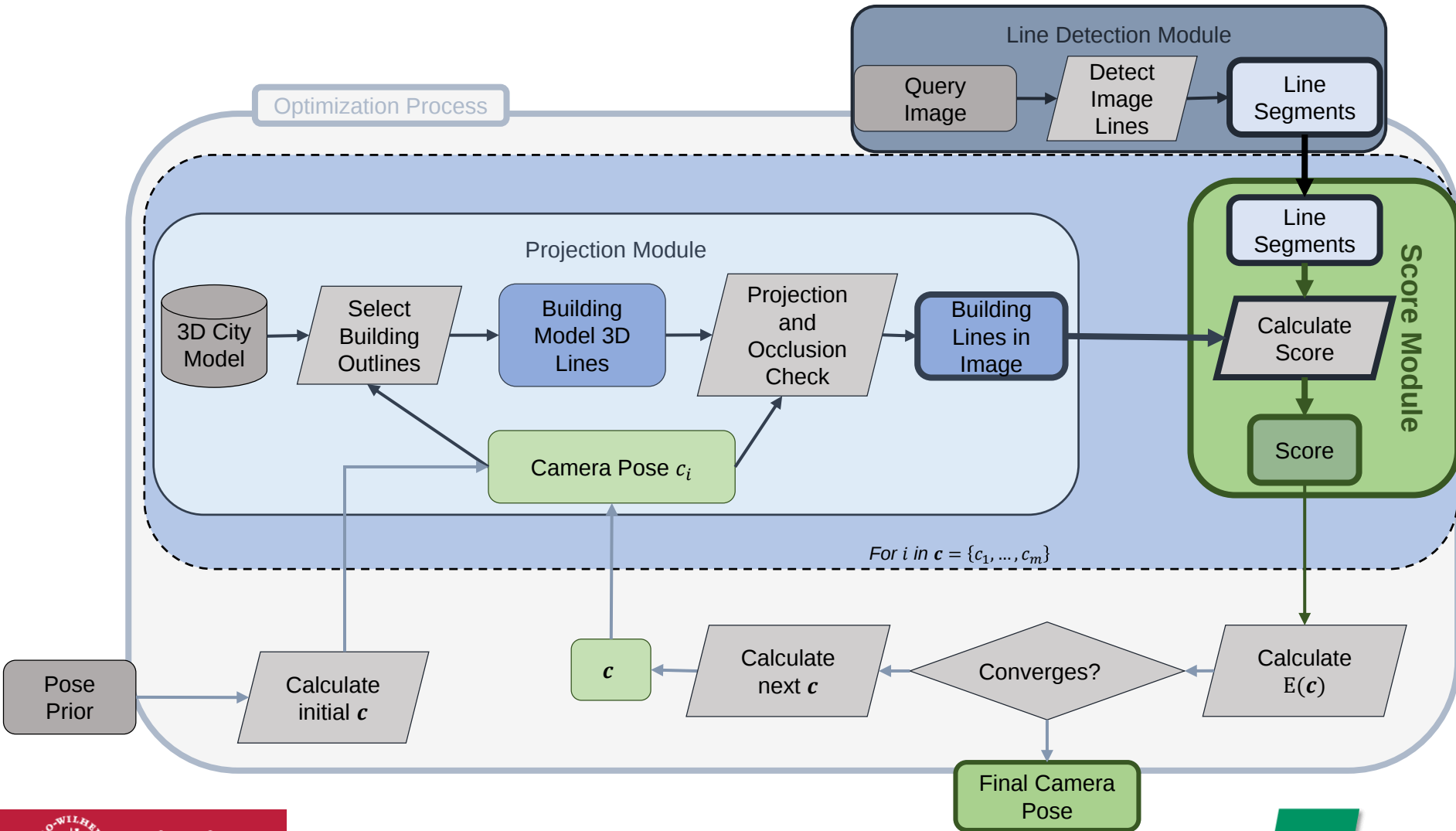
Extracted building lines

- ▶ Based on 6 DoF requesting all surrounding buildings
- ▶ Transformation into camera coordinate system
- ▶ Application of occlusion check
- ▶ Extract lines

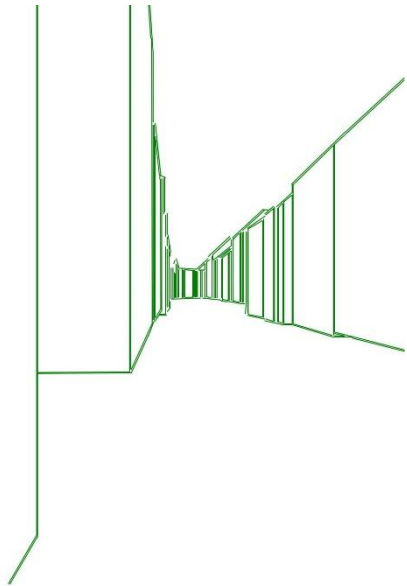
Object-based Visual Localization Workflow



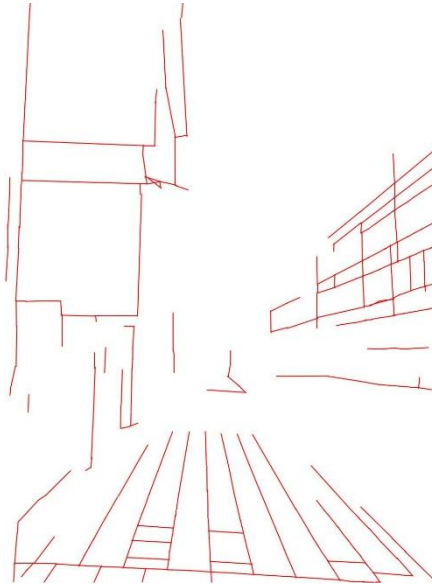
Object-based Visual Localization Workflow



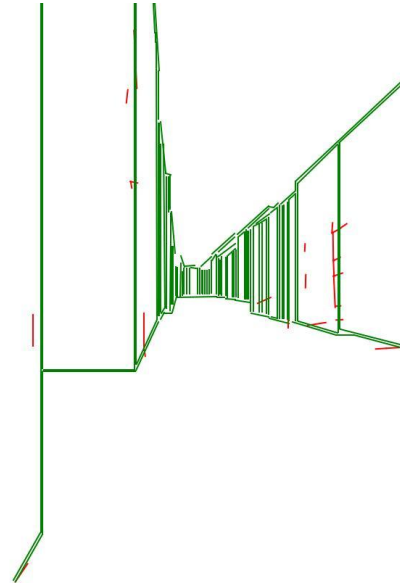
Score Module



Extracted building lines



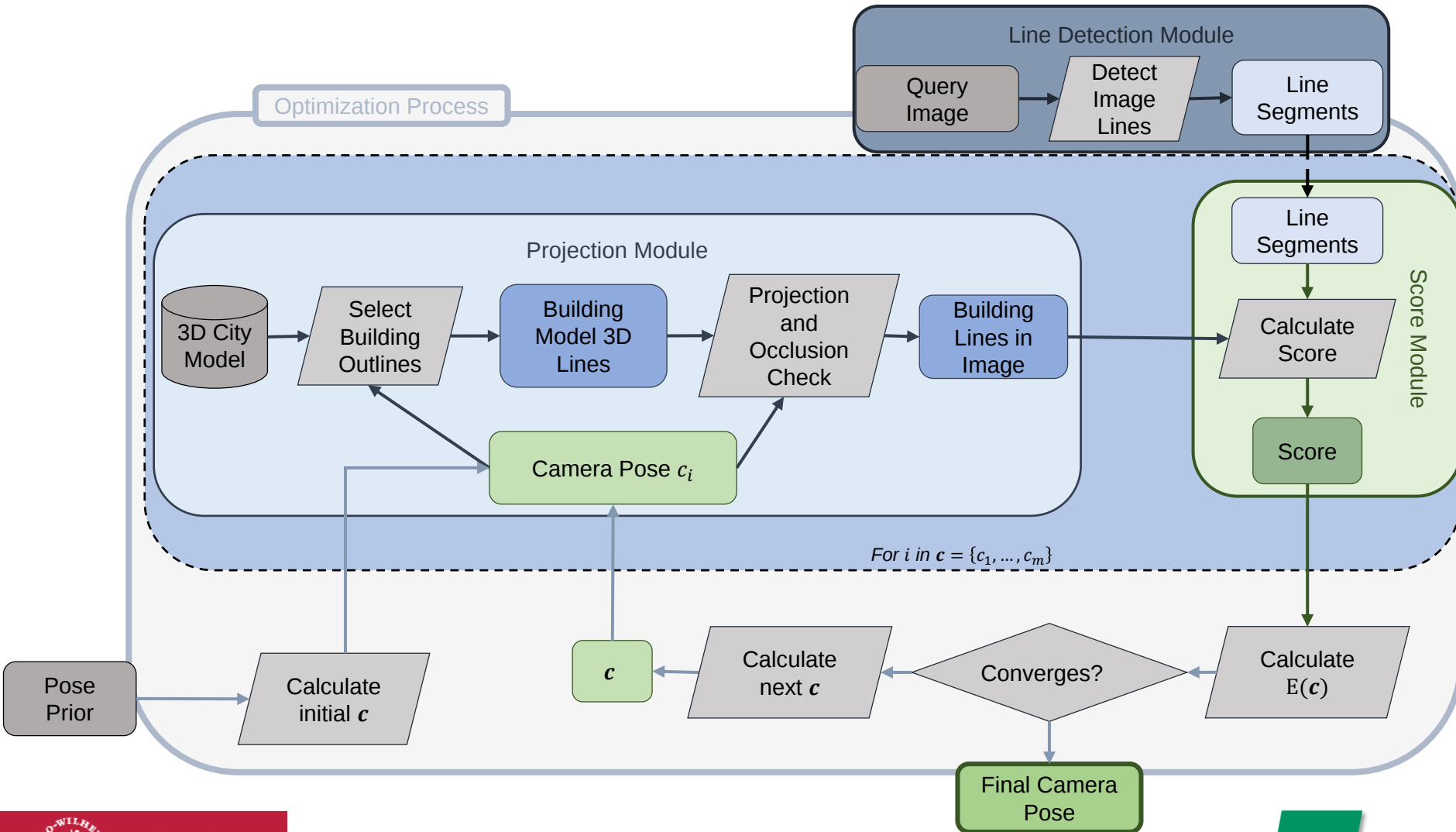
Detected lines in query image
(with SOLD2)



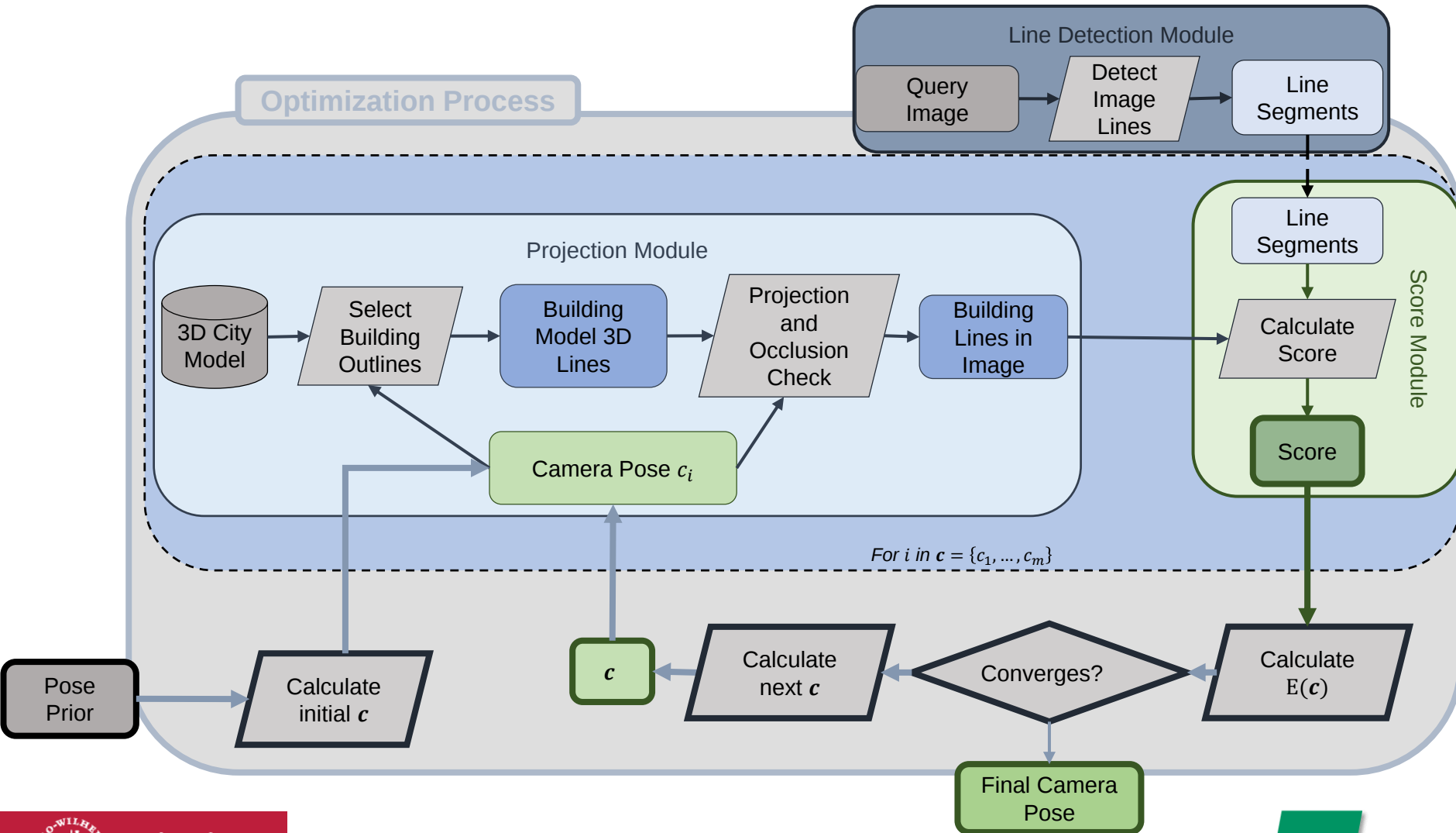
Corresponding image lines to
the building lines

- ▶ Calculating the angle of the building lines
- ▶ Comparing the building line angle with angle of query image lines and select pairs with similar angle
- ▶ Calculating orthogonal distance of selected pairs
- ▶ Calculate distance score and score based on number of matched lines

Object-based Visual Localization Workflow



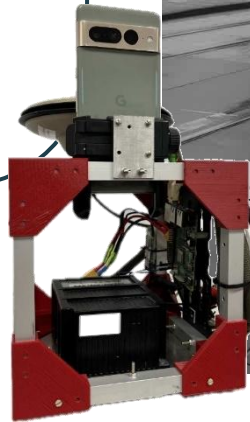
Optimization Process



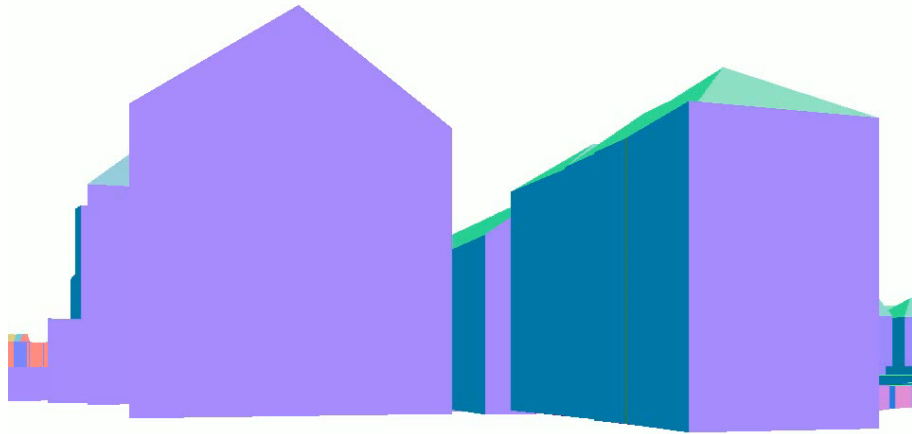
Experiments

Query dataset

- ▶ Image size 969 x 1280
- ▶ GSD of 4 cm
- ▶ RMSE at GCP of (6; 7; 2) cm in X, Y, Z;
mean errors at CPs of (7; 4; 1) cm
- ▶ EO parameters mean error:
1.5 cm (in X, Y), 0.7 cm (in Z);
standard deviations: 6, 2 mm;
rotation components mean error:
0.02° at $\sigma = 0.04^\circ$



Experiments



Reference dataset

- ▶ 3D reference data: city model in LoD2 model of Braunschweig [4]
- ▶ Building outlines from cadastral data, DTM in 5 m resolution and 3D data from laser scan or matching point cloud.
- ▶ Positional accuracy depends on the cadastral data and the height accuracy on the matching point cloud

Results

Assumptions

- ▶ Number of tested images: 30
- ▶ Pose prior and certain search area
- ▶ Tested search area: 25%, 50%, 75%, 100%

Accuracy

▶ Average translation error: 8.9 m
in X, Y direction and $\pm 20^\circ$ for κ

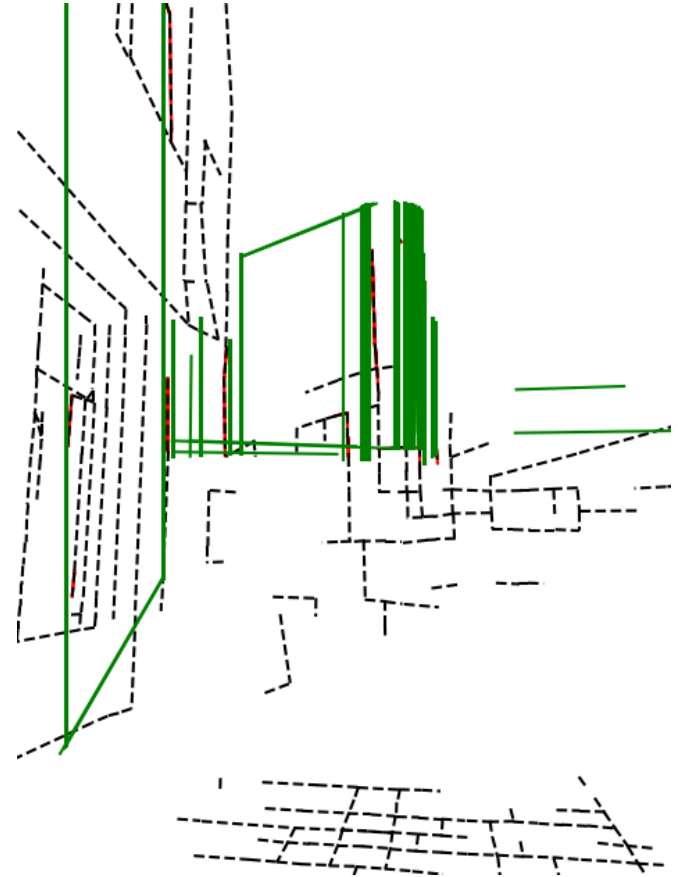
▶ Average rotation error: 2.23°

▶ MAD: 4.88 m / 14.02°

Translation error (m)	3.90	9.95	13.68
Rotation error κ ($^\circ$)	2.68	4.44	11.91

Results and Discussion

- ▶ Ambiguity due to the definition of the score
- ▶ Further conditions required to determine the best pose
- ▶ Compromise between general validity and accuracy
- ▶ Reliability in difficult scences not given



Conclusion and Future Work

- ▶ Visual localization using low cost 3D model data
- ▶ Requires little storage space
- ▶ Quality of the model influences the accuracy of proposed camera poses
- ▶ Highlight uniqueness of the poses by testing to include segmented information, including gradient information of query image and even more than just straight lines

References

- [1] Panek, Vojtech; Kukelova, Zuzana; Sattler, Torsten (2022): MeshLoc: Mesh-Based Visual Localization. 10.48550/arXiv.2207.10762
- [2] Panek, Vojtech; Kukelova, Zuzana; Sattler, Torsten (2023): Visual Localization using Imperfect 3D Models from the Internet. 10.48550/arXiv.2304.05947
- [3] Pautrat, Rémi; Lin, Juan-Ting; Larsson, Viktor; Oswald, Martin R.; Pollefeys, Marc (2021): SOLD2: Self-supervised Occlusion-aware Line Description and Detection. 10.48550/arXiv.2104.03362
- [4] Landesamt für Geoinformation und Landesvermessung Niedersachsen, 2024

Appendix: Related Work

