Real-Time 3D Visual SLAM with a Hand-Held RGB-D Camera

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Motivation

- Our goal:

  Learn 3D models of (indoor) scenes

- Applications:
  - Architecture
  - Gaming
  - Archaeology

Related Work

- Visual SLAM

  [Konolige, IROS 09], [Klein, ISMAR 09]

- Laser scanners

  [Wurm, ICRA 10]

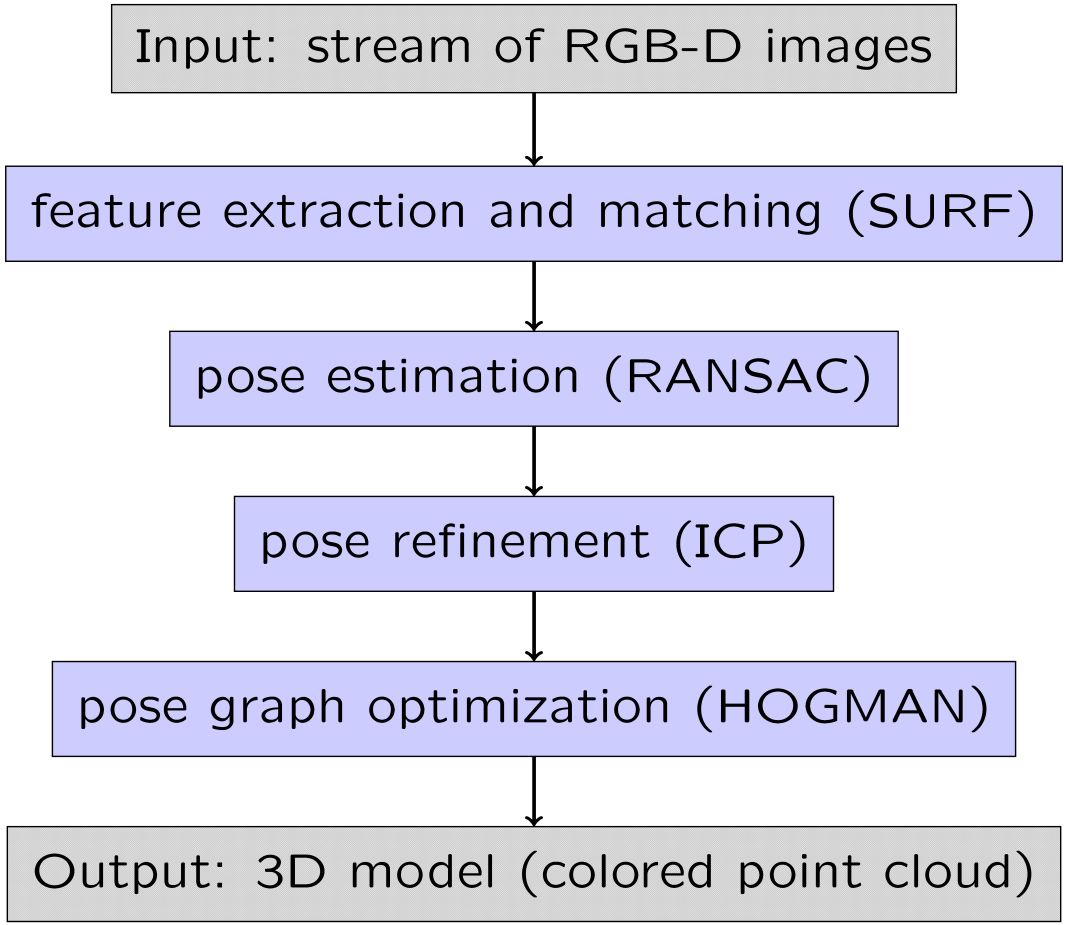
- RGB-D

  [Pitzer, ICRA 10], [Henry, ISER 10]

RGB-D Sensor

- Principle: structured light
  - IR projector + IR camera
  - RGB camera
- Dense depth images
- Full video frame rate

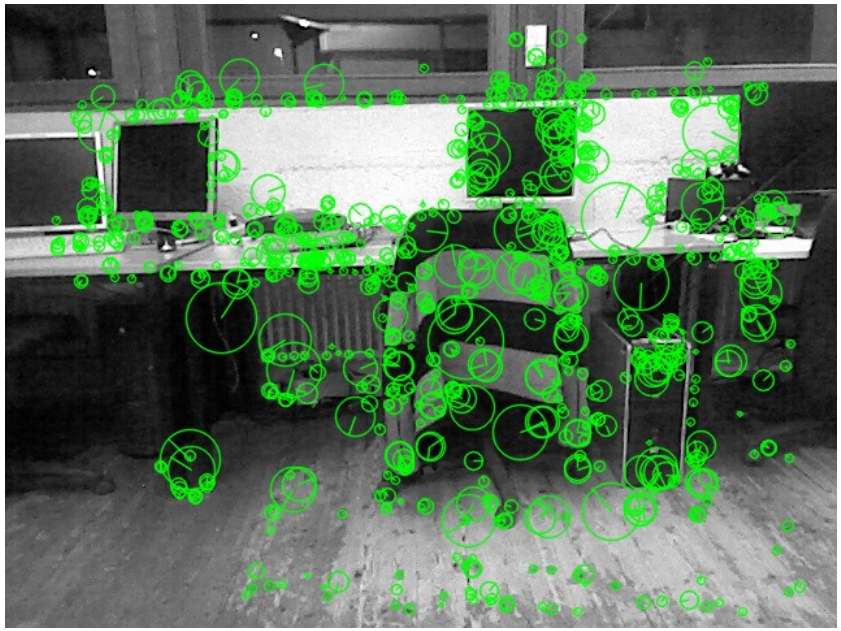
Schematic Overview



Feature Extraction and Matching

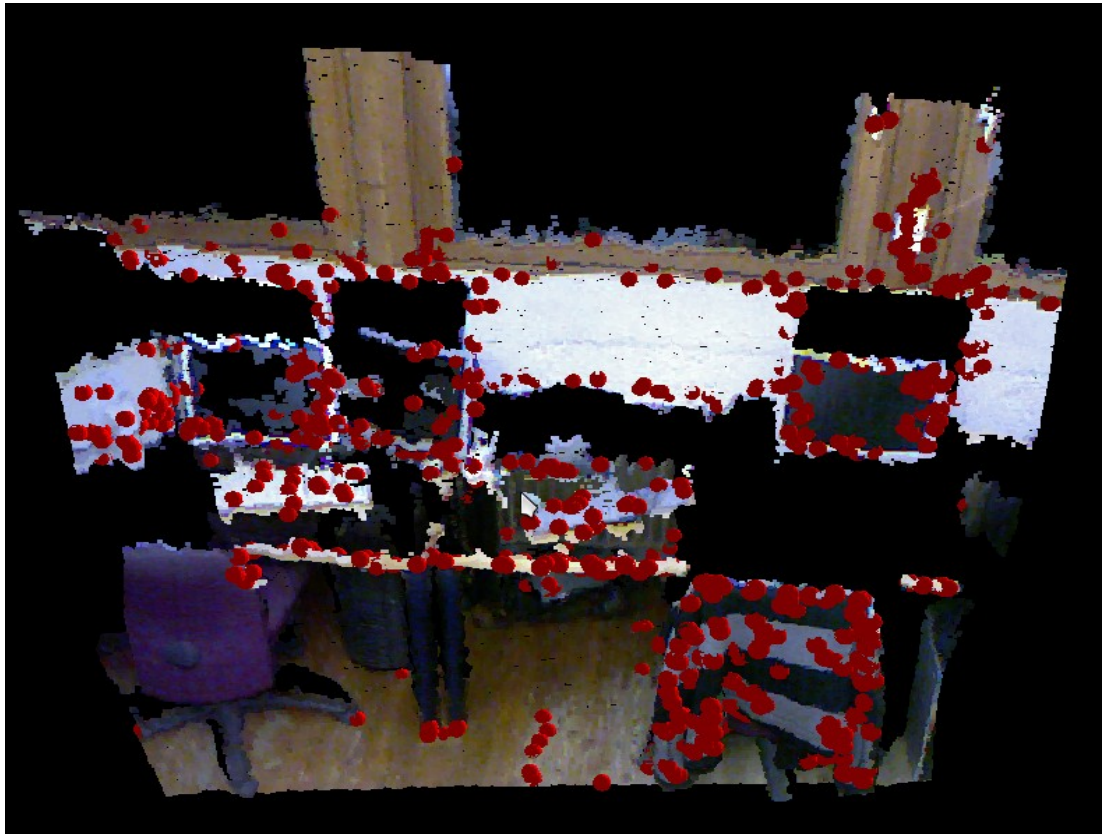
- SURF: scale and rotation invariant descriptor

- Runtime
  - 600-800 features
  - OpenCV: 1 sec
  - SurfGPU: 40 ms
- Matching
  - FLANN
  - < 15 ms



Features in 3D

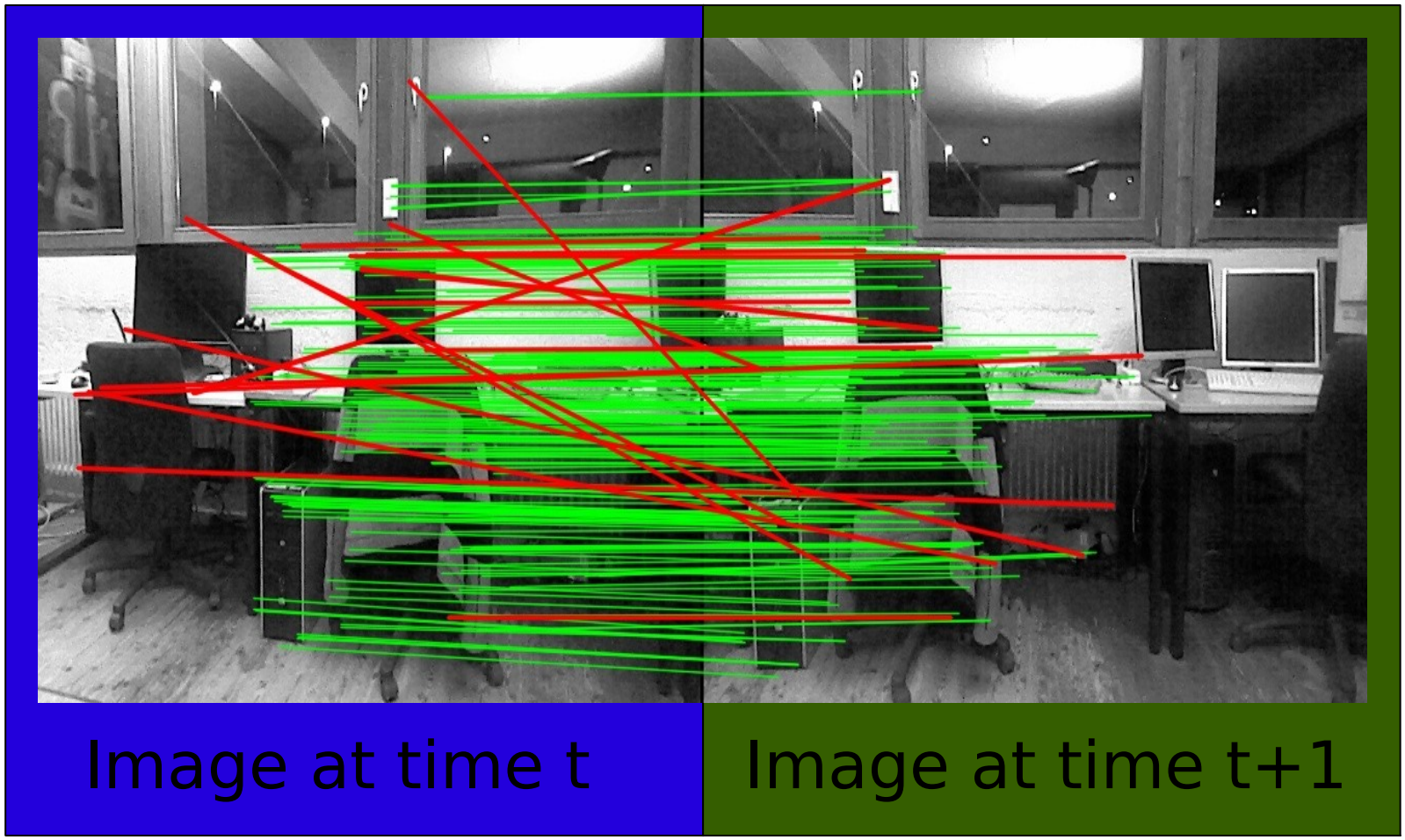
- Associate features with 3D points
- Problem: missing data (glass, occlusion)



Estimate Relative Pose

- RANSAC: good for estimating models in the presence of outliers
- Algorithm:
  - Find correspondences
  - Repeatedly sample three correspondences, estimate pose, count inliers (and optimize)
  - Return pose with most inliers
- Runtime: < 5 ms

Correspondences in 2D



Pose Refinement

- Iterative Closest Point
- Generalized ICP [Segal, 2009]
  - Plane-to-Plane metric
- Local optimization (prone to local maxima)
- Needs good initialization

- Runtime: ~500 ms on a sampled subset

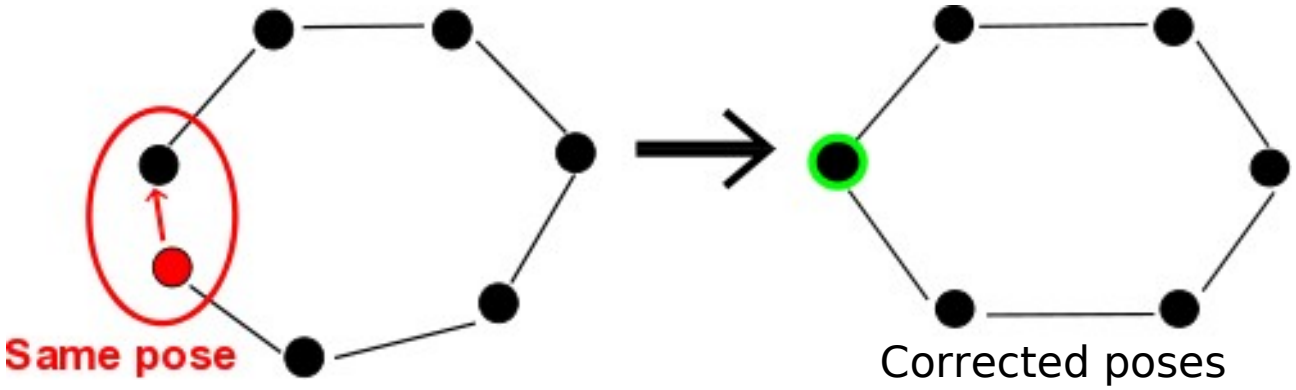
Pose Refinement (2)

Without ICP

With ICP

Loop Closing

- Summation of incremental error → drift
- Detect loops and average errors
- Model as pose graph
- Pose graph optimization [Grisetti, 2010]
  - System is over-determined
  - Needs to find the best globally consistent alignment



Example Pose Graph

- Axes = estimated camera poses
- White edges = relative transformations

Video (1/3)

[http://www.youtube.com/watch?v=XejNctt2Fcs]

Video 2/3

[http://www.youtube.com/watch?v=5qrBEPfEPaY]

Video 3/3

[http://www.youtube.com/watch?v=NR-ycTNcQu0]

Conclusions

- Visual SLAM system
  - SURF feature matching
  - RANSAC pose estimation
  - ICP pose refinement
  - Pose graph optimization
- Real-time
- Open-source (in ROS) + Tutorial available:
  http://www.ros.org/wiki/openni/Contests/ROS 3D/RGBD-6DSLAM

→ Live demo after the coffee break!

Future Work

- Ground truth evaluation using a Motion Capturing system (in cooperation with ETH Zurich)
- Improve speed of ICP
- Parallelization

Thank you!