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Learning Correspondence Uncertainty via Differentiable Nonlinear Least Squares




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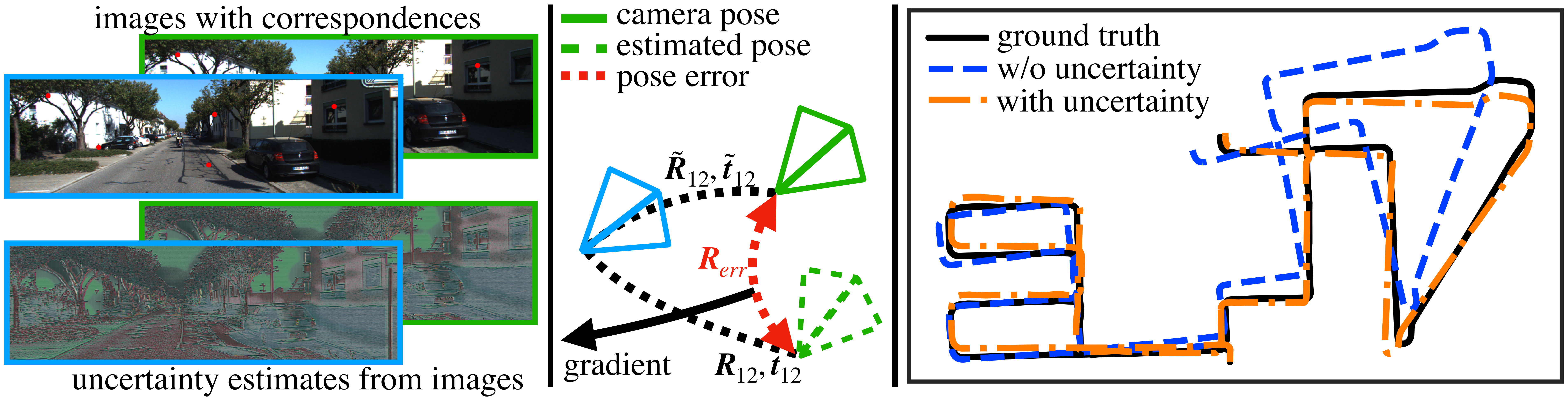

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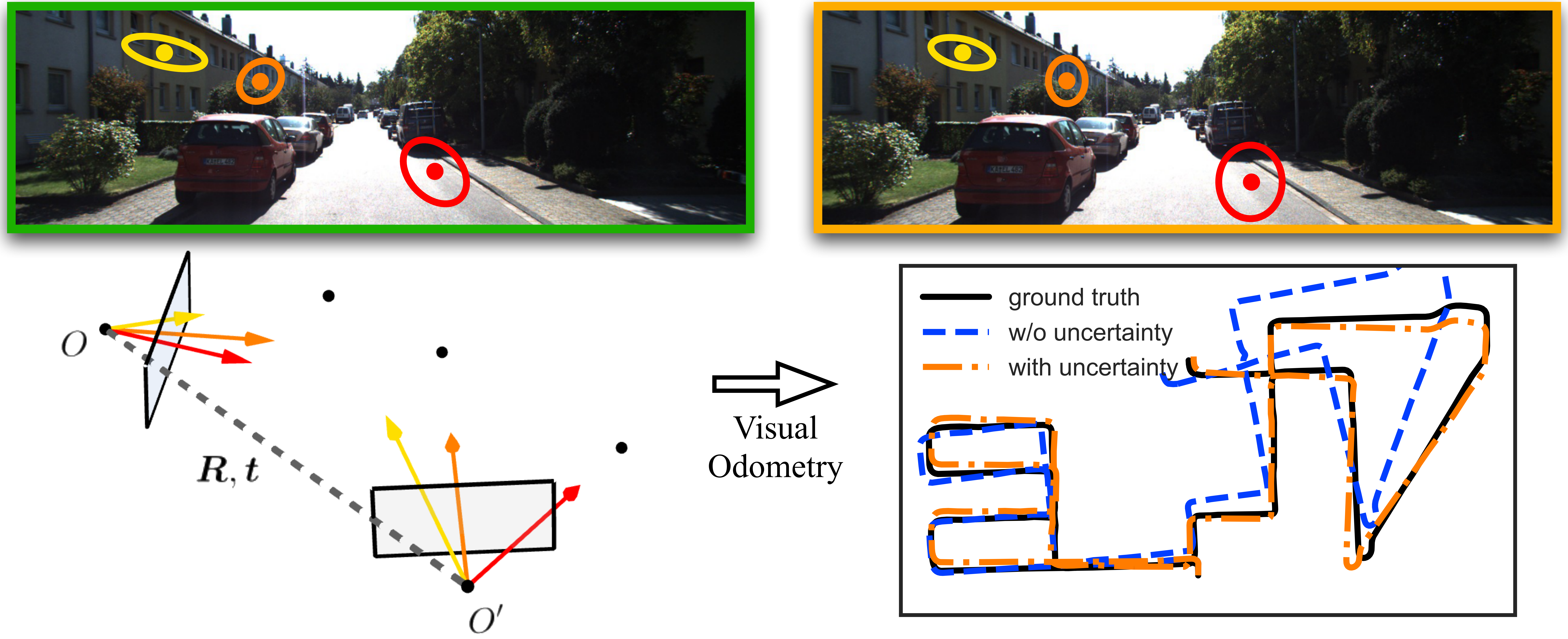
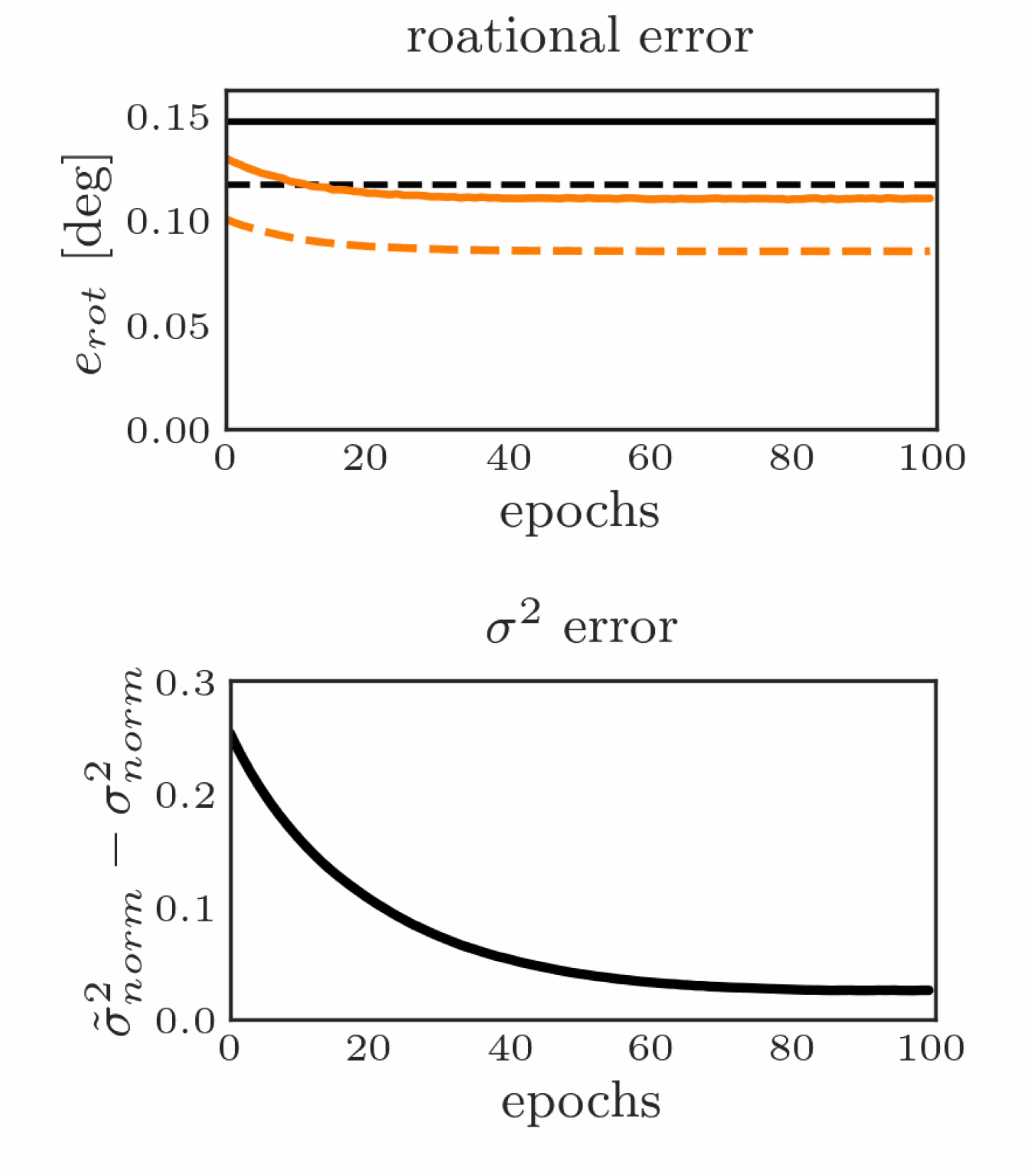
Why use Uncertainty in Visual Odometry?

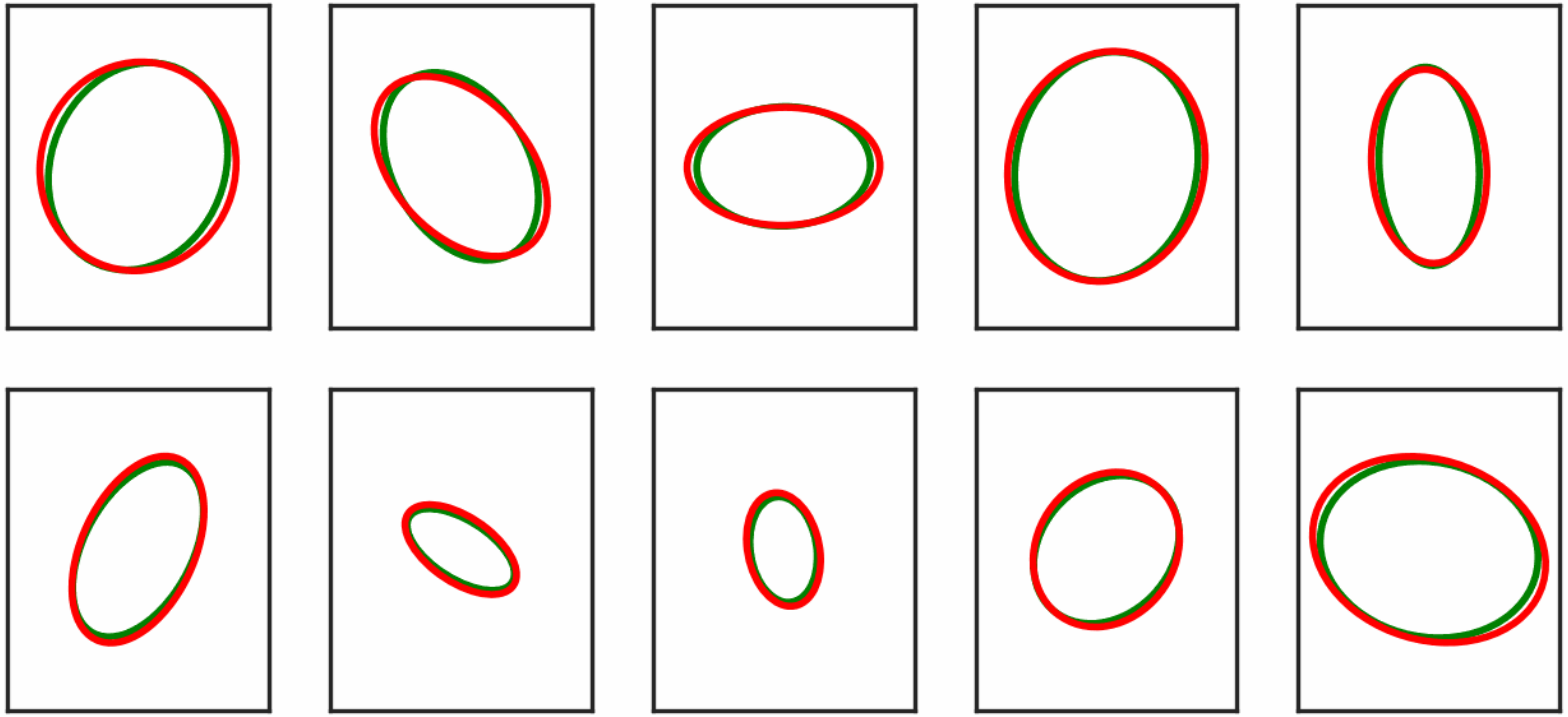


Training on Real World Data

Architecture: The formulation of our framework allows us to train our network in a supervised and with more than 3 images in a self-supervised manner.

Synthetic Evaluation





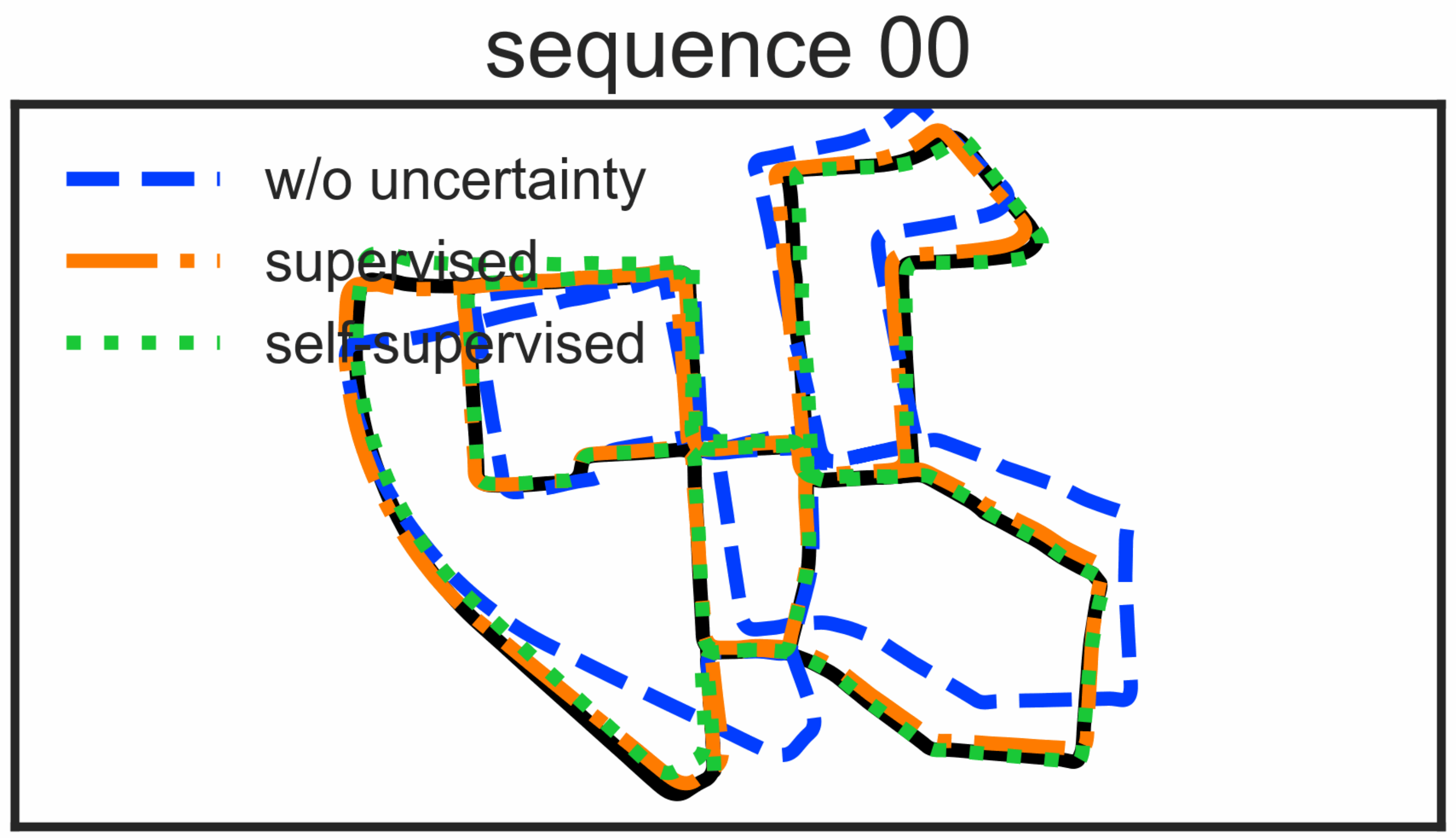
$$\sigma_{s,i}^2 = \boldsymbol{t}^\top((\hat{\boldsymbol{R}}\boldsymbol{f}_i')\boldsymbol{\Sigma}_i(\hat{\boldsymbol{R}}\boldsymbol{f}_i')^\top + \hat{\boldsymbol{f}}_i\boldsymbol{R}\boldsymbol{\Sigma}_i'\boldsymbol{R}^\top\hat{\boldsymbol{f}}_i^\top)\boldsymbol{t}$$

residual variance

image covariances

Evaluation on Real World Data

	NISTÉR-5PT [50]			NEC [33]			NEC-LS			WEIGHTED NEC-LS			OURS SUPERVISED			OURS SELF-SUPERVISED		
Seq.	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t
08	0.195	17.020	4.24	0.081	8.284	3.66	0.056	7.004	2.50	0.054	6.059	2.50	**0.050**	**4.067**	2.46	0.050	4.118	**2.46**
09	0.142	5.754	1.74	0.053	1.646	1.43	0.052	1.553	0.71	0.051	1.354	**0.70**	0.049	1.317	0.71	**0.049**	**1.278**	0.70
10	0.295	16.678	6.57	0.167	9.264	4.43	0.064	4.787	1.79	**0.063**	4.389	1.76	0.063	**3.513**	**1.64**	0.065	3.821	1.65
train	0.249	11.506	4.13	0.141	10.127	2.97	0.082	6.910	1.72	0.081	6.410	1.72	0.077	**2.378**	**1.69**	**0.077**	2.505	1.69
test	0.200	14.349	4.07	0.089	6.917	3.28	0.056	5.353	1.96	0.055	4.676	1.95	**0.052**	**3.333**	1.91	0.053	3.408	**1.91**



Evaluation on the KITTI odometry dataset for SuperPoint + SuperGlue keypoints. As there are no uncertainty estimates for SuperPoint, we use SuperGlue confidence as a stand-in for the WEIGHTED NEC-LS

[33] Laurent Kneip and Simon Lynen. Direct optimization of frame-to-frame rotation. *ICCV*, 2013

[50] D. Nister. An efficient solution to the five-point relative pose problem. *CVPR*, 2003

Results: Our estimated covariances lead to lower rotational and translational error for a supervised and self-supervised training. They outperform non-probabilistic and probabilistic pose estimates.

Evaluation on Real World Data

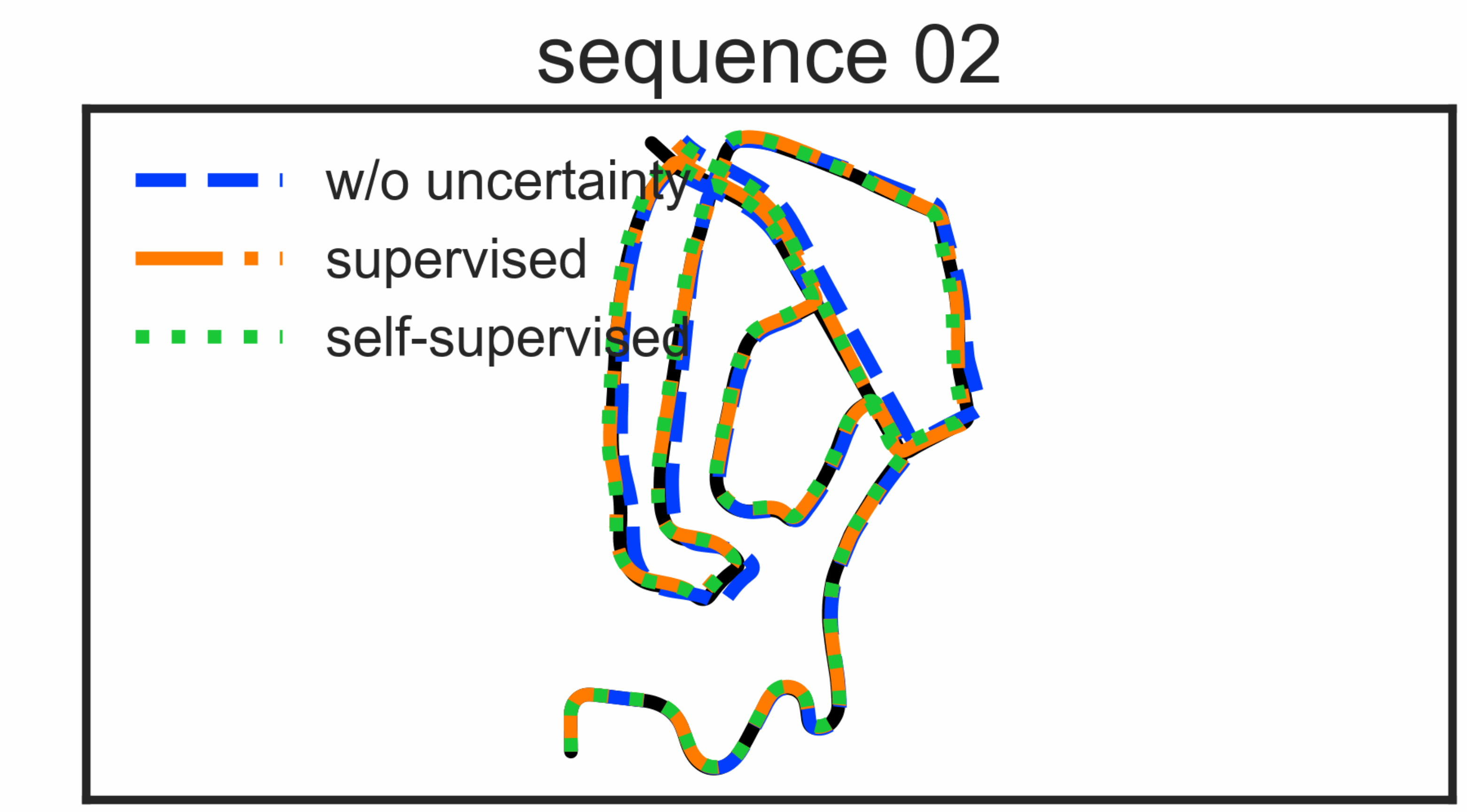
	NISTÉR-5PT [50]			NEC [33]			NEC-LS			KLT-PNEC [48]			OURS SUPERVISED			OURS SELF-SUPERVISED		
Seq.	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t	RPE_1	RPE_n	e_t
08	0.126	6.929	3.44	0.088	3.902	8.91	0.053	2.908	2.49	0.054	2.524	2.42	0.048	2.373	**2.36**	**0.047**	**1.706**	2.36
09	0.090	2.544	1.28	0.054	2.027	6.76	0.052	2.307	0.74	0.046	**1.003**	0.69	0.043	1.244	**0.64**	**0.042**	1.141	0.64
10	0.188	11.554	4.43	0.119	8.302	8.53	0.066	4.576	1.78	0.063	4.480	1.71	0.058	3.789	**1.58**	**0.056**	**3.623**	1.60
train	0.204	9.677	3.19	0.173	8.301	8.59	0.103	3.955	1.73	0.104	4.213	1.66	**0.094**	2.782	**1.60**	0.096	**2.737**	1.61
test	0.129	6.722	3.11	0.085	4.237	8.34	0.055	3.060	1.96	0.054	2.514	1.90	0.048	2.359	**1.82**	**0.048**	**1.910**	1.83

Evaluation on the KITTI odometry dataset for Kanade-Lucas-Tomasi tracking keypoints.

[33] Laurent Kneip and Simon Lynen. Direct optimization of frame-to-frame rotation. *ICCV*, 2013

[48] D Muhle, L Koestler, N Demmel, F Bernard, and D Cremers. The probabilistic normal epipolar constraint for frame-to-frame rotation optimization under uncertain feature positions. *CVPR*, 2022

[50] D. Nister. An efficient solution to the five-point relative pose problem. *CVPR*, 2003



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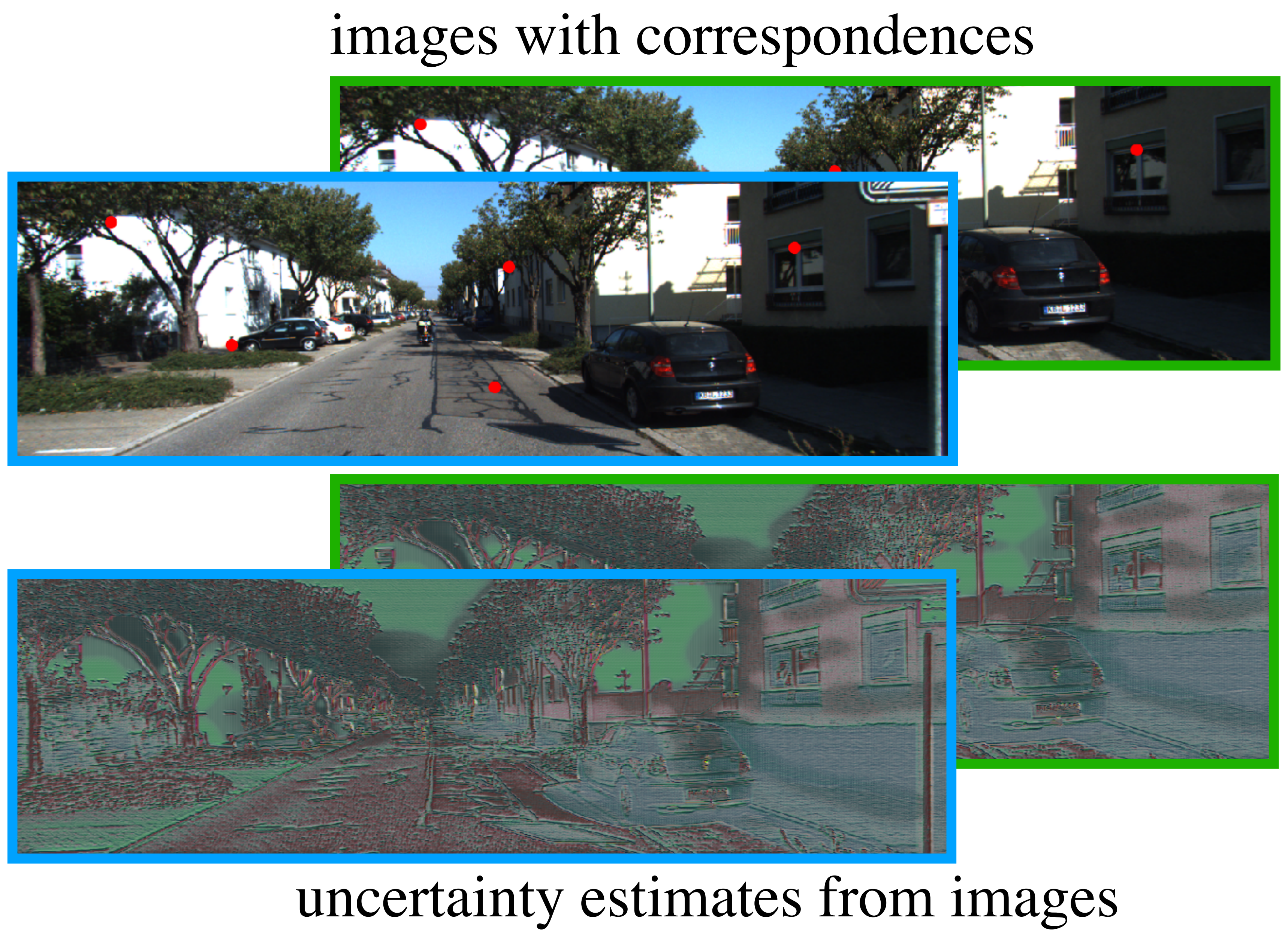

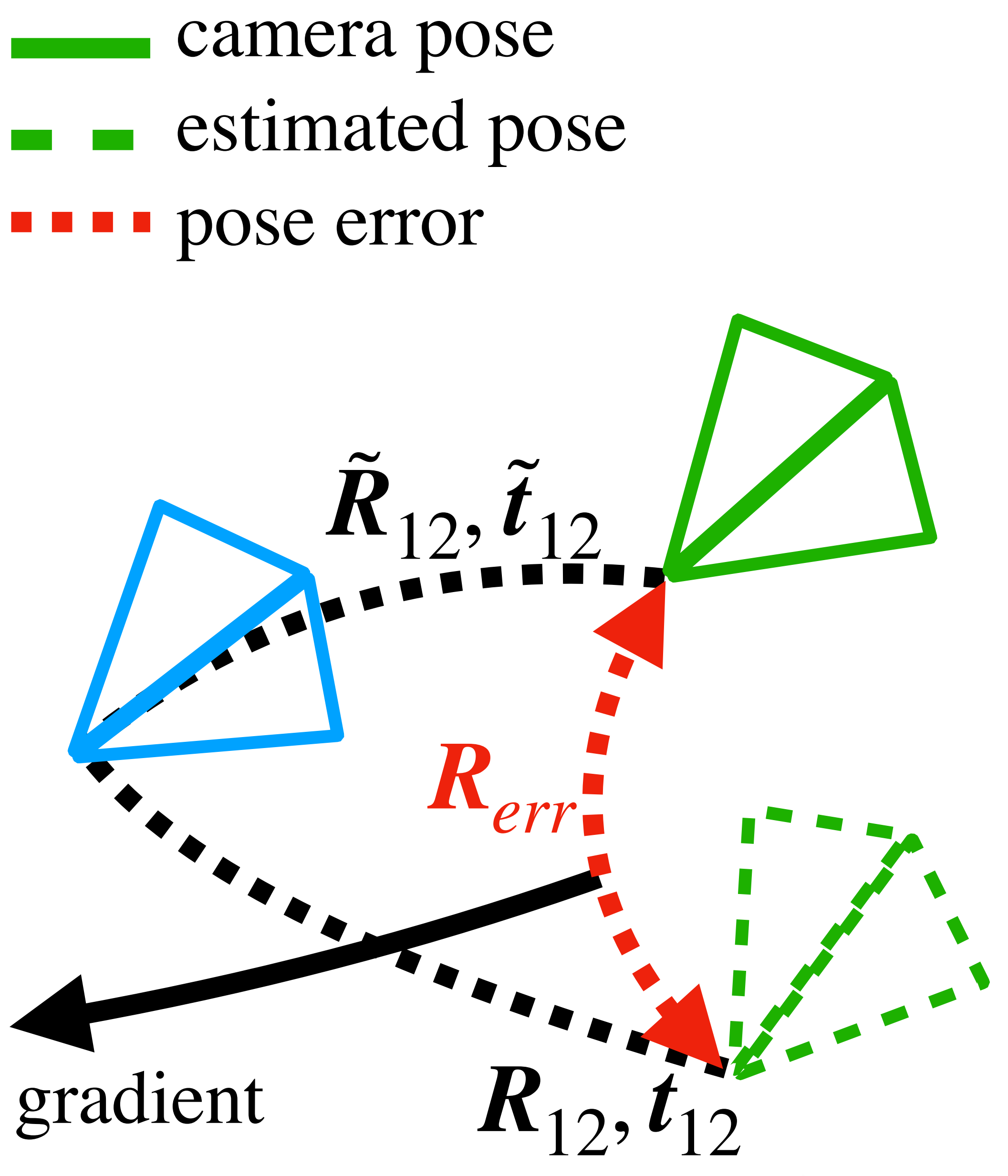

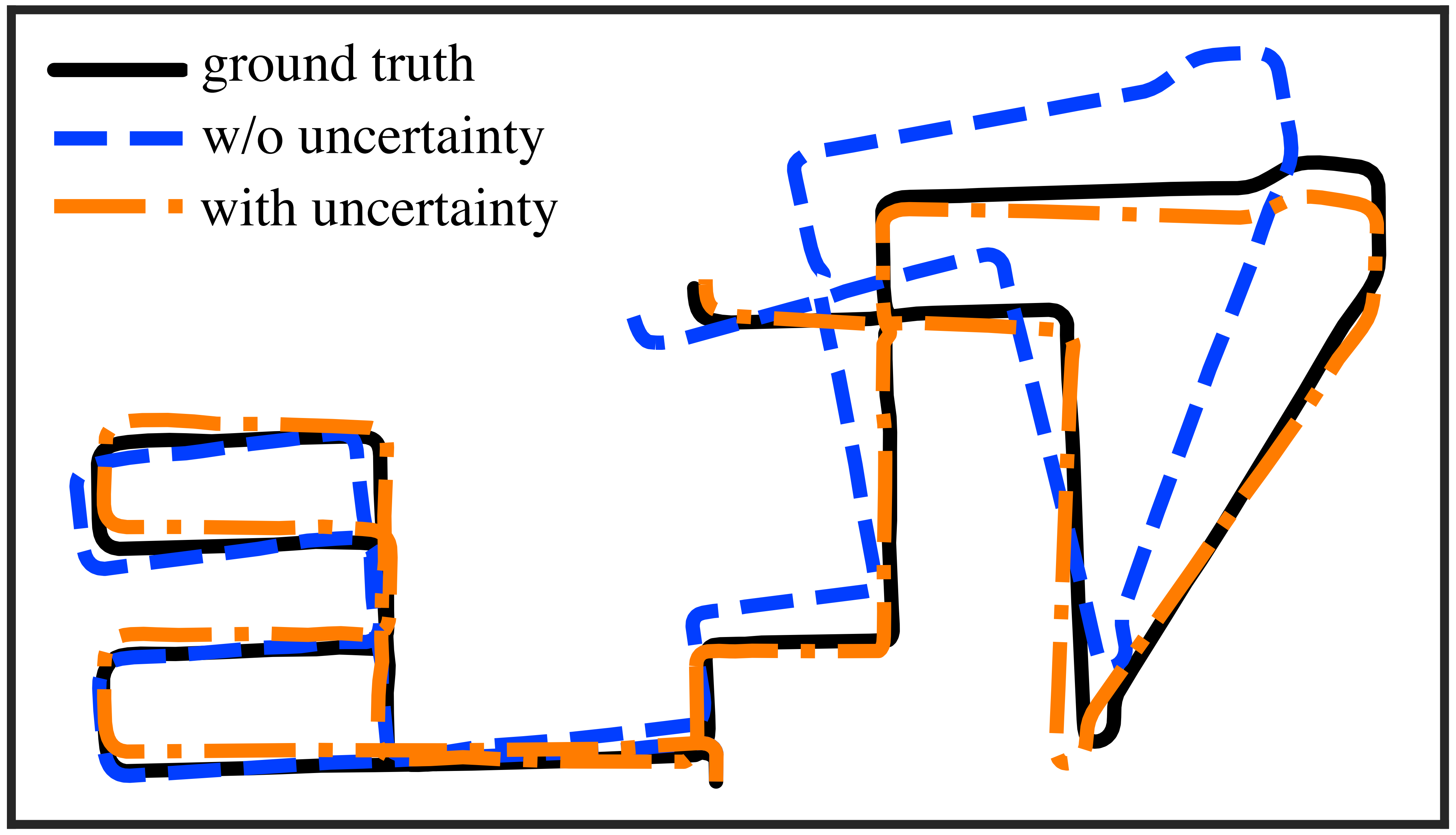

Code
Paper
Data

https://dominikmuhle.github.io/dnls_covs/