Indirect Visual Odometry with Optical Flow

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Vision Based Navigation

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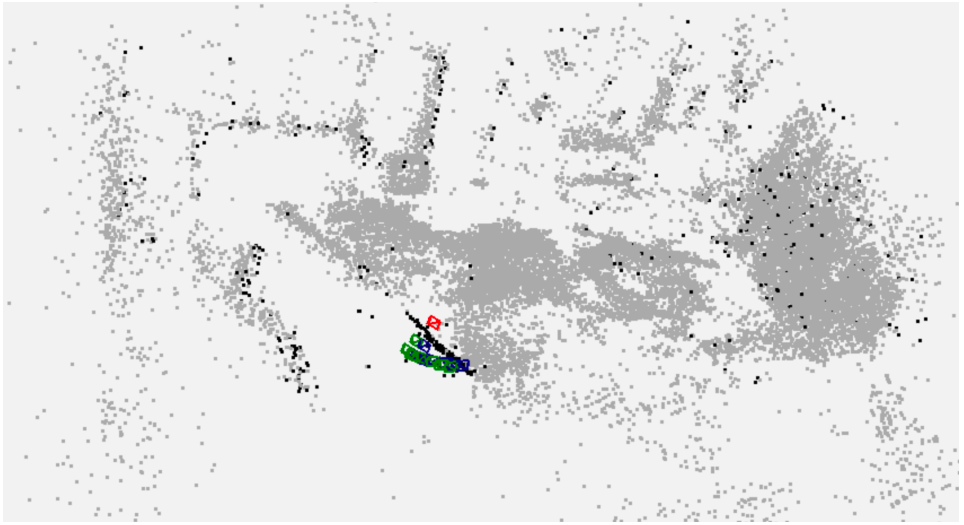
Visual Odometry



- What we had after exercises:
  - keypoints and descriptors
  - match keypoints and keypoint – landmark pairs using descriptors
- Goal: use optical flow to track (and match) keypoints

Optical Flow

- Motion from image sequence
- ill posed problem, need assumptions

(OpenCV)

- Assumption: Brightness constancy
  - $I(x, y, t) = I(x + \Delta x, y + \Delta y, t + \Delta t)$

- Optical Flow Constraint: $\boxed{\nabla I^T \vec{v} + I_t = 0}$ (via Taylor exp)

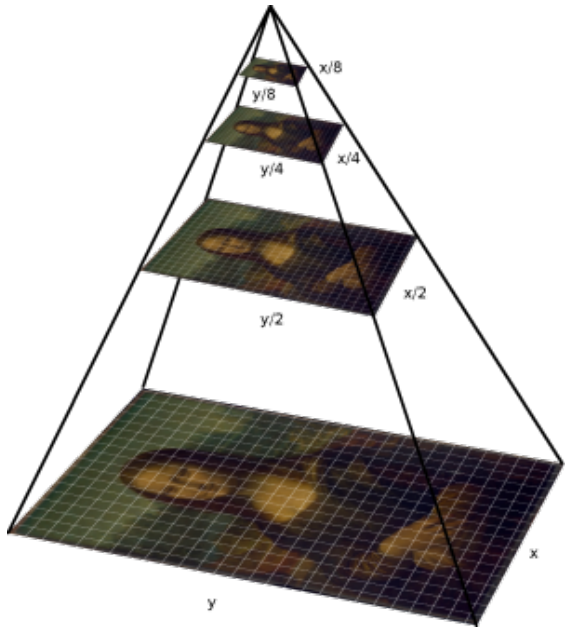
- need another assumption to solve

Lucas – Kanade Method

- Assumption: movement is **constant** in local neighborhoods around pixels

- Solve optical flow for all pixels in local neighborhood via least squares approach

- Use **image pyramids** to track points
  - from level n to level 0 (original image)



(IIPImage)

Method

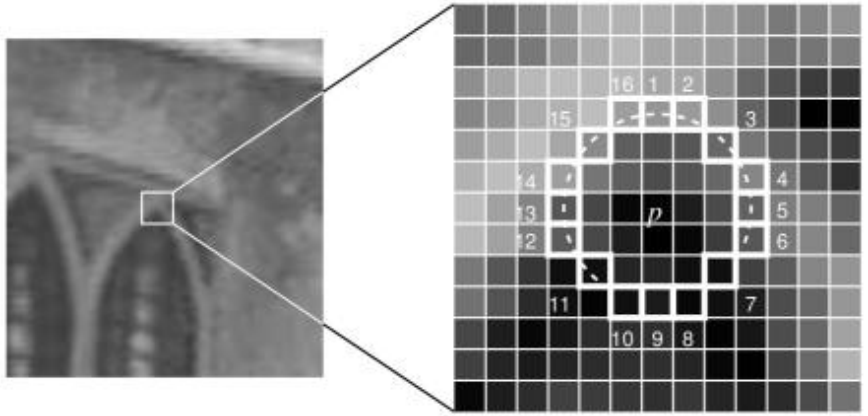
- Select keypoints for first frame
- Track keypoints
- Add new keypoints (if necessary)
- Track keypoints from left image to right image for stereo matches

- Triangulate stereo matches
- Add new landmarks
- Optimize via reprojection error of landmark observations

same logic as before

Keypoint Selection

- FAST feature detector
  - cv::FAST

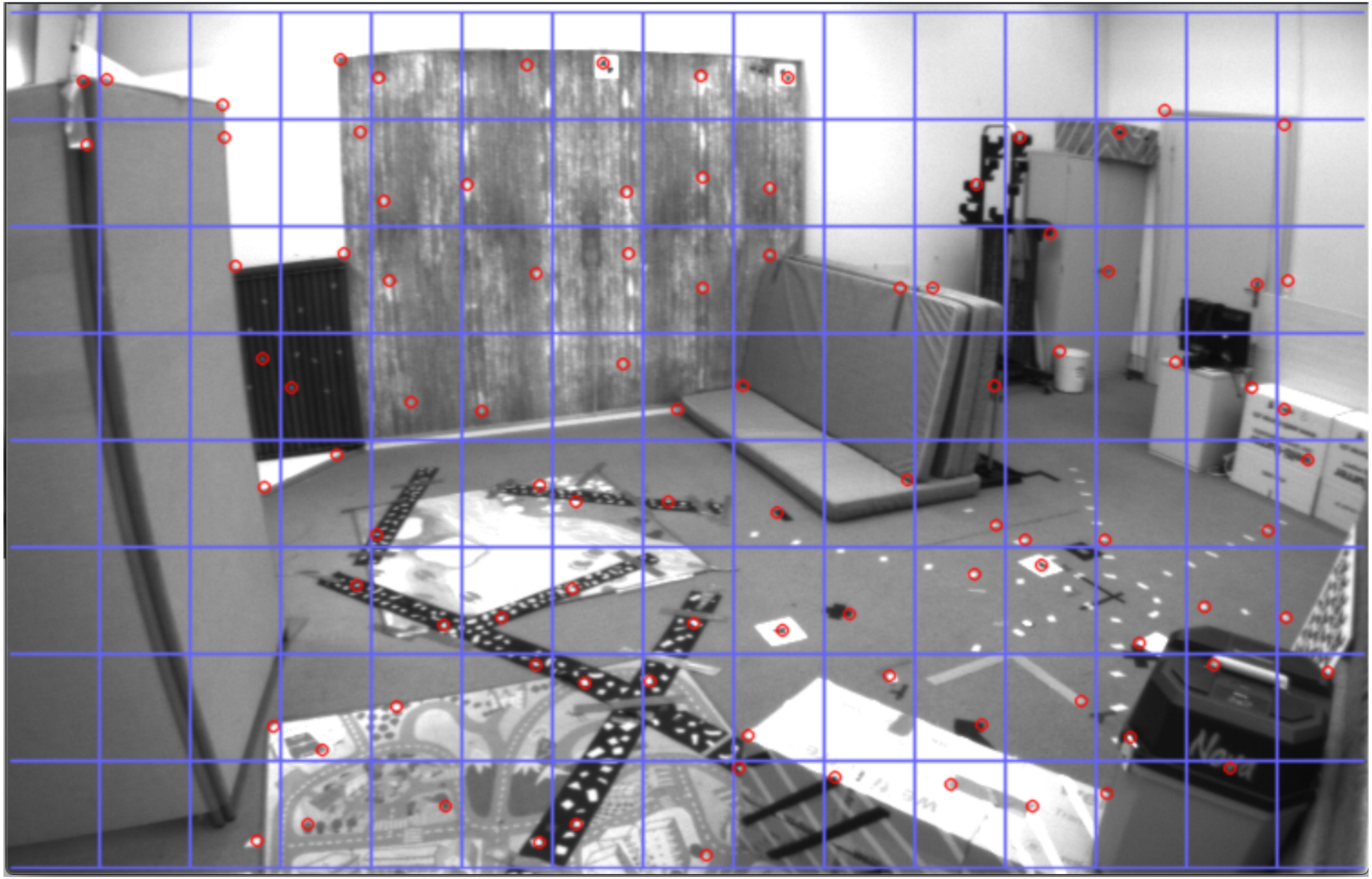


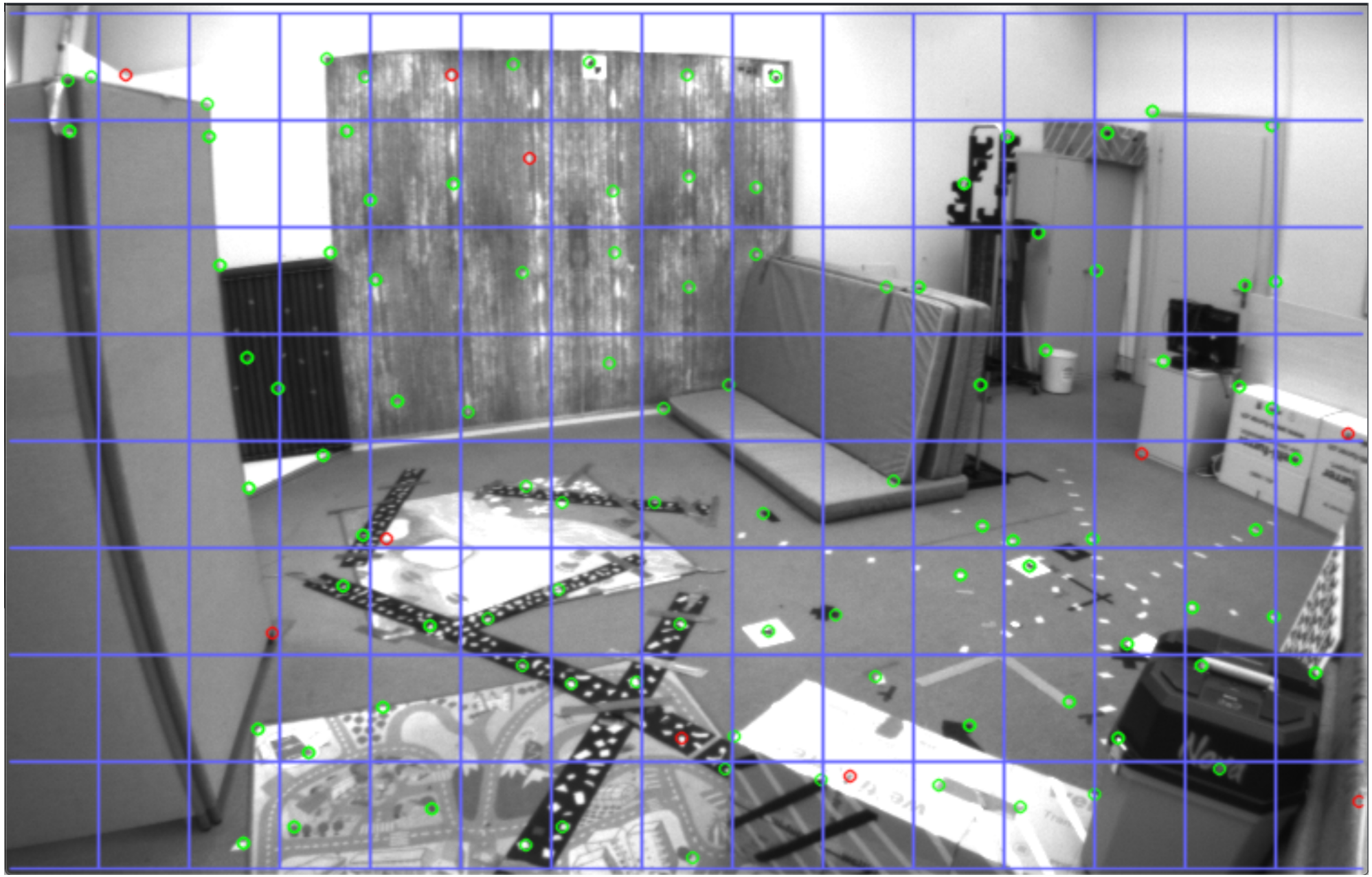
n contiguous brighter or darker pixels

➢Consider image as a grid

- evaluate each cell separately
- add selected number of keypoints if possible

➢Do not pick keypoints very close to each other





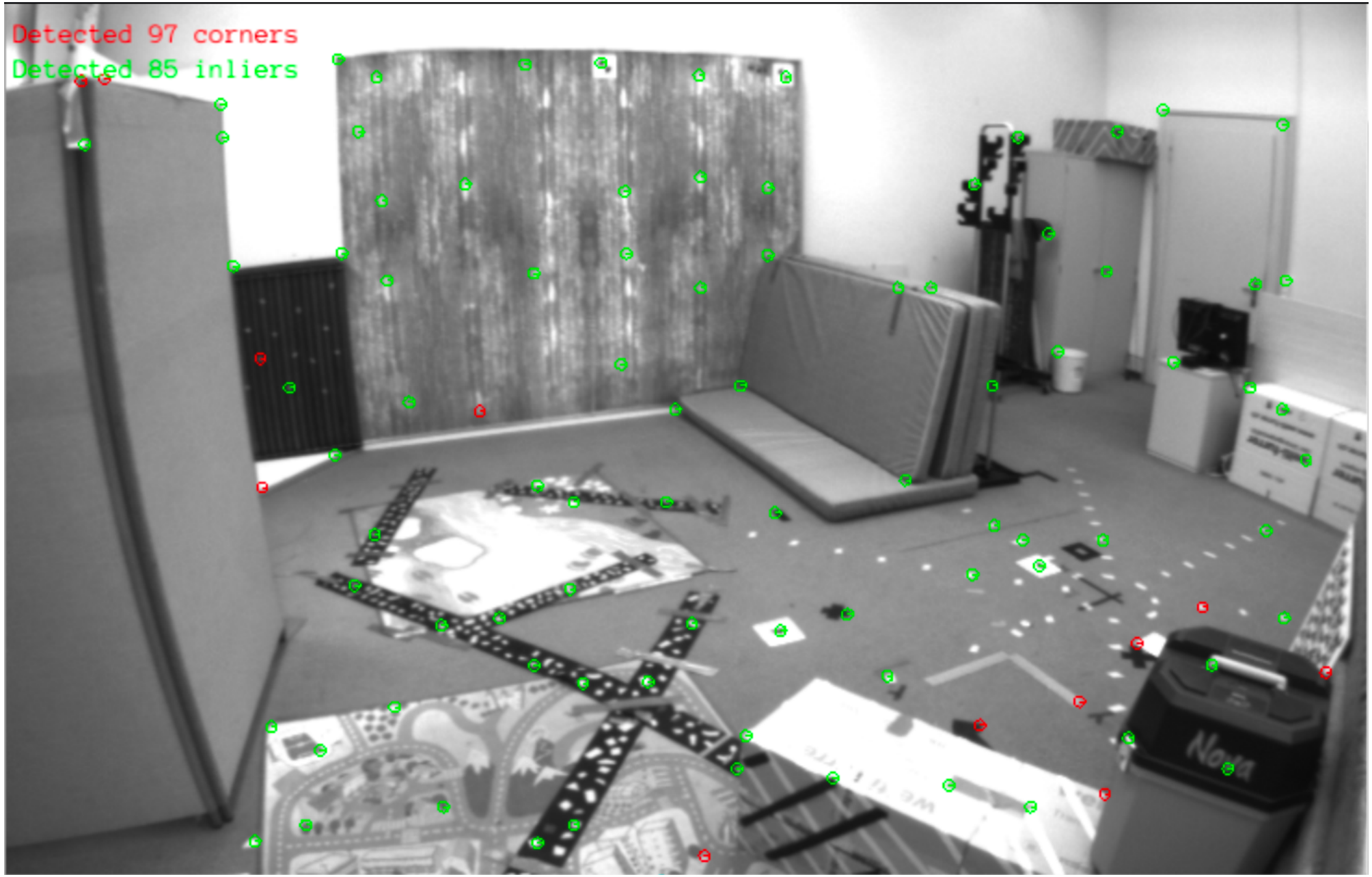
Tracking via Optical Flow

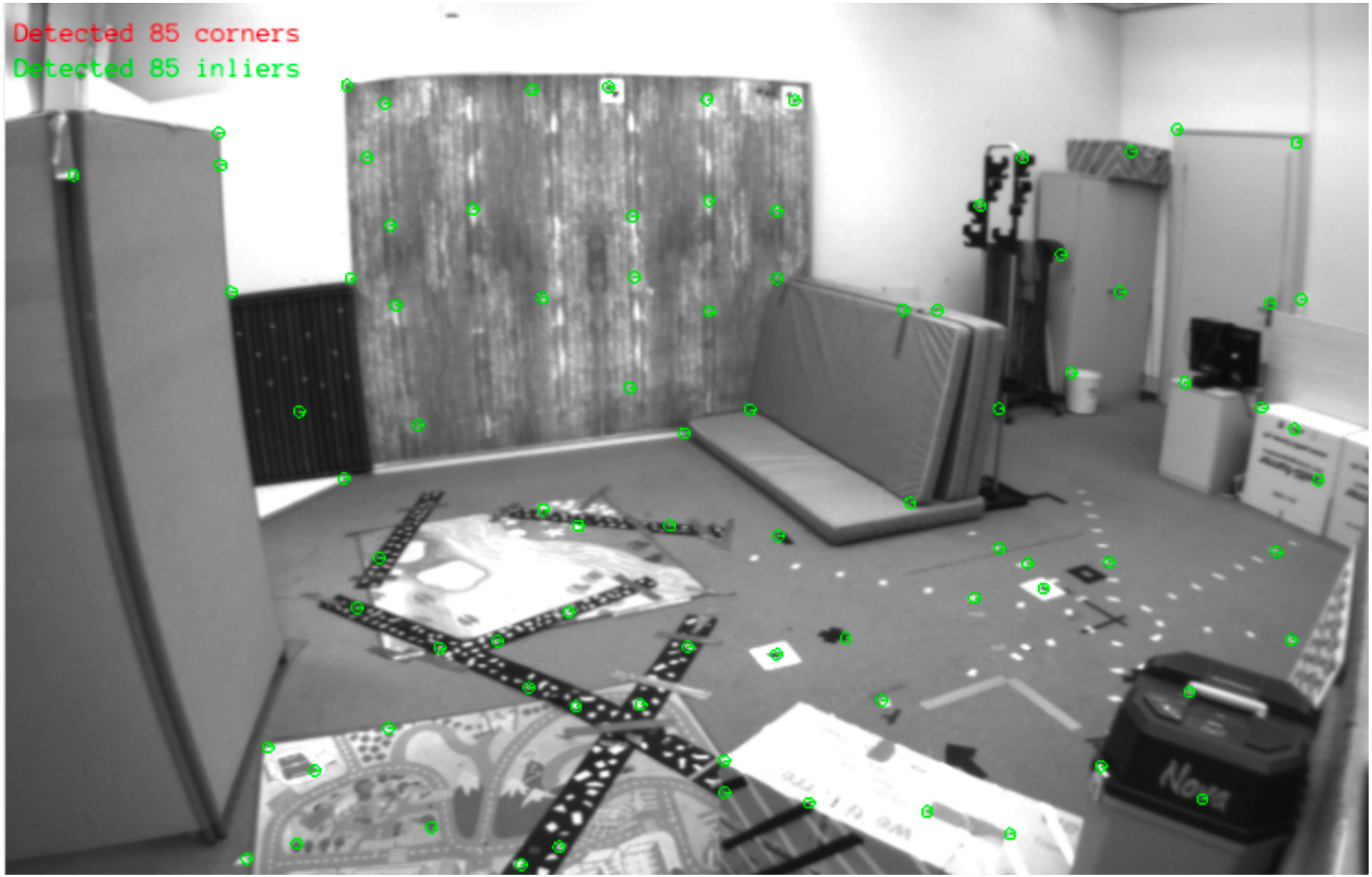
- cv:: calcOpticalFlowPyrLK
  - implementation of Lucas – Kanade method with image pyramids

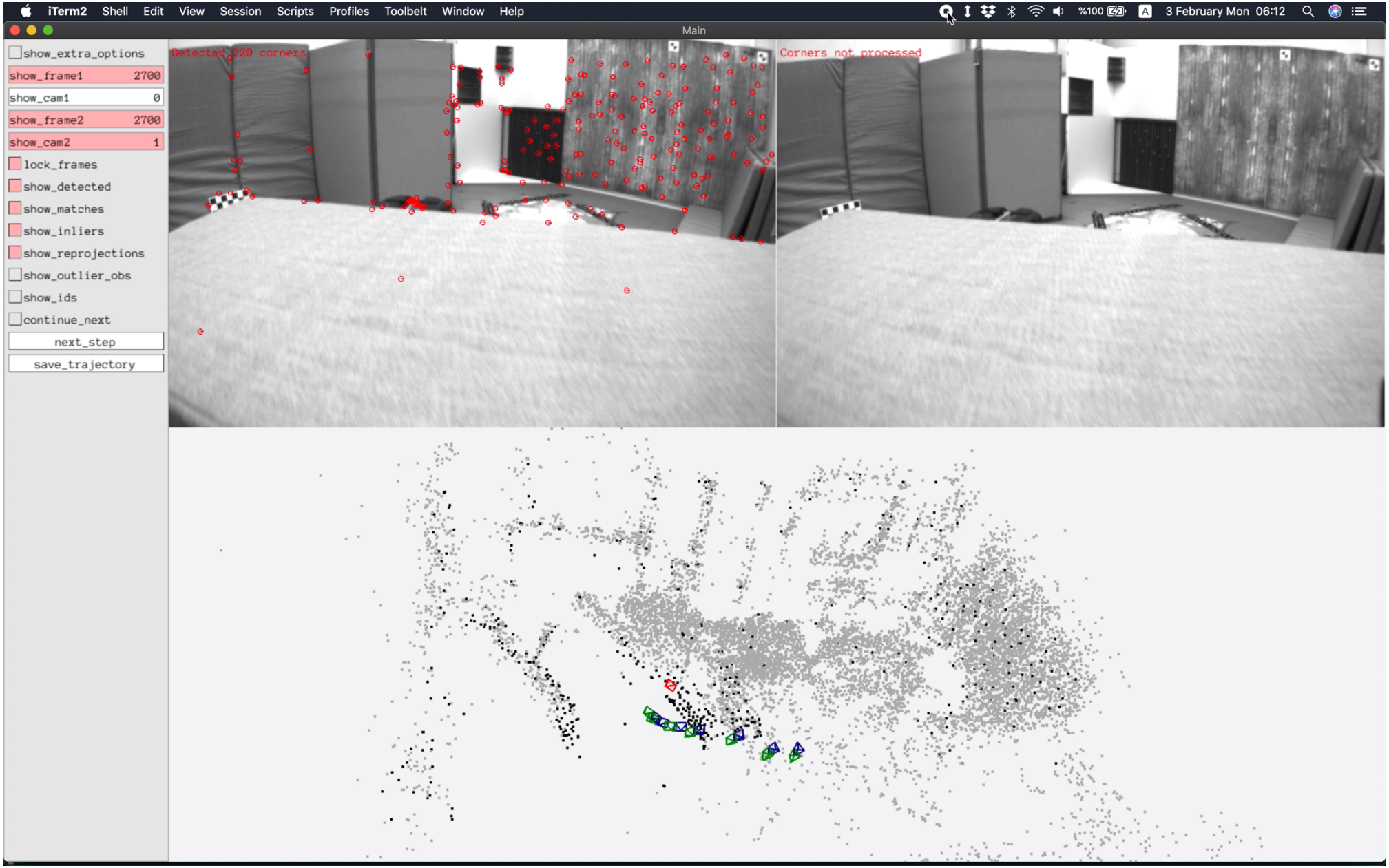
➢Apply optical flow twice to track back points.

Only select points which are near the original point

➢Apply epipolar constraint for stereo images


Detected 97 corners
Detected 85 inliers


Detected 85 corners
Detected 85 inliers


iTerm2 Shell Edit View Session Scripts Profiles Toolbelt Window Help
%100 3 February Mon 06:12
Main
show_extra_options
show_frame1 2700
show_cam1 0
show_frame2 2700
show_cam2 1
lock_frames
show_detected
show_matches
show_inliers
show_reprojections
show_outlier_obs
show_ids
continue_next
next_step
save_trajectory
Detected 220 corners
Corners not processed

Evaluation

- Runtime

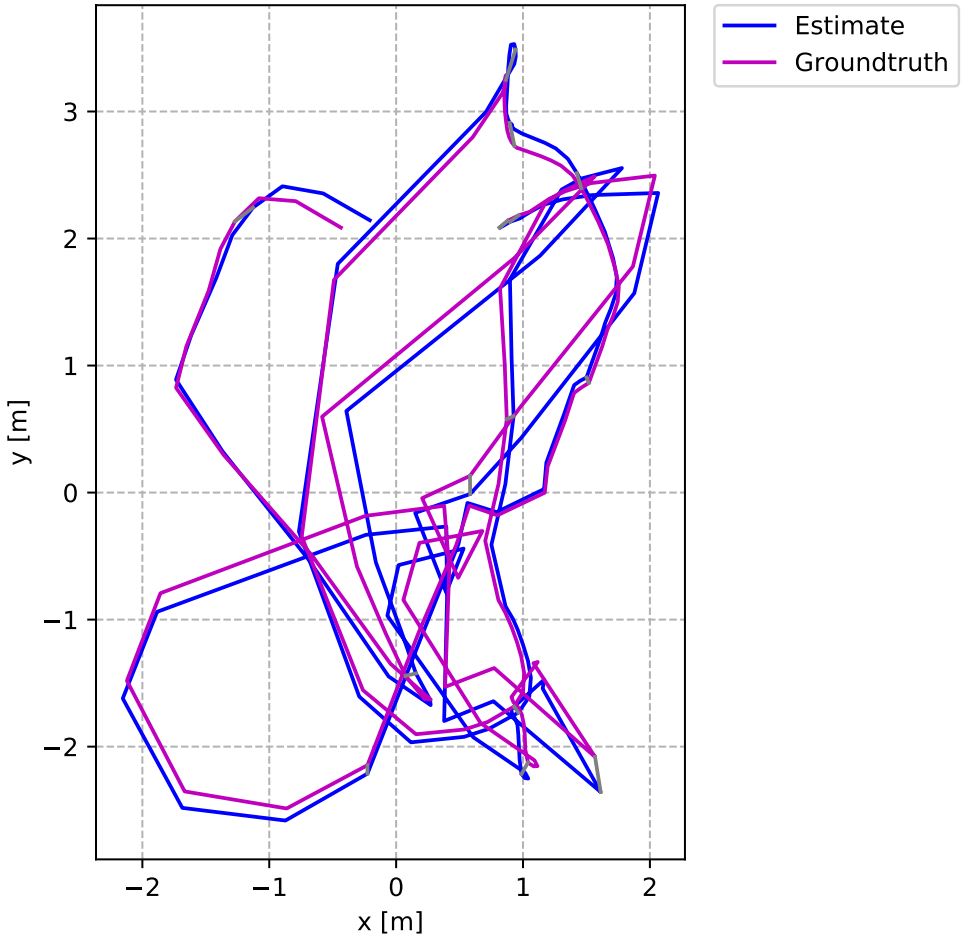
- Absolute Trajectory Error
  - align trajectories
  - compute difference between each pair of camera poses
  - root mean square error

  - github: uzh-rpg/rpg_trajectory_evaluation (visualization and evaluation)
    - Zhang et al. IROS 2018
  - tum rgbd_benchmark_tools (evaluation)
    - Sturm et al. IROS 2012

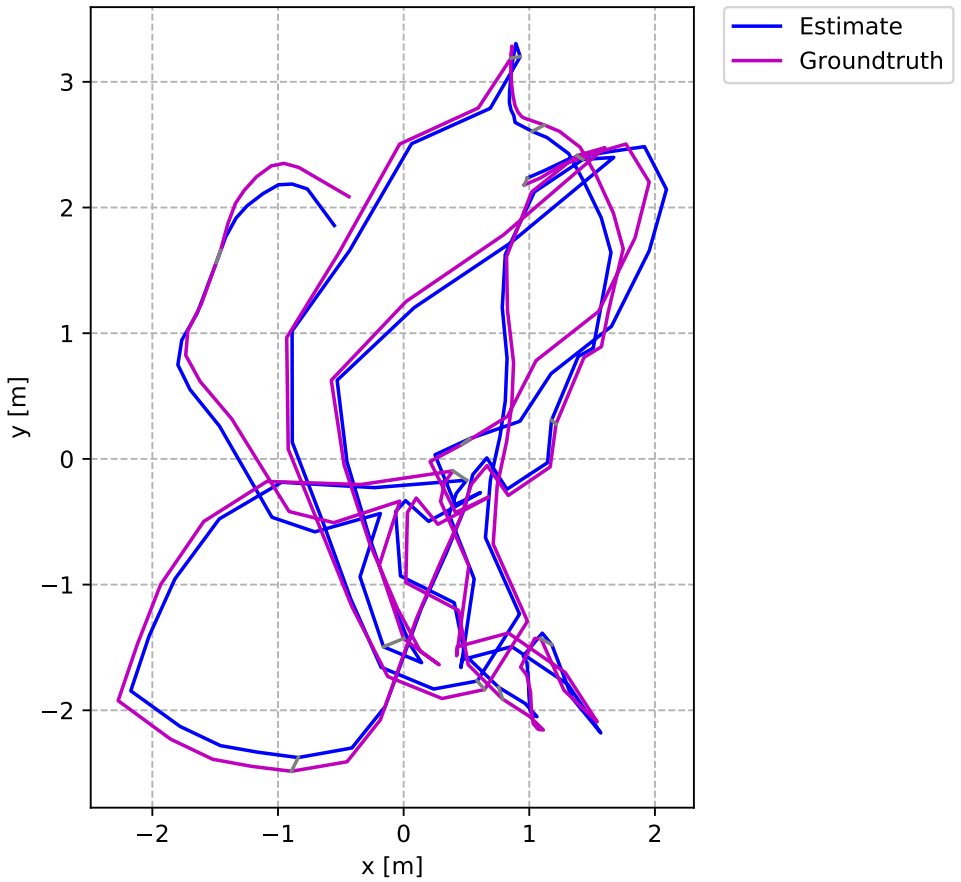
Results

Method	RMS ATE (m)	RMS ATE stddev	Runtime (s)	Runtime stddev
VO optical flow	0.143596	0.043500	47.44	0.41
VO descriptor	0.122272	0.031707	52.76	0.97

Each method is run 5 times



optical flow (0.144867)



descriptor (0.127981)

Conclusion

- No feature descriptor computation
- Relatively faster

- Slightly worser performance than descriptor based VO

Thank you for listening

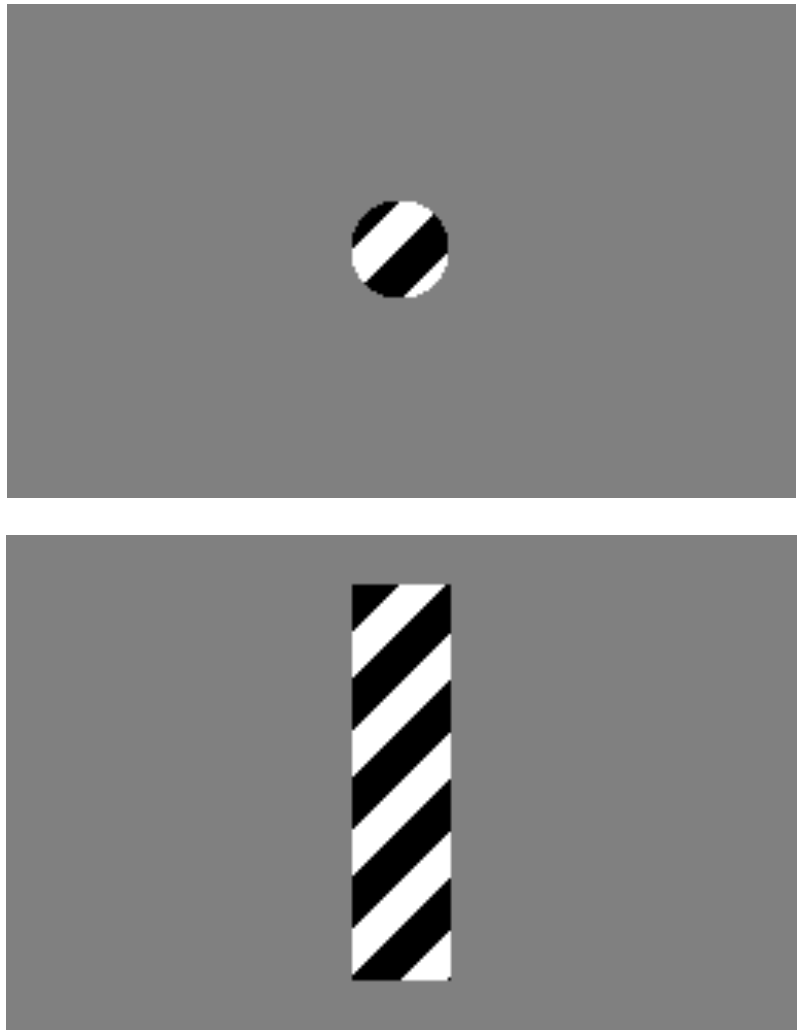
References

- **Visual-Inertial Mapping with Non-Linear Factor Recovery** (V. Usenko, N. Demmel, D. Schubert, J. Stueckler and D. Cremers), *In IEEE Robotics and Automation Letters (RA-L) & Int. Conference on Intelligent Robotics and Automation (ICRA)*, IEEE, volume 5, 2020.
- **Machine learning for high-speed corner detection** (Rosten, Edward, and Tom Drummond), *European conference on computer vision, 2006*
- **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.
- **A Tutorial on Quantitative Trajectory Evaluation for Visual(-Inertial) Odometry** (Zhang, Zichao and Scaramuzza, Davide), IEEE/RSJ Int. Conf. Intell. Robot. Syst. (IROS), 2018
- **A Benchmark for the Evaluation of RGB-D SLAM Systems** (J. Sturm, N. Engelhard et al.), Proc. of the International Conference on Intelligent Robot Systems (IROS), 2012

Aperture Problem

- Cannot see motion in direction of constant brightness

- Need to make another assumption
  - determines the optical flow method



Same motion both both image
Barberpole illusion (Wikipedia)