Practical Course: Vision-based Navigation
Summer Semester 2019

Projects

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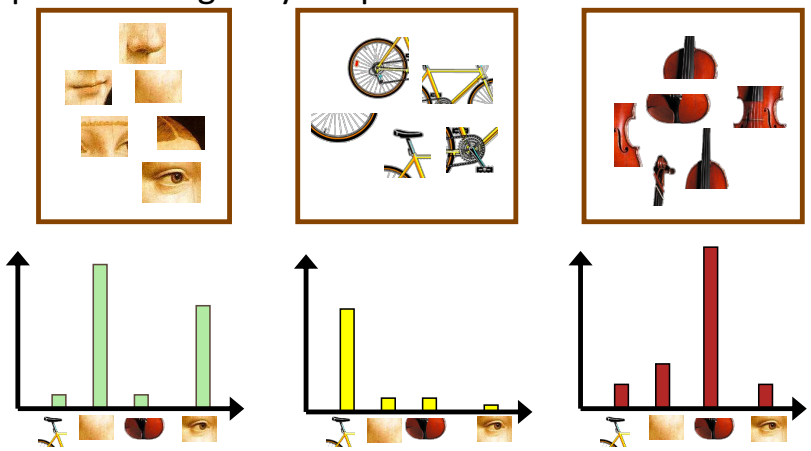
1. Bag of Words for Place Recognition

1. Extract local features
2. Learn “visual vocabulary”
3. Quantize local features using visual vocabulary
4. Represent images by frequencies of “visual words”

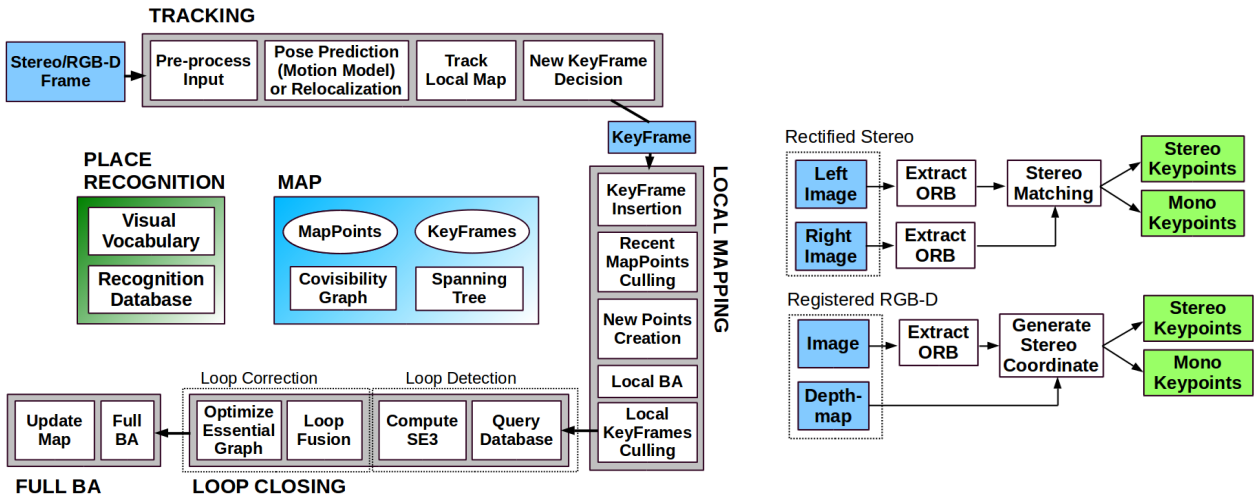


Slide credit: Svetlana Lazebnik

- Applications:
  - SfM: Speed up pairwise matching
  - SLAM: re-localization, loop-closure

- DBoW2/3
  - Paper: http://doriangalvez.com/papers/GalvezTRO12.pdf
  - Code: https://github.com/rmsalinas/DBow3
- HBST: A Hamming Distance embedding Binary Search Tree
  - Paper: https://arxiv.org/abs/1802.09261
  - Code: https://gitlab.com/srrg-software/srrg_hbst

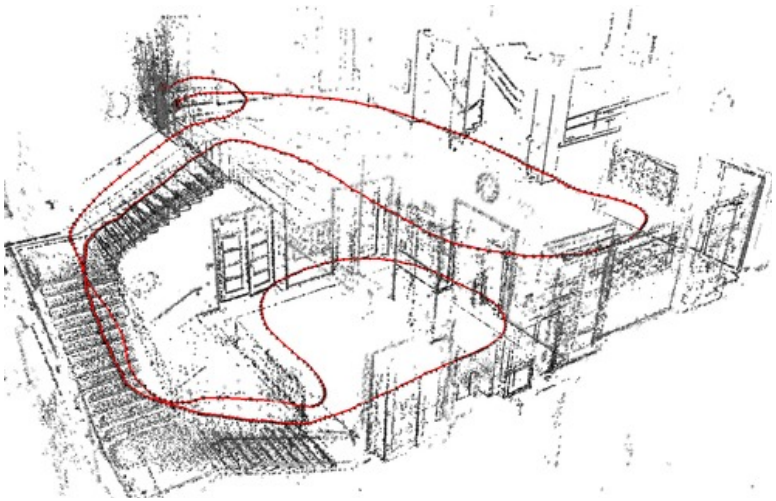
2. SLAM



(a) System Threads and Modules. (b) Input pre-processing

- ORB_SLAM: http://webdiis.unizar.es/~raulmur/MurMontielTardosTRO15.pdf
- ORB_SLAM2: https://arxiv.org/abs/1610.06475
- Map management
- Reusing Keyframes
- Spanning tree for optimization

3. Photometric Bundle Adjustment

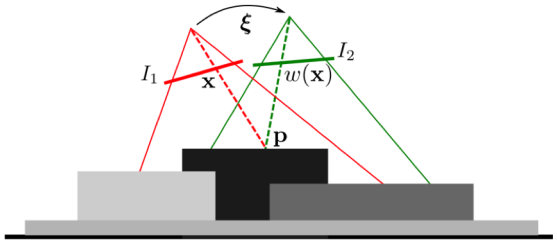


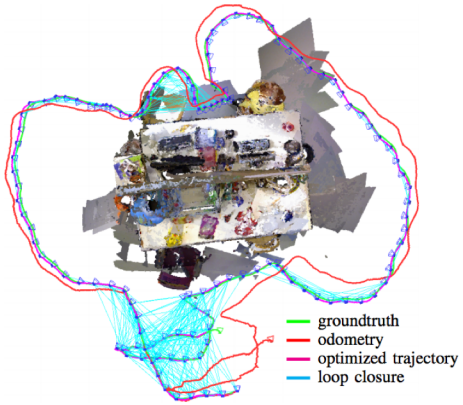
$$E_{\mathbf{p}j} := \sum_{\mathbf{p}\in\mathcal{N}_{\mathbf{p}}} w_{\mathbf{p}} \left\| (I_j[\mathbf{p}'] - b_j) - \frac{t_j e^{a_j}}{t_i e^{a_i}} (I_i[\mathbf{p}] - b_i) \right\|_{\gamma}$$

- Photometric Bundle adjustment in SFM
  - Error metric similar to DSO (https://arxiv.org/pdf/1607.02565.pdf)
  - Initialize and optimize additional (non-feature) points
  - Possibly use vignetting and response from online calibration

4. Direct Visual Odometry for RGB-D Images

- Estimate the relative pose via Direct Image Alignment
- Implement Gauss-Newton (or LM) manually
- Frame-to-frame or frame-to-keyframe
- Different image warping strategies
- coarse-to-fine to improve convergence
- robust-norm to handle outliers

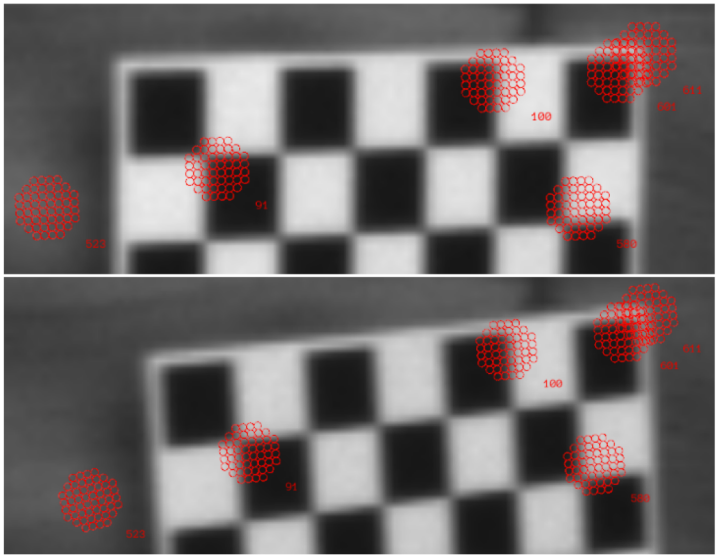




- **Robust Odometry Estimation for RGB-D Cameras** (C. Kerl, J. Sturm and D. Cremers), *In International Conference on Robotics and Automation (ICRA)*, 2013.
  https://vision.in.tum.de/_media/spezial/bib/kerl13icra.pdf
- **Equivalence and efficiency of image alignment algorithms** (Baker, Simon, and 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

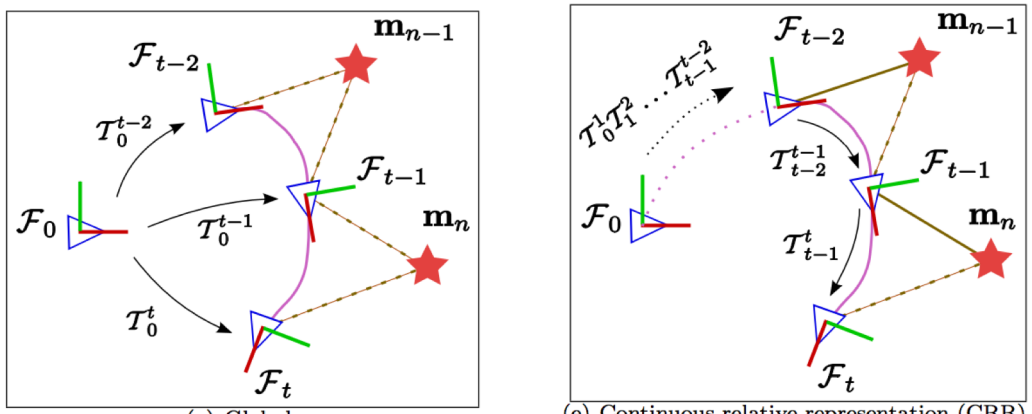
5. Indirect Visual Odometry with Optical Flow

- Sparse optical flow as alternative to feature matching
- Implement Gauss-Newton (or LM) manually
- image warping strategies
- patch similarity norms
- Keyframing, local optimization



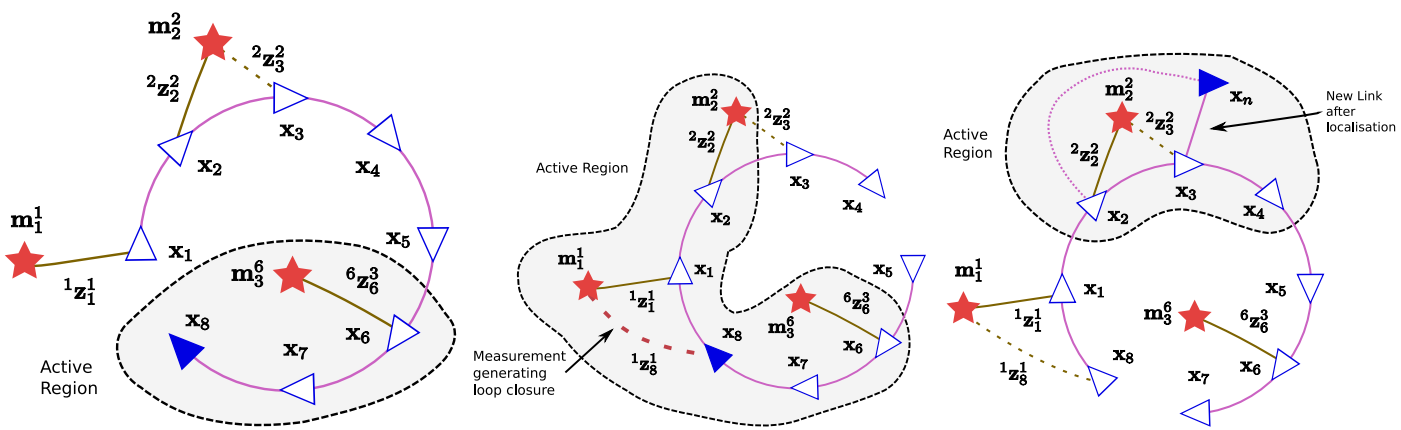
- **Visual-Inertial Mapping with Non-Linear Factor Recovery** (V. Usenko, N. Demmel, D. Schubert, J. Stueckler and D. Cremers), *In arXiv:1904.06504*, 2019.
  https://arxiv.org/pdf/1904.06504
- **Equivalence and efficiency of image alignment algorithms** (Baker, Simon, and Iain Matthews), *In IEEE Computer 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

6. Relative Map Formulation for SLAM



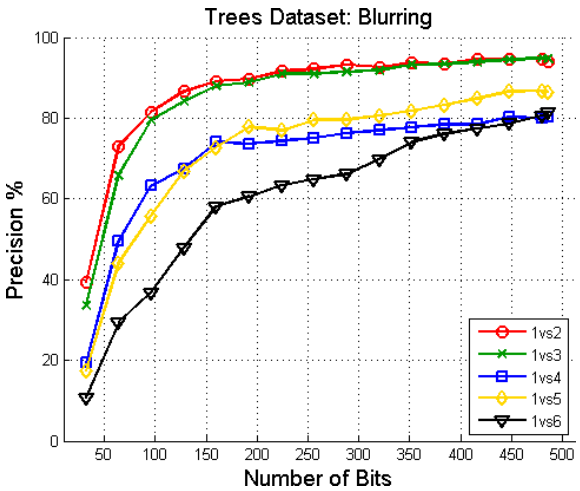
(a) Global (e) Continuous relative representation (CRR)

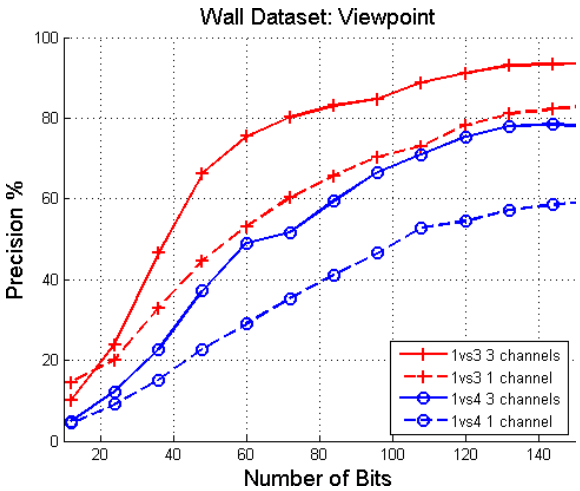
- Change the map formulation to the relative one
- All points are defined relative to some frame
- Paper: http://www.robots.ox.ac.uk/~mobile/Papers/2010IJCV_mei.pdf

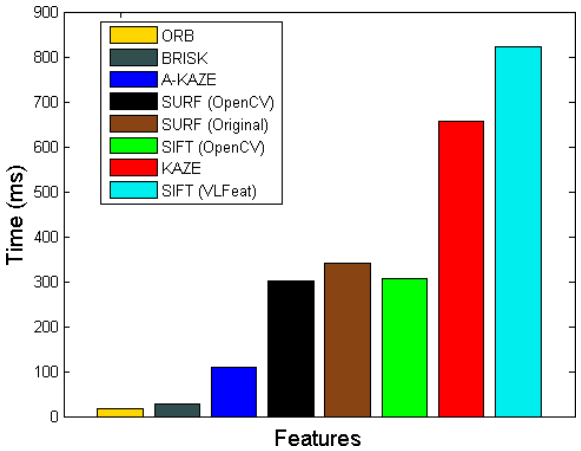


(a) (b) (c)

7. Advanced Matching and Keypoint Evaluation

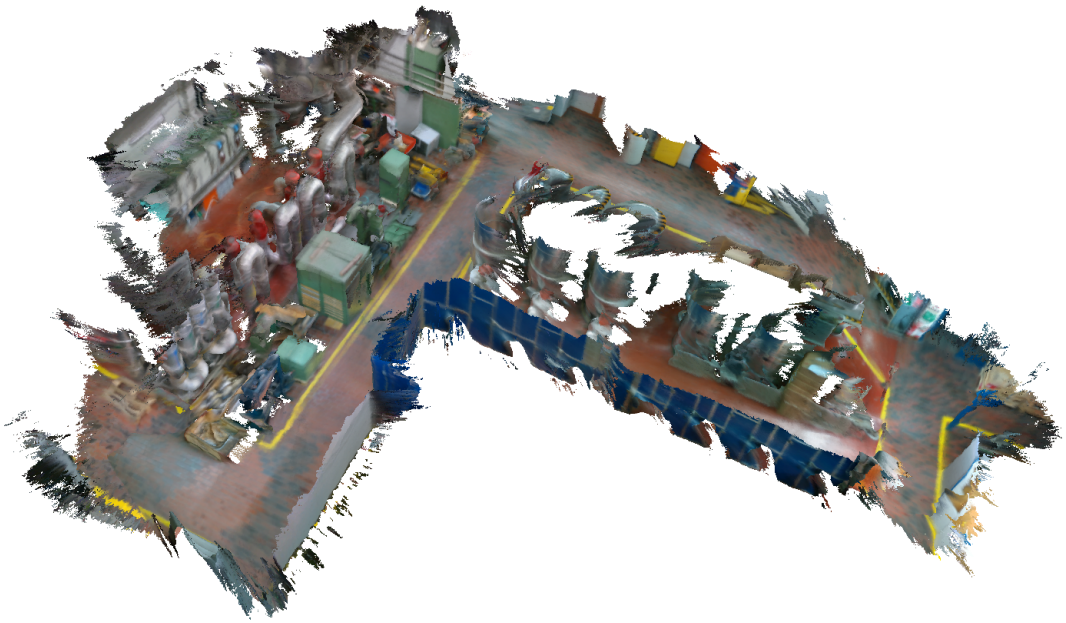






- Keypoints evaluation:
  - ORB, AKAZE, SIFT, BRISK
  - Computation time / Matching statisctics
- Cascade Hashing for descriptor matching:
  - http://www.nlpr.ia.ac.cn/jcheng/papers/CameraReady-CasHash.pdf

8. Dense 3D reconstruction for SFM



- PSMNet
  - https://arxiv.org/abs/1803.08669
  - https://github.com/JiaRenChang/PSMNet
- Depth images Fusion
  - Voxblox: https://github.com/ethz-asl/voxblox