Indirect Visual Odometry with Optical Flow

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Team 2

Visual-Inertial Mapping with Non-Linear Factor Recovery

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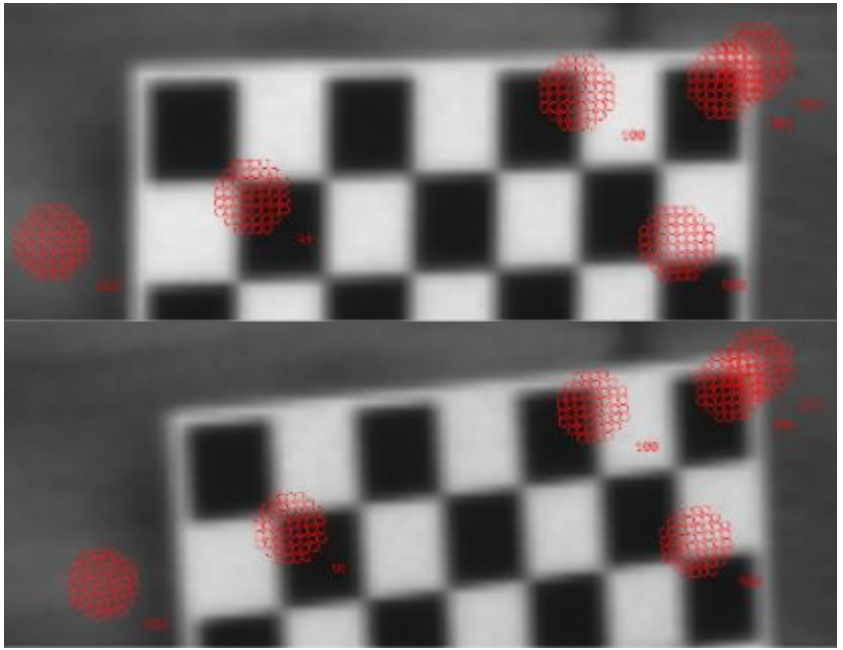
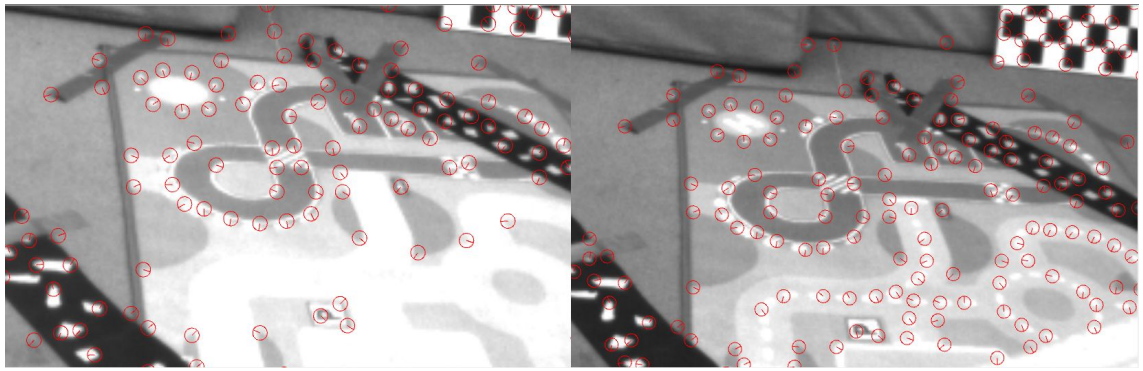


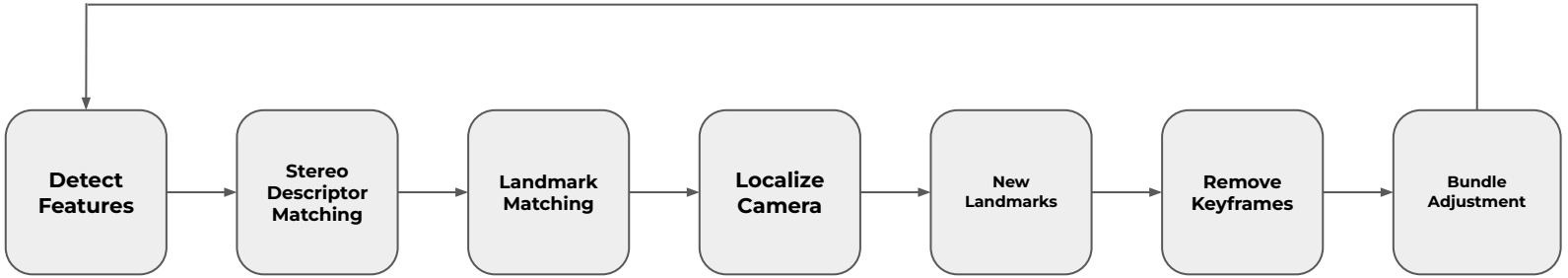
Optical flow feature tracking with BASALT

Outline

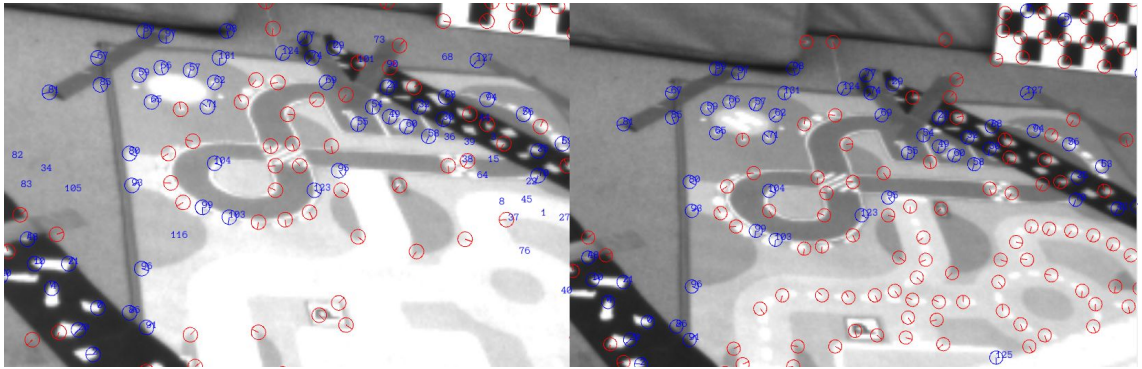
- Initial odometry recap and our extensions to the pipeline
- Optical flow and optimization explanation
- Analysis of results and conclusion

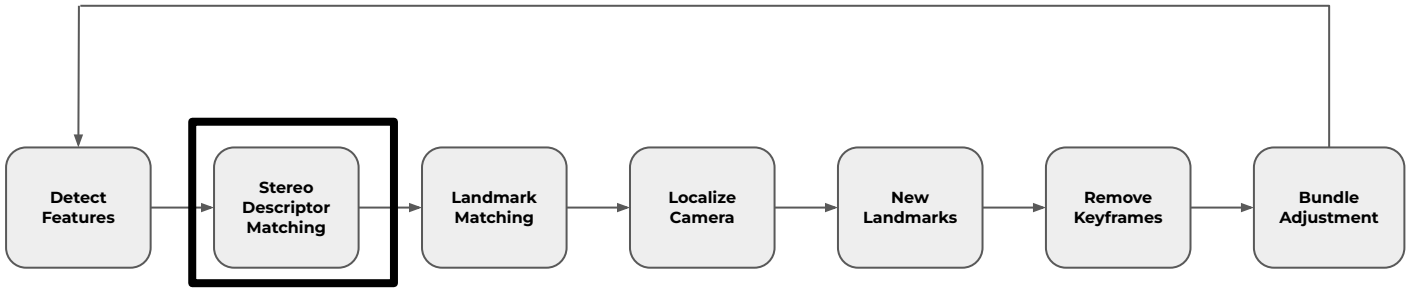
Odometry Pipeline



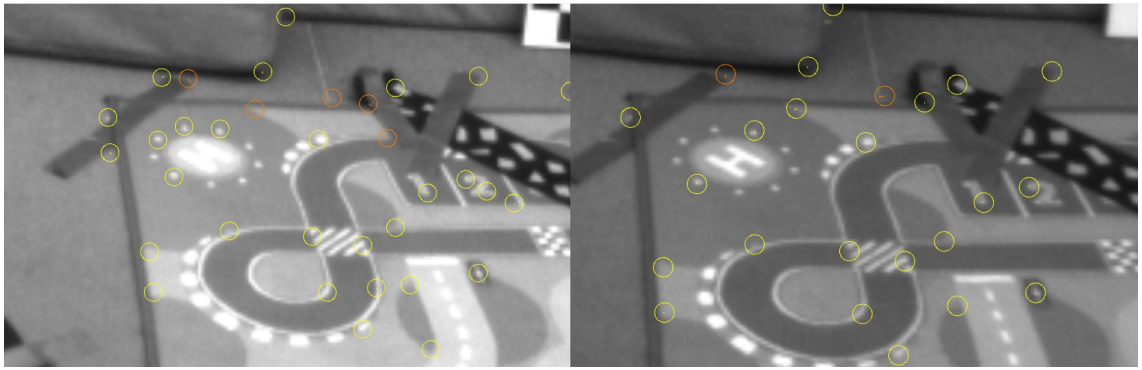


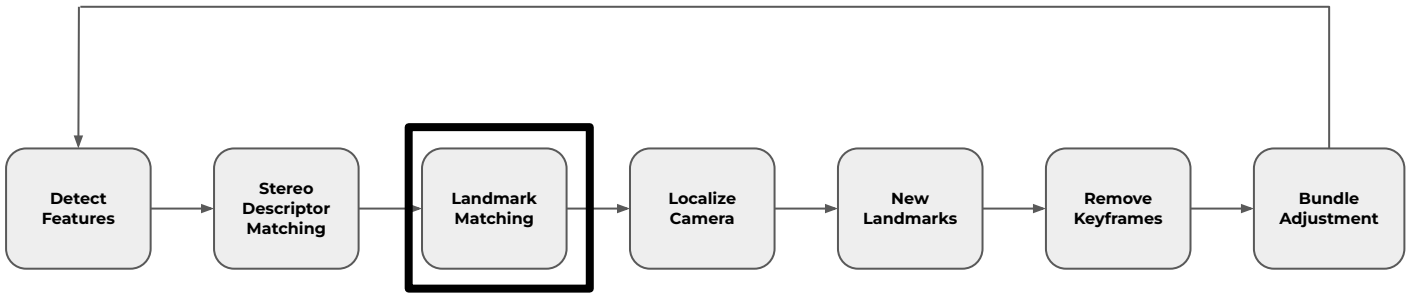
Odometry Pipeline



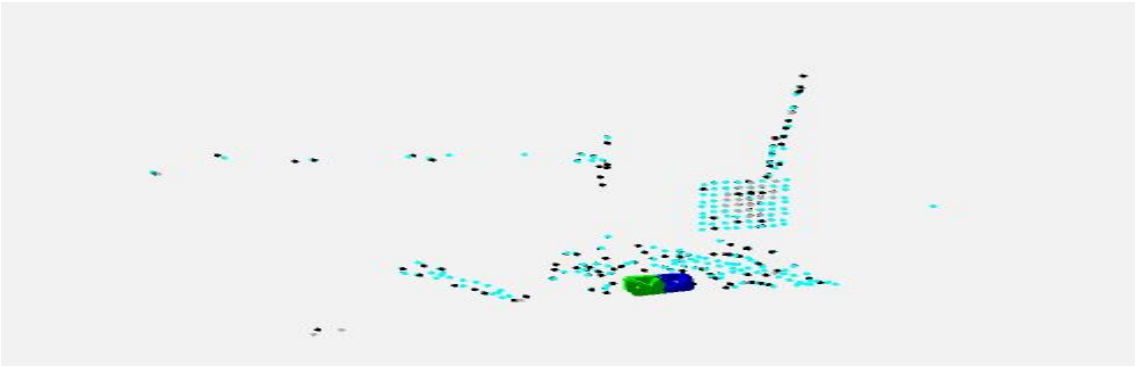


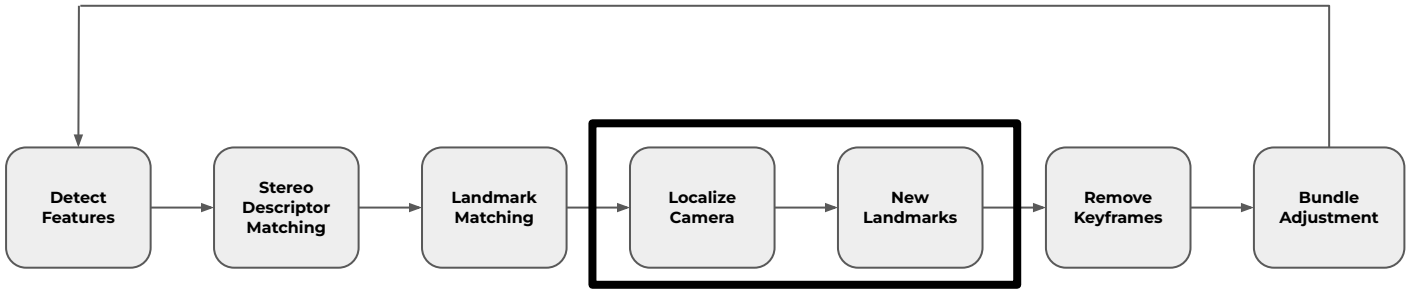
Odometry Pipeline



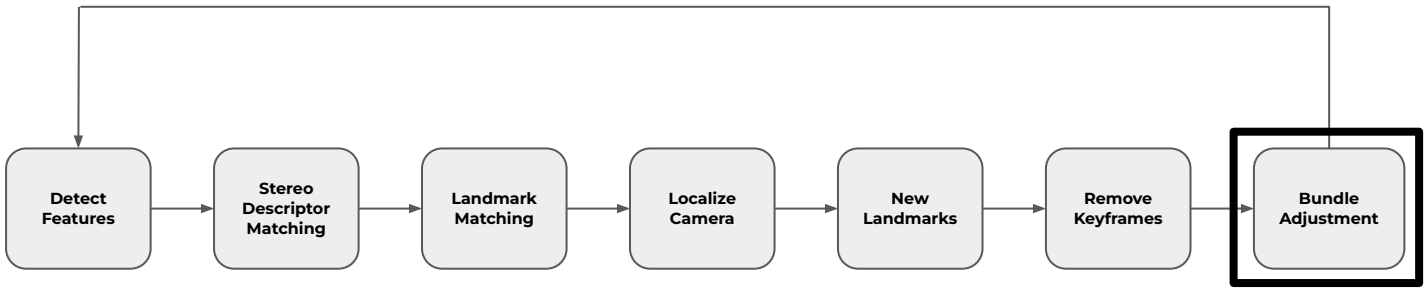


Odometry Pipeline

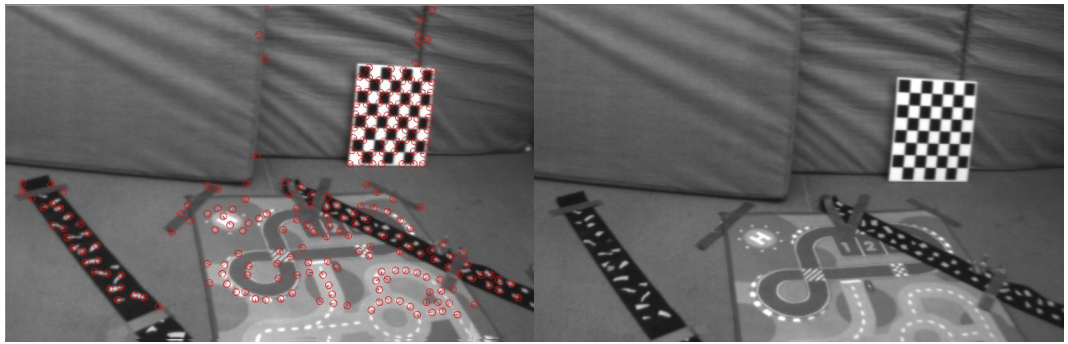


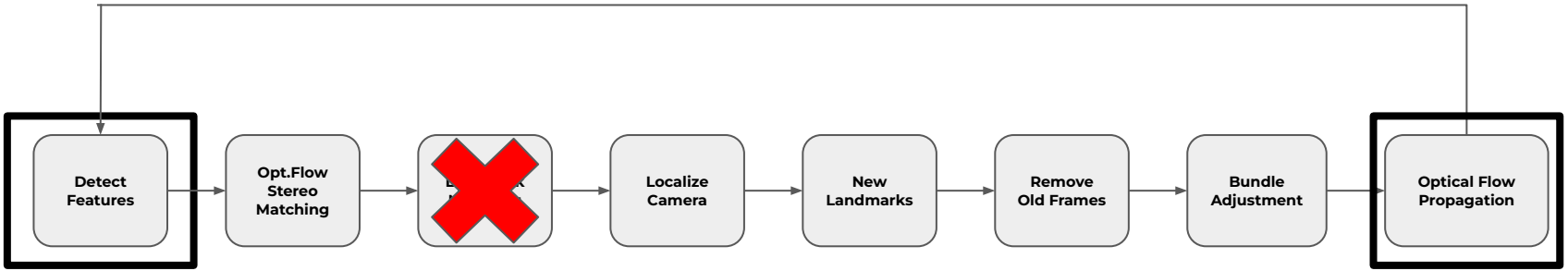


Odometry Pipeline



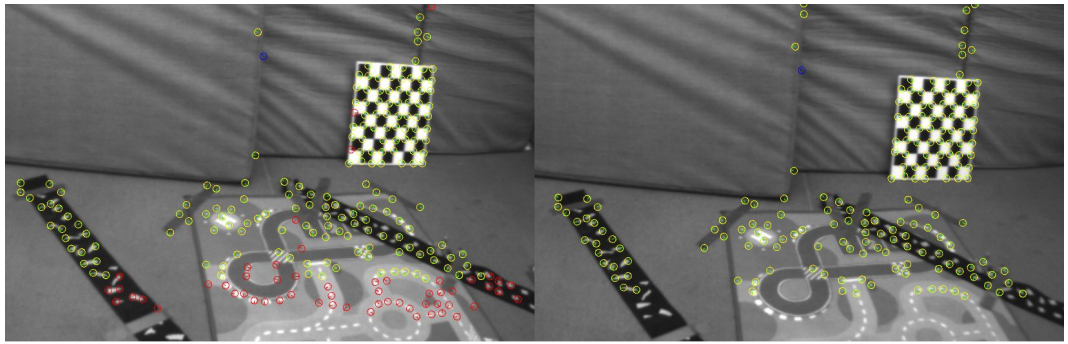
Our Method Summary

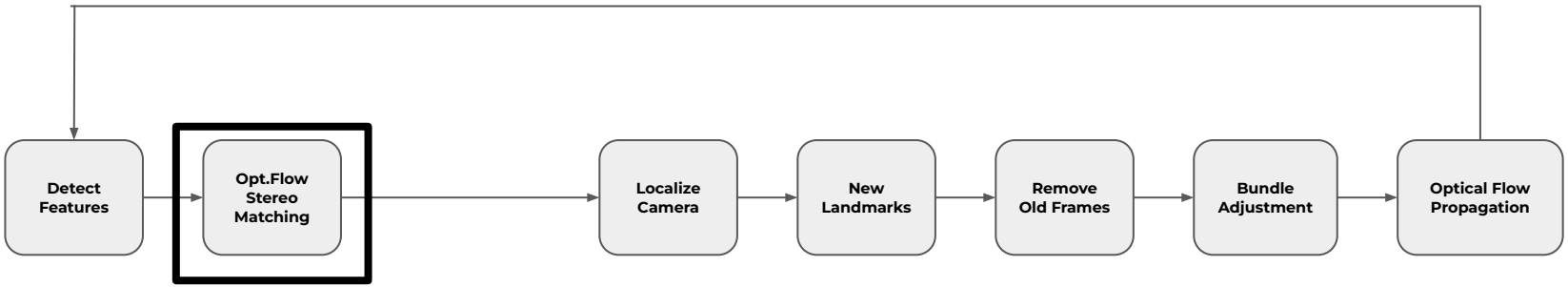




Only if not enough points!

Our Method Summary





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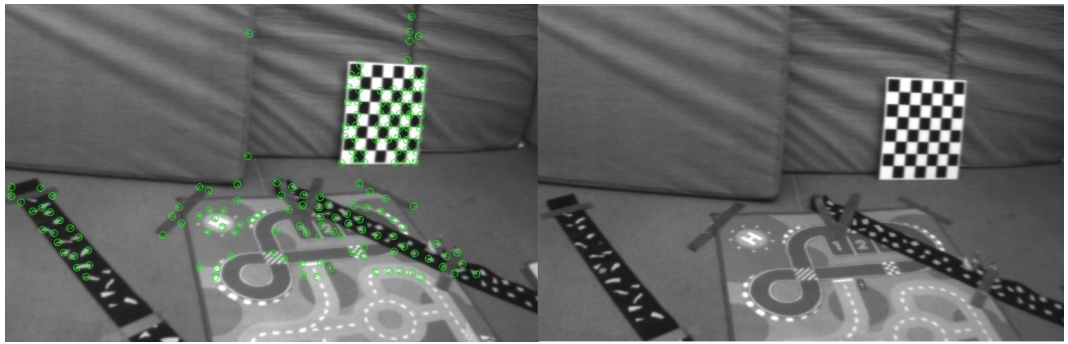

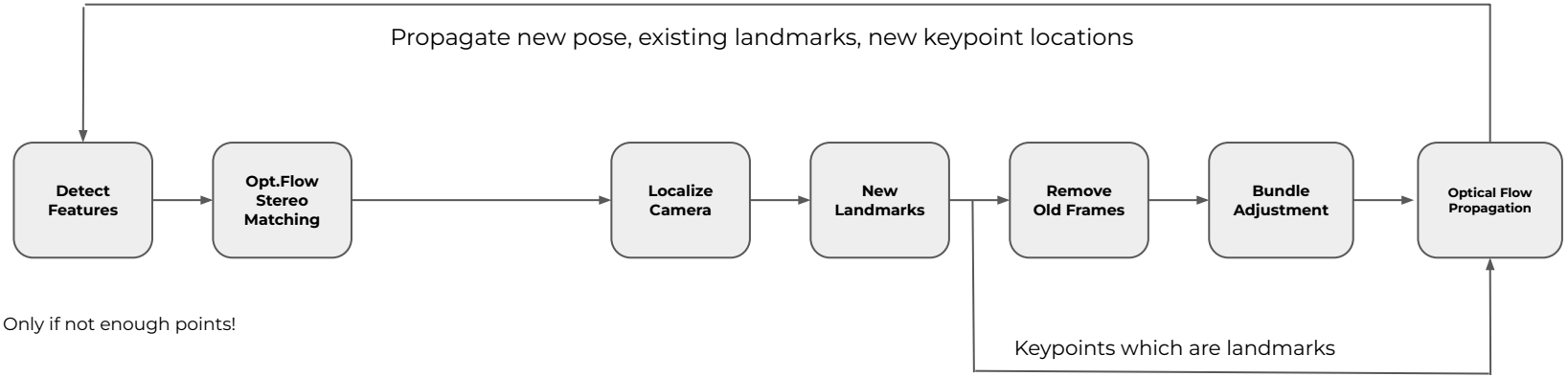

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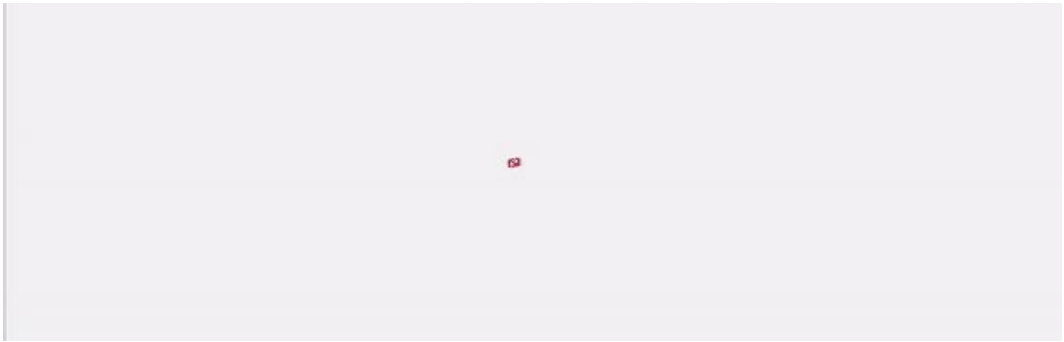
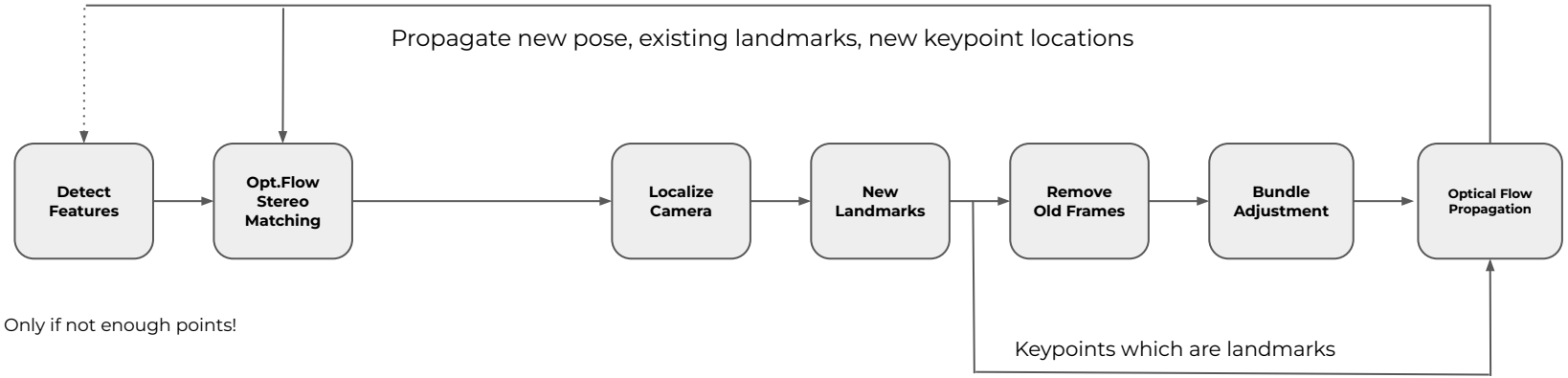
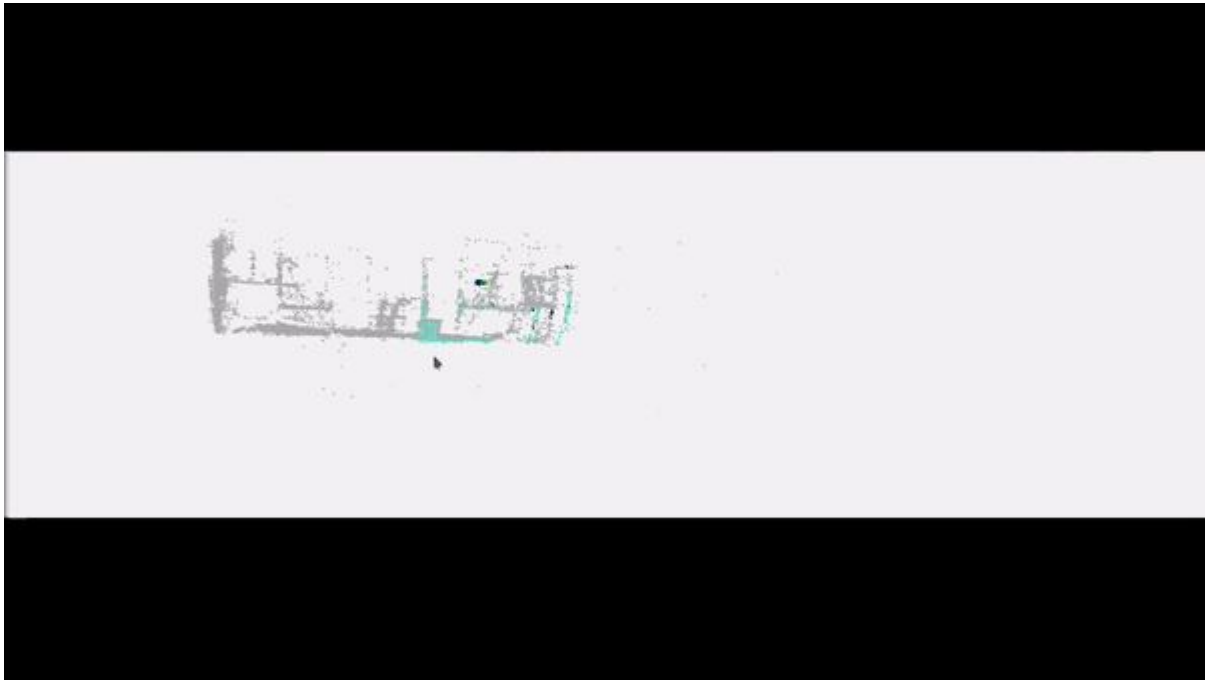




Generated 3D Map



Optical Flow

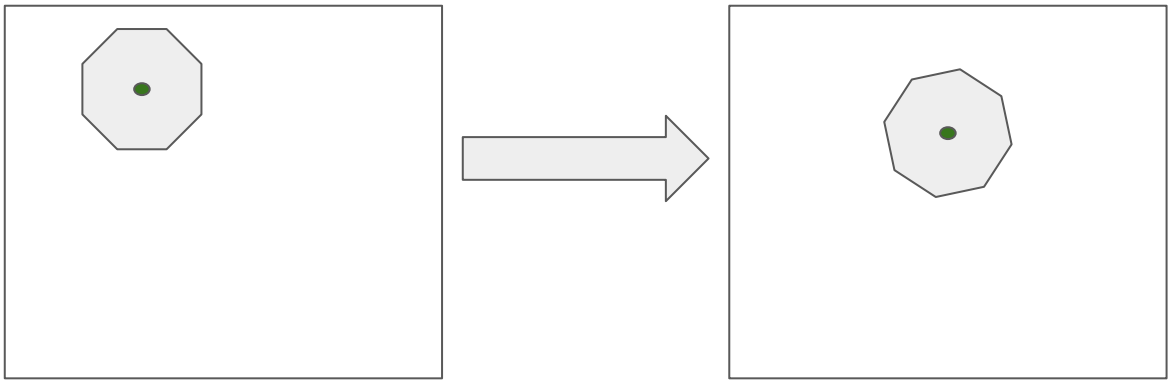
- Given two images:
  - Construct “Pyramids” from the images.
  - Track the points from image I to I’ on each level of the pyramids.
  - Track the points from I’ back to I.

- Patch Based Tracking.
- Find a warp that minimizes:

Tracking a point:

$$T \in SE(2)$$

$$r_i(\xi) = \frac{I_{t+1}(T\mathbf{x}_i)}{\overline{I_{t+1}}} - \frac{I_t(\mathbf{x}_i)}{\overline{I_t}} \; \forall \mathbf{x_i} \in \Omega$$

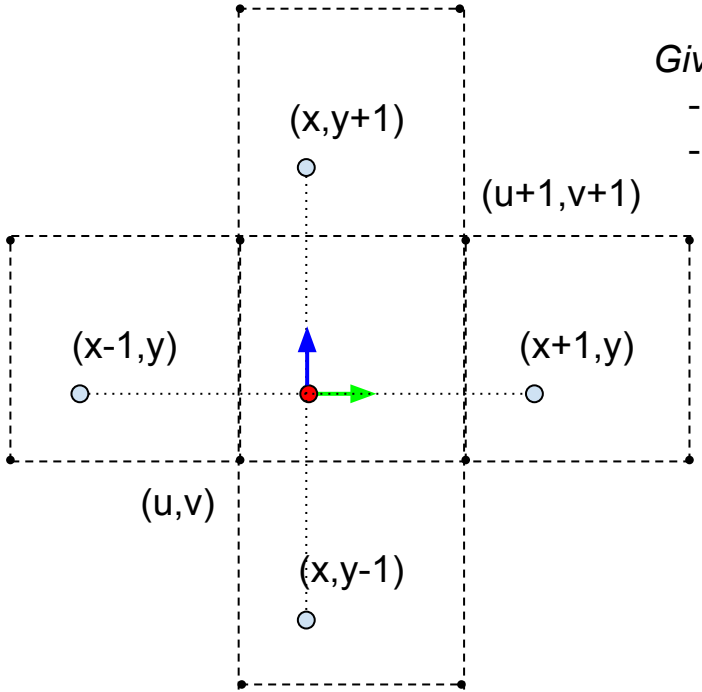


Optimizing the warp:

- Compute the gradients of each point in a patch.
- Incrementally update the warp until convergence.

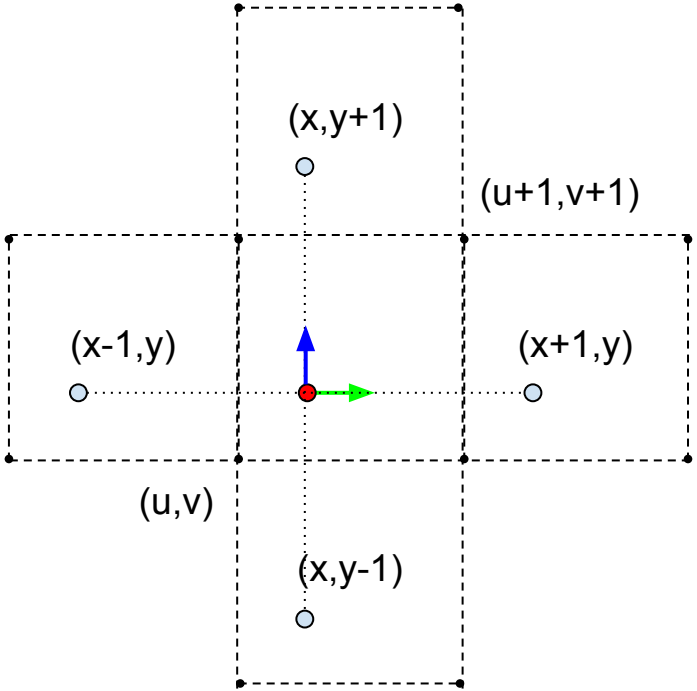
Point Gradients:

- Utilizing floating points.
- Bilinear Interpolation & Central Difference



Given point (x,y) *let*:

- u = ⌊x⌋
- v = ⌊y⌋

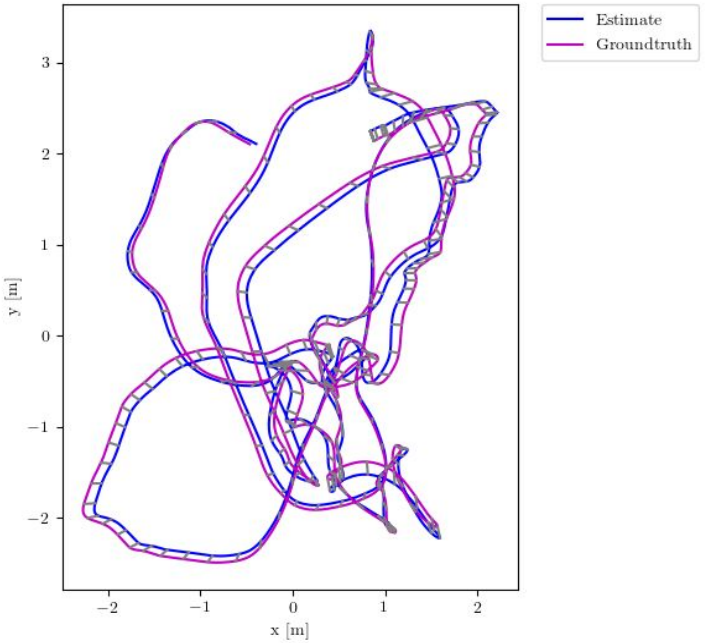

(x,y+1)
(u+1,v+1)
(x-1,y)
(x+1,y)
(u,v)
(x,y-1)

Computing the Increments:

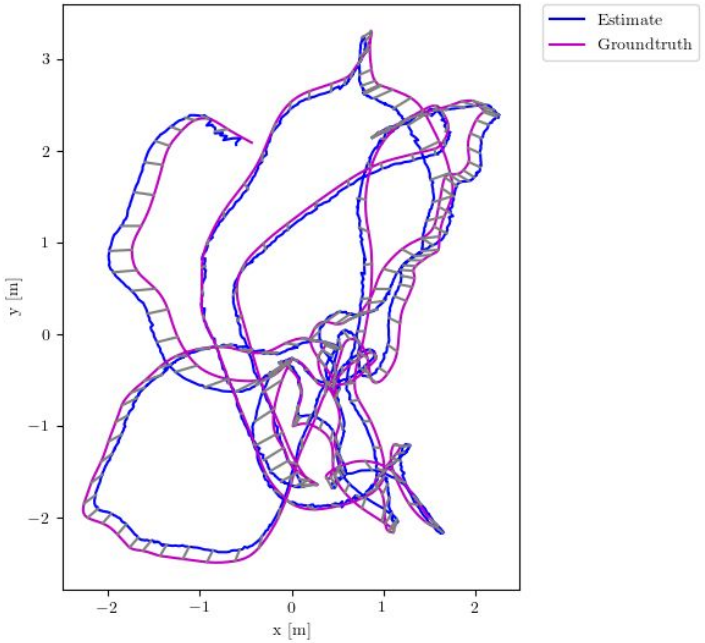
- Compute the Jacobian based on the gradients.
- Estimate the inverse Hessian using Cholesky Decomposition.
- Apply Gauss-Newton to the calculated residual $R^{t+1} = R^t exp(\xi)$
- The increment is applied to the rotation as:

Results and Experiments:

Results and Experiments: Trajectory Alignment

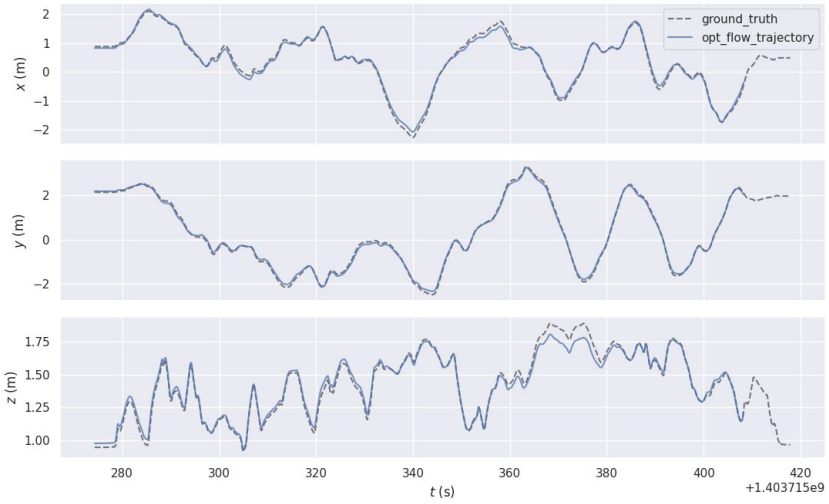


Ours

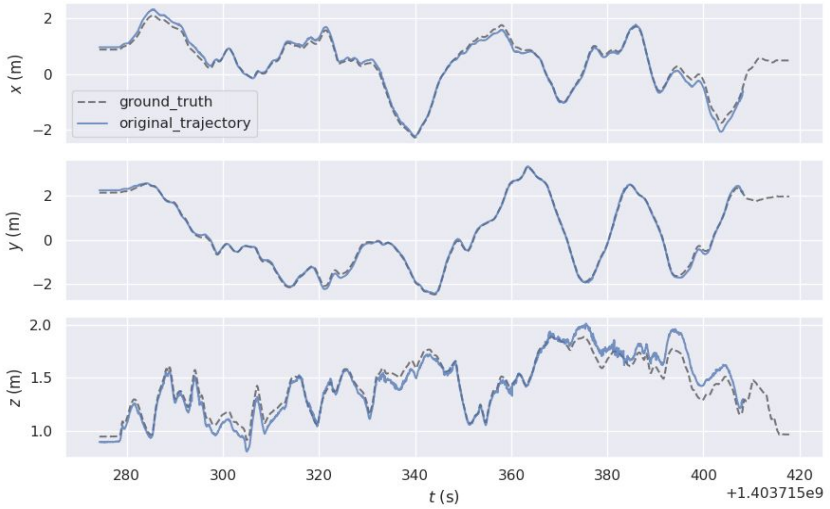


Original Odometry

Results and Experiments: XYZ difference in trajectory



Ours



Original Odometry

Relative Pose Error

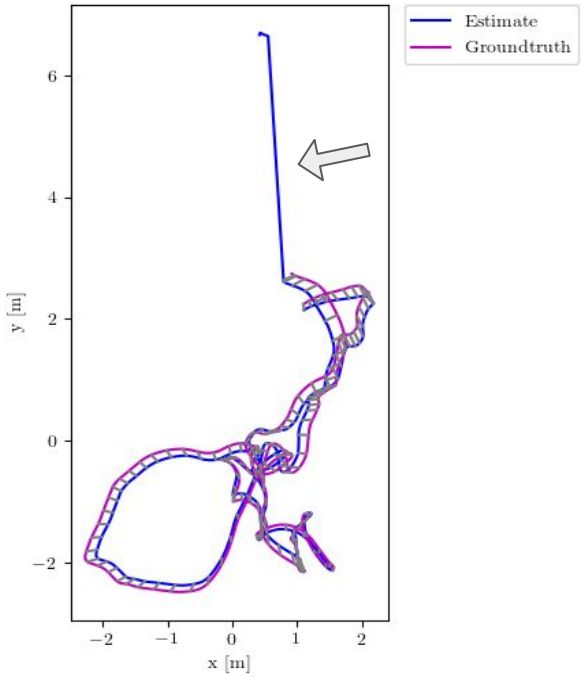
Method	rmse	mean	median	std	min	max
OpenCV	0.09	0.03	0.02	0.09	0.00	4.29
Ours	**0.03**	**0.03**	**0.02**	**0.02**	**0.00**	**0.07**
Original Odometry	0.04	0.03	0.03	0.02	0.00	0.17

Absolute Pose Error

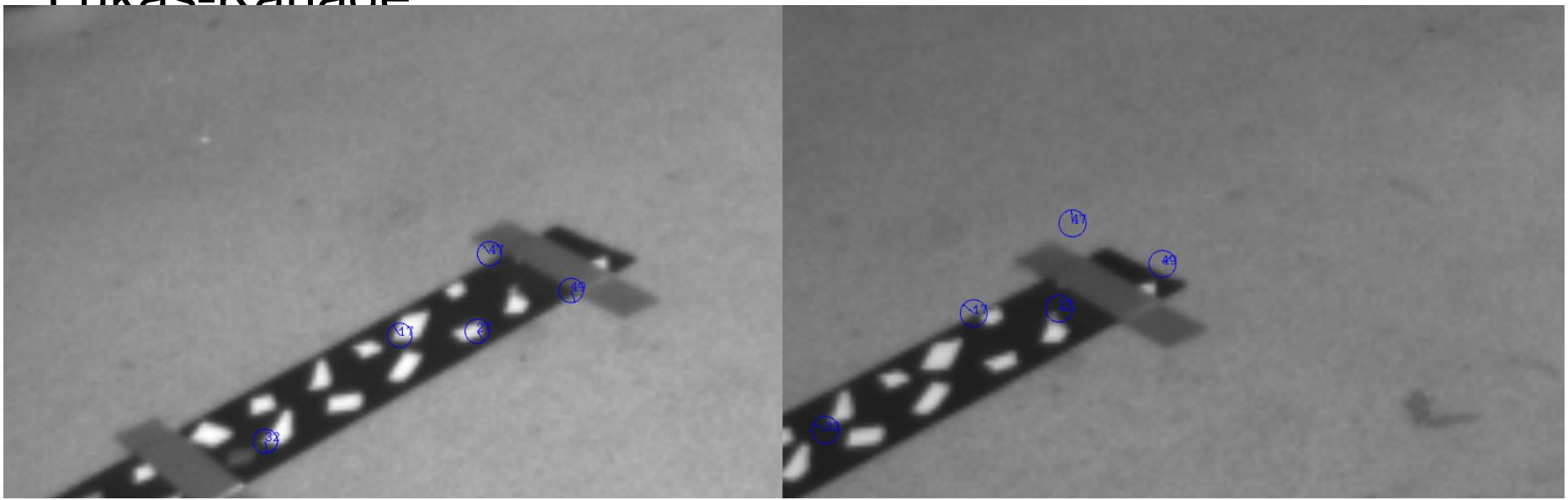
Method	rmse	mean	median	std	min	max
OpenCV	4.24	3.57	2.64	2.28	1.28	10.55
Ours	**0.12**	**0.11**	**0.11**	**0.04**	**0.01**	**0.21**
Original Odometry	0.16	0.14	0.14	0.07	0.01	0.37

Failure Case with OpenCV Lukas-Kanade

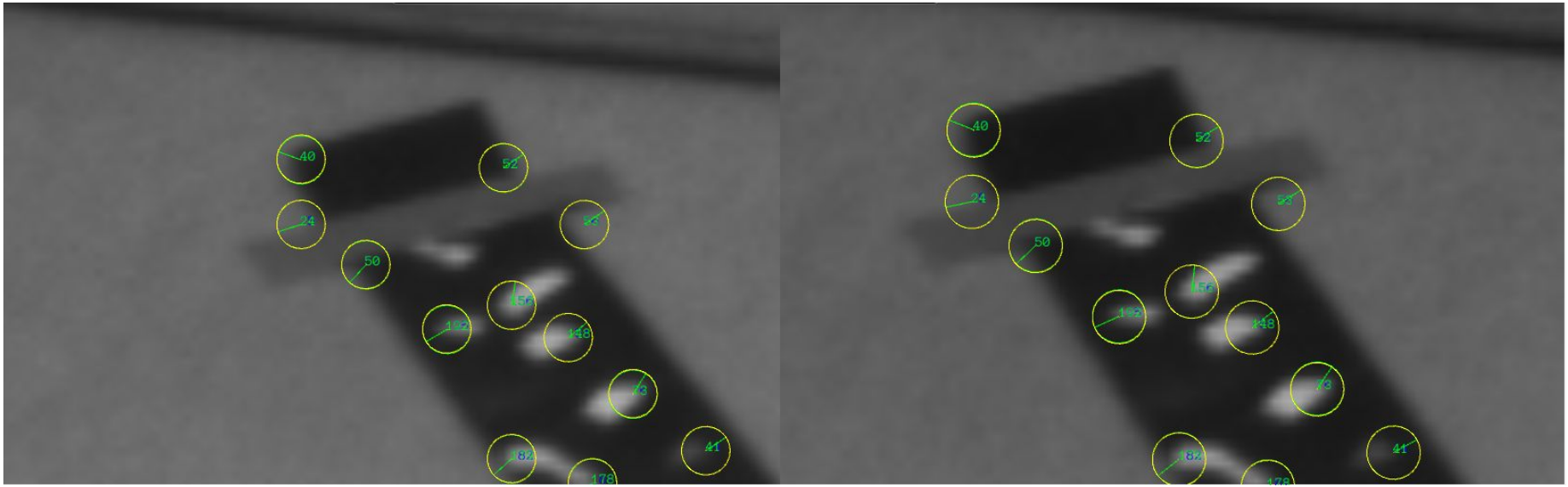
- When tracking fails, it is not able to recover
- For left to right optical flow, Lukas-Kanade didn’t work
- Hence we used Basalt approach for left to right



Stereo Matching with Optical Flow: OpenCV Lukas-Kanade



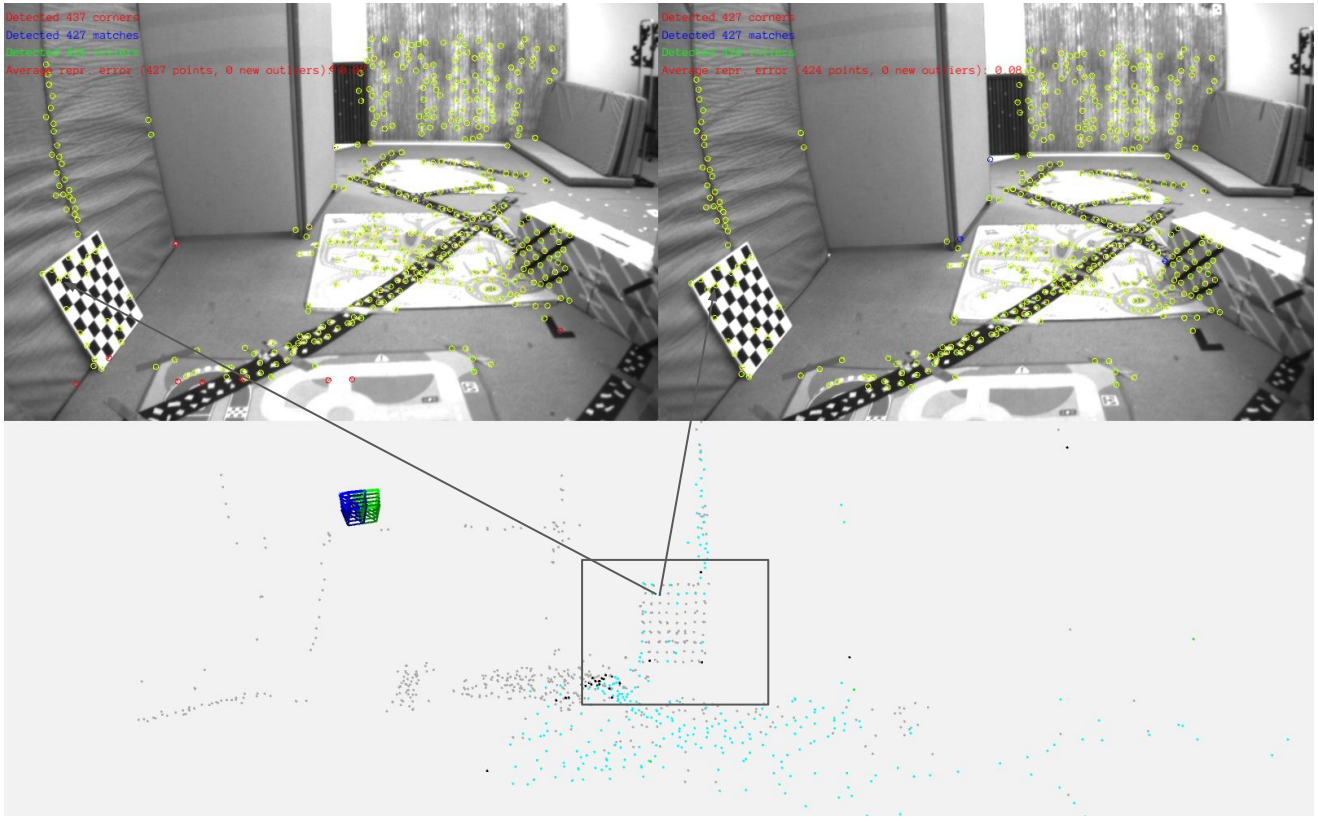
Stereo Matching with Optical Flow: Basalt



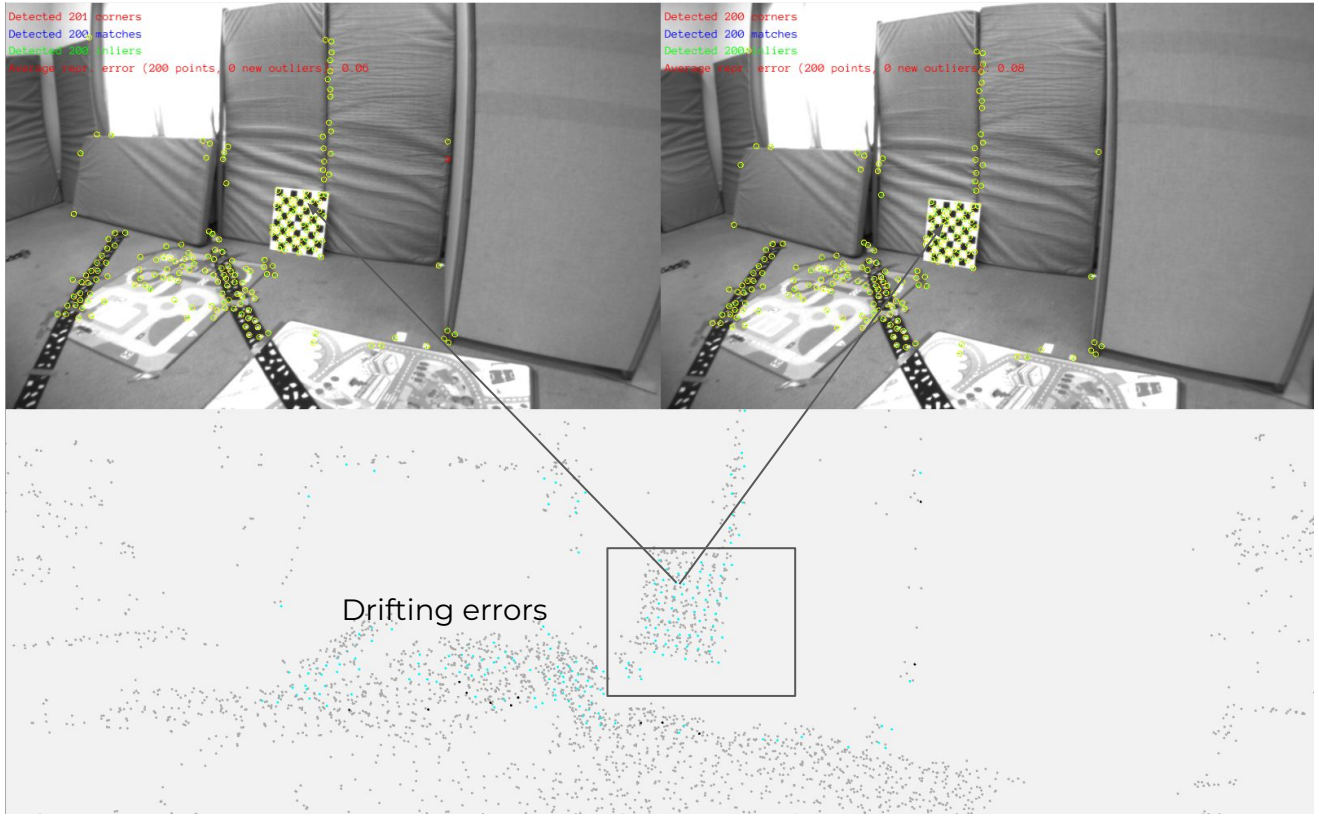
Shortcomings of the Method

- Frame to frame approach slower than Key Frame approach
- Detecting new keypoints slows down the system for a while
- Drift accumulation
- Optical flow fails in case of moves with big baseline (More robust with image pyramids)

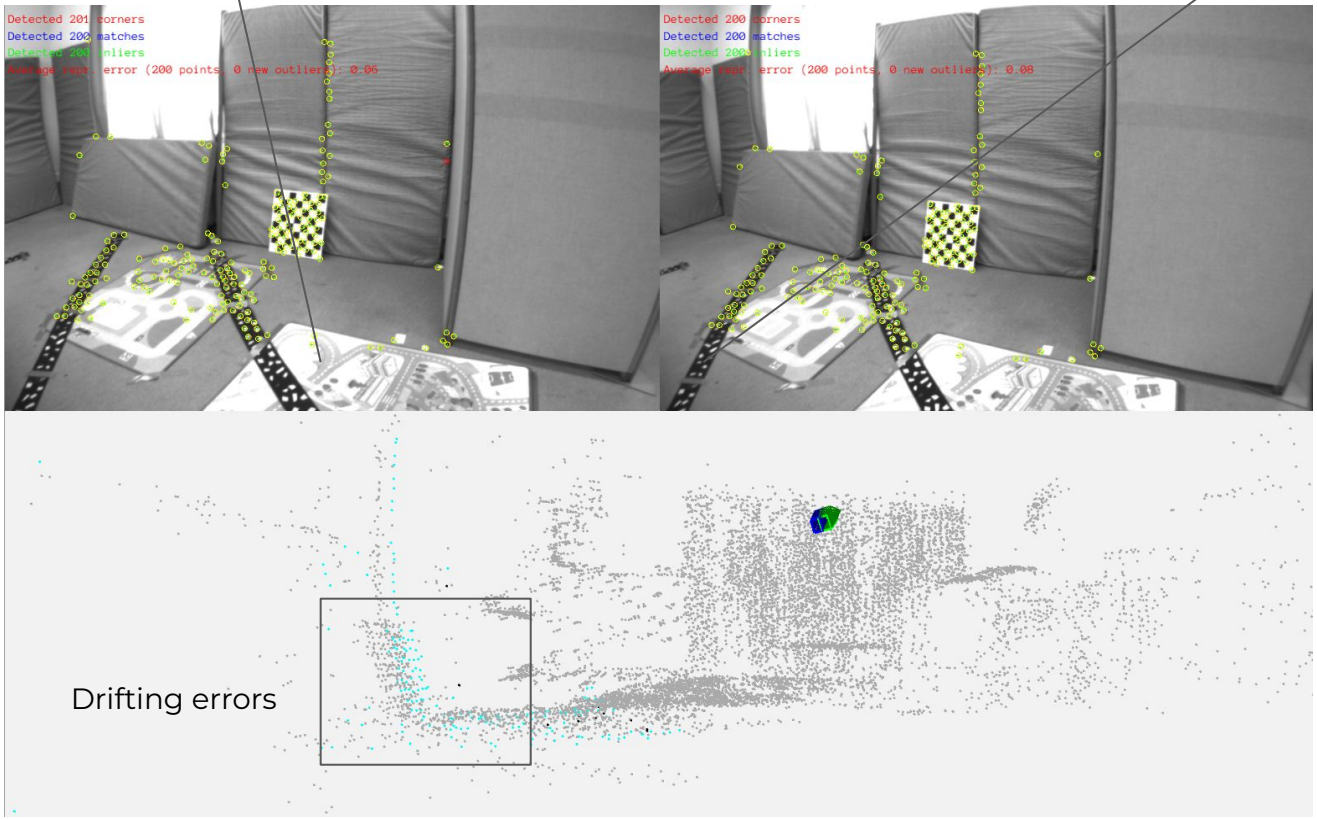
Effect of the Drift (Frame ~380)



Effect of the Drift (Frame ~ 1200)



Effect of the Drift (Frame ~2200)



Possible Extensions for Shortcomings

- Frame to frame will be slower inherently, possible parallelization of code
- Divide image in a grid and detect Keypoints separately for each grid
- For drift, loop closure is necessary

Conclusion

- Frame to frame drift is inevitable
- Good optical flow is more robust than descriptor matching
- Camera sequences with very big movements are not suitable

References

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2. Equivalence and efficiency of image alignment algorithms (Baker, Simon, and Iain Matthews), In IEEE Computer Society Conference on Computer Vision and Pattern Recognition. Vol. 1. IEEE Computer Society; 1999, 2001. http://citeseerx.ist.psu.edu/ viewdoc/download?doi=10.1.1.70.20&rep=rep1&type=pdf
3. Basalt Codebase: https://gitlab.com/VladyslavUsenko/basalt
4. https://docs.opencv.org/3.4/d4/dee/tutorial_optical_flow.html
5. EVO https://github.com/MichaelGrupp/evo
6. RPG Toolbox https://github.com/uzh-rpg/rpg_trajectory_evaluation