

# Natural Environment Monitoring at Georgia Tech

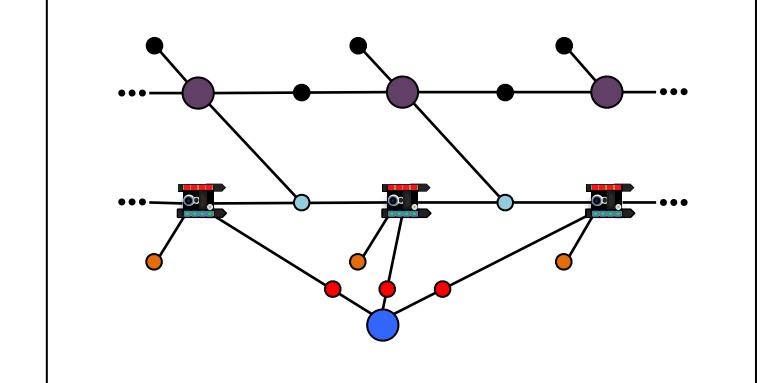
15 min

1. Introduction
2. Problem Constraints
3. SLAM
4. Loop Closures
5. Evaluation

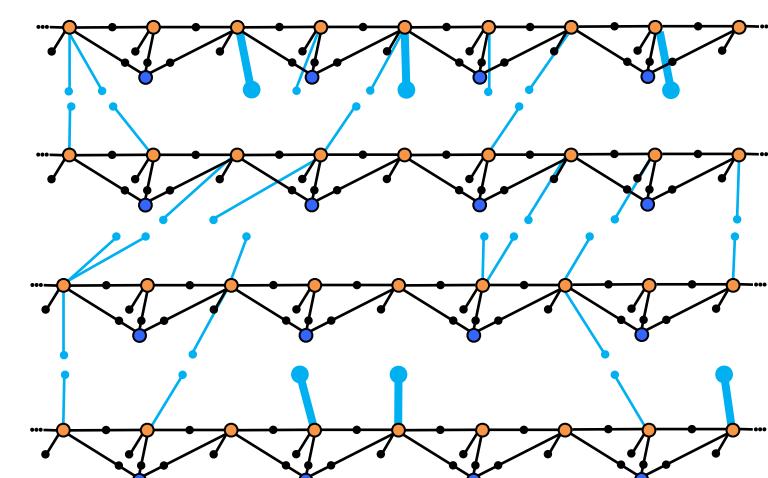
USV and Environment



One Session



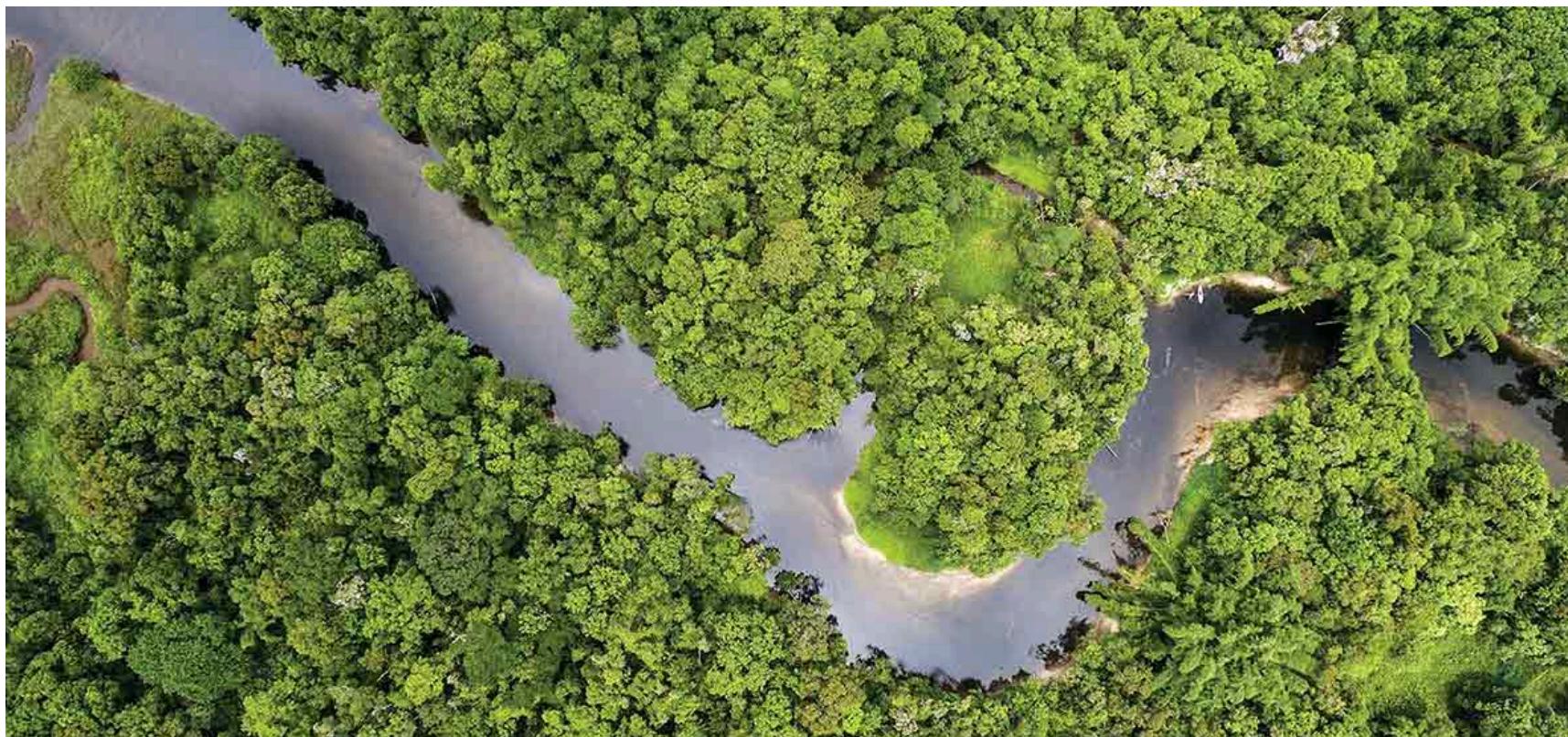
Multi-Session



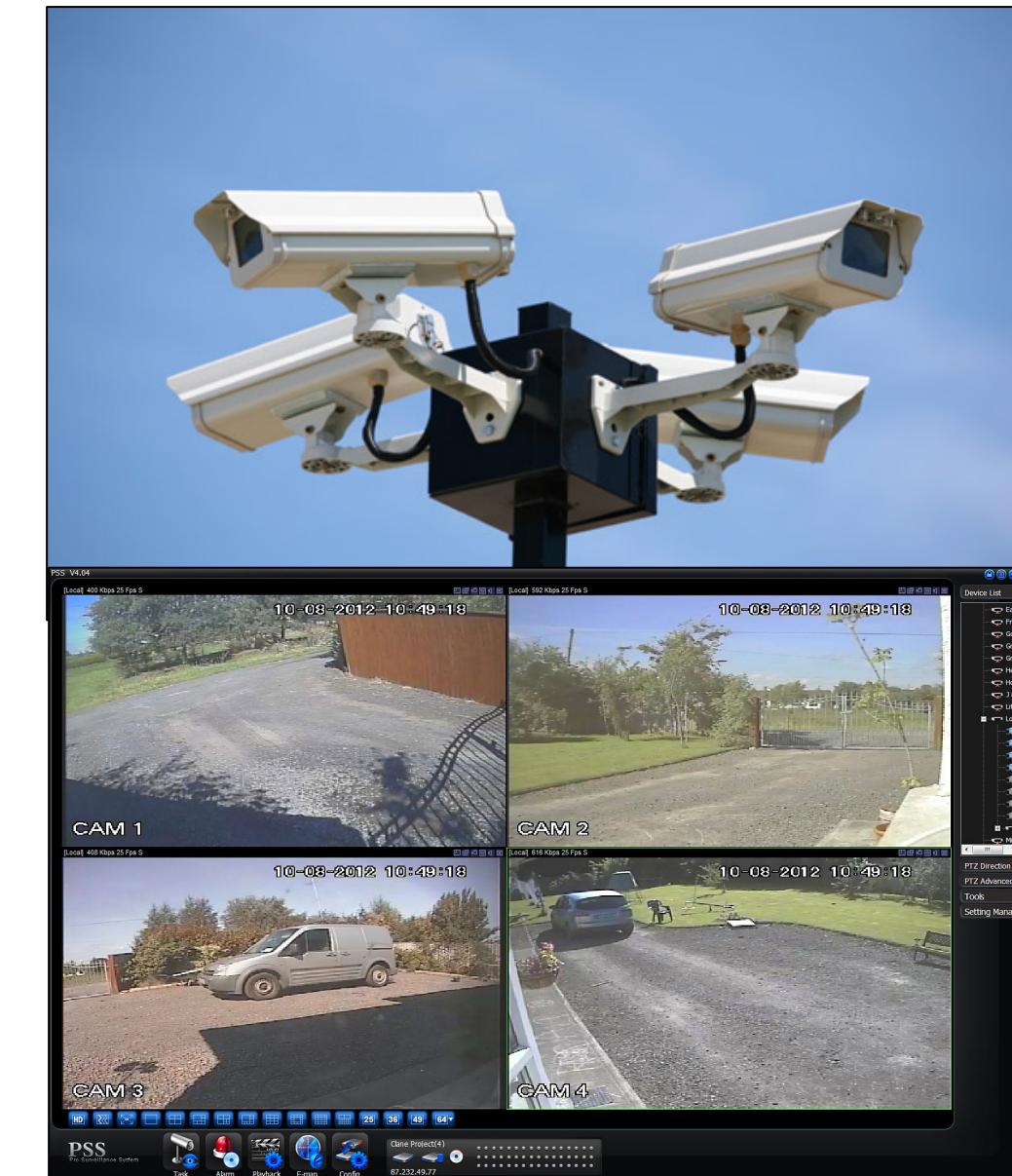
Impact: Opportunities for new monitoring applications in natural environments

# 1. Introduction: 1. Visual Environment Monitoring

Satellite views



Stationary cameras



Moving camera



Fidelity



Spatial Coverage



Continuous Time



2



✗ (On demand)

# 1. Introduction: 2. Desired Results

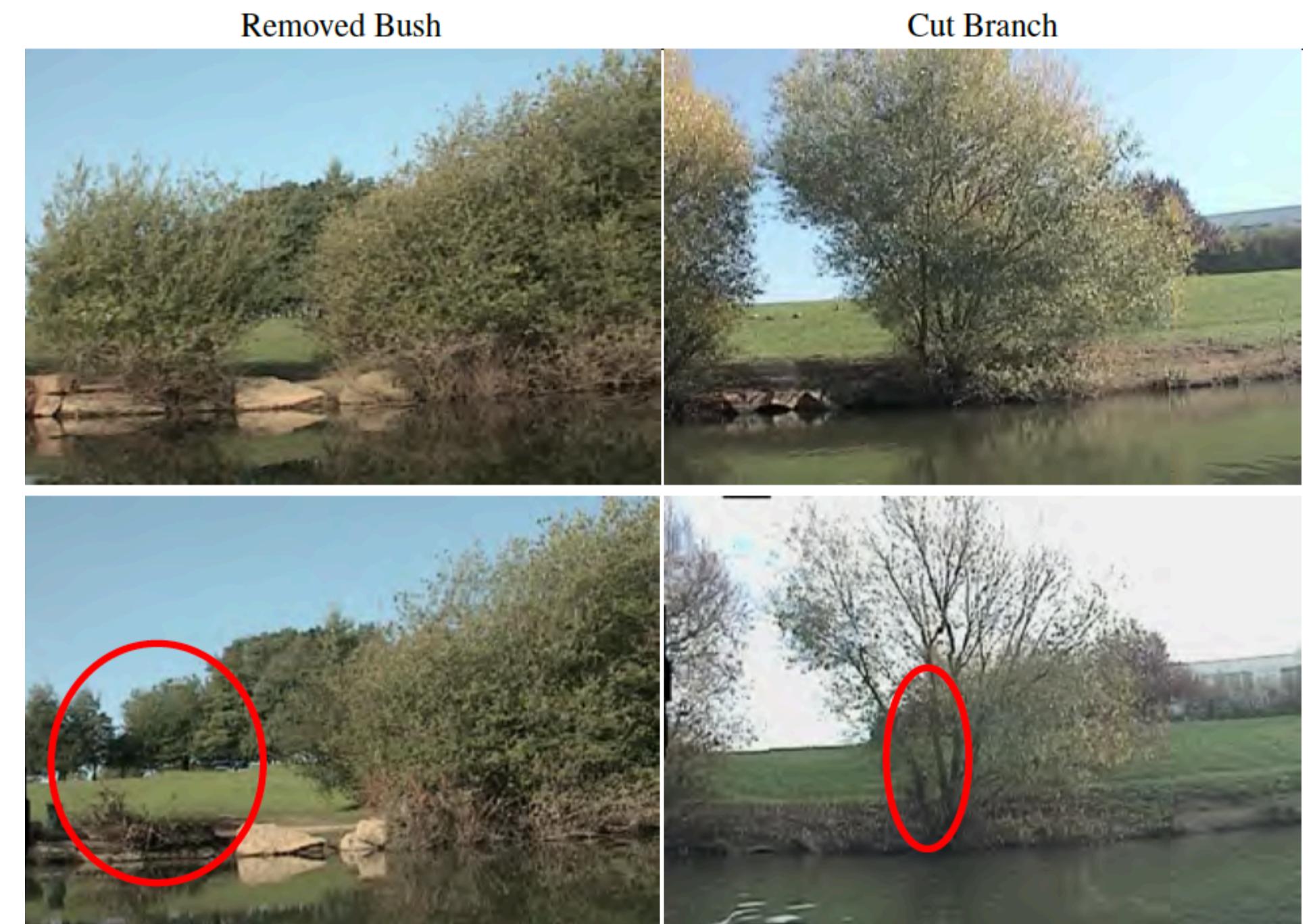
Time-lapses



Sequence 1: unaligned

Sequence 2: aligned

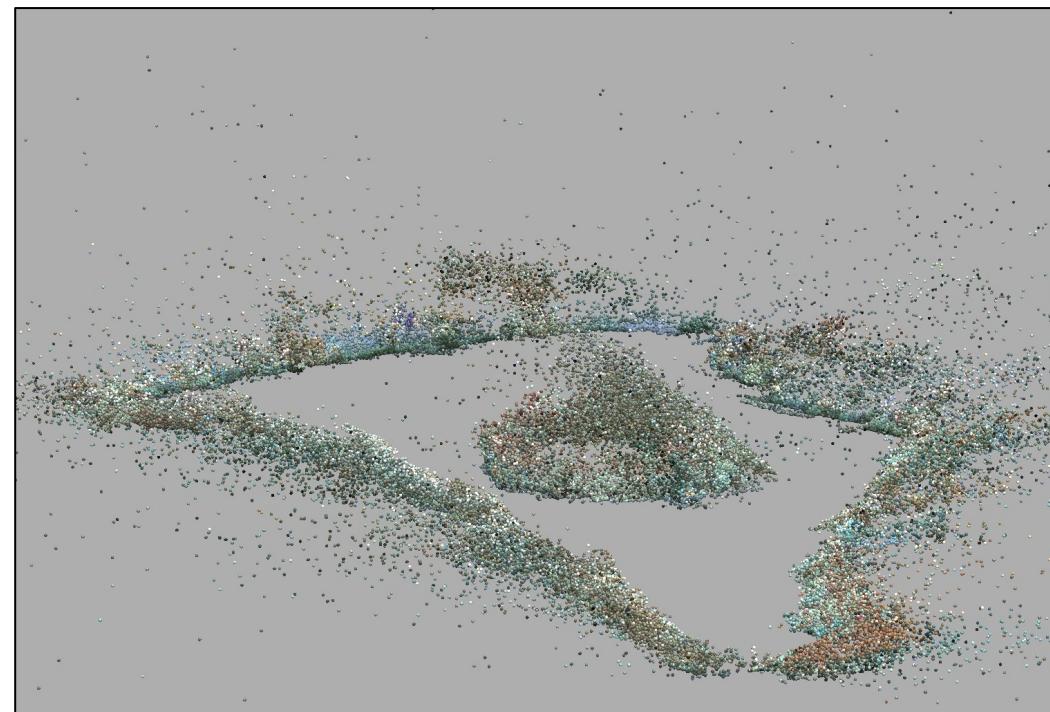
Changes



# 1. Introduction: 3. Direction

*Exploit spatial information to achieve data association across seasons.*

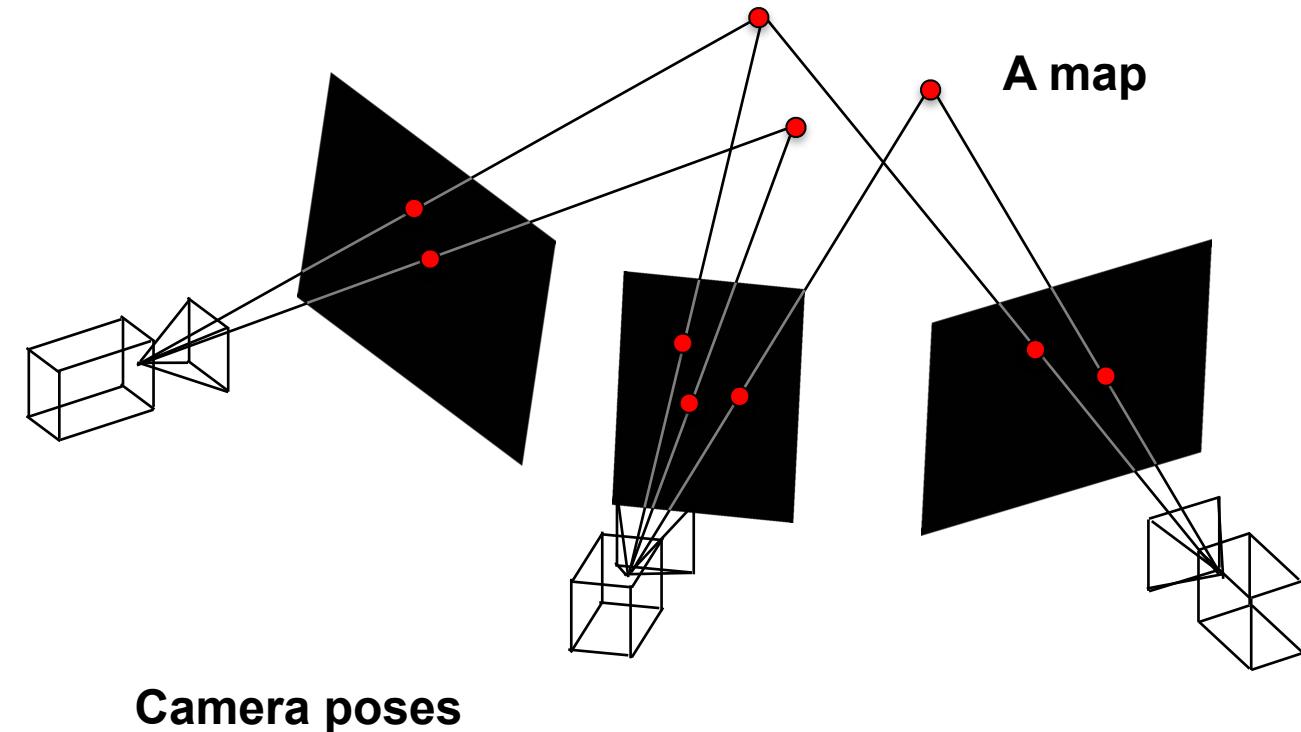
## Geometry-based



## Appearance-based



Correspondences are appearance-invariant  
(given the map and the camera poses)



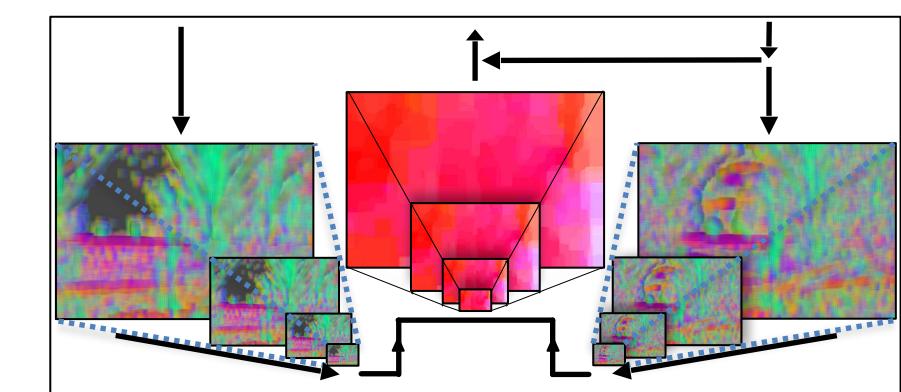
Less robust  
points

patches

Whole images

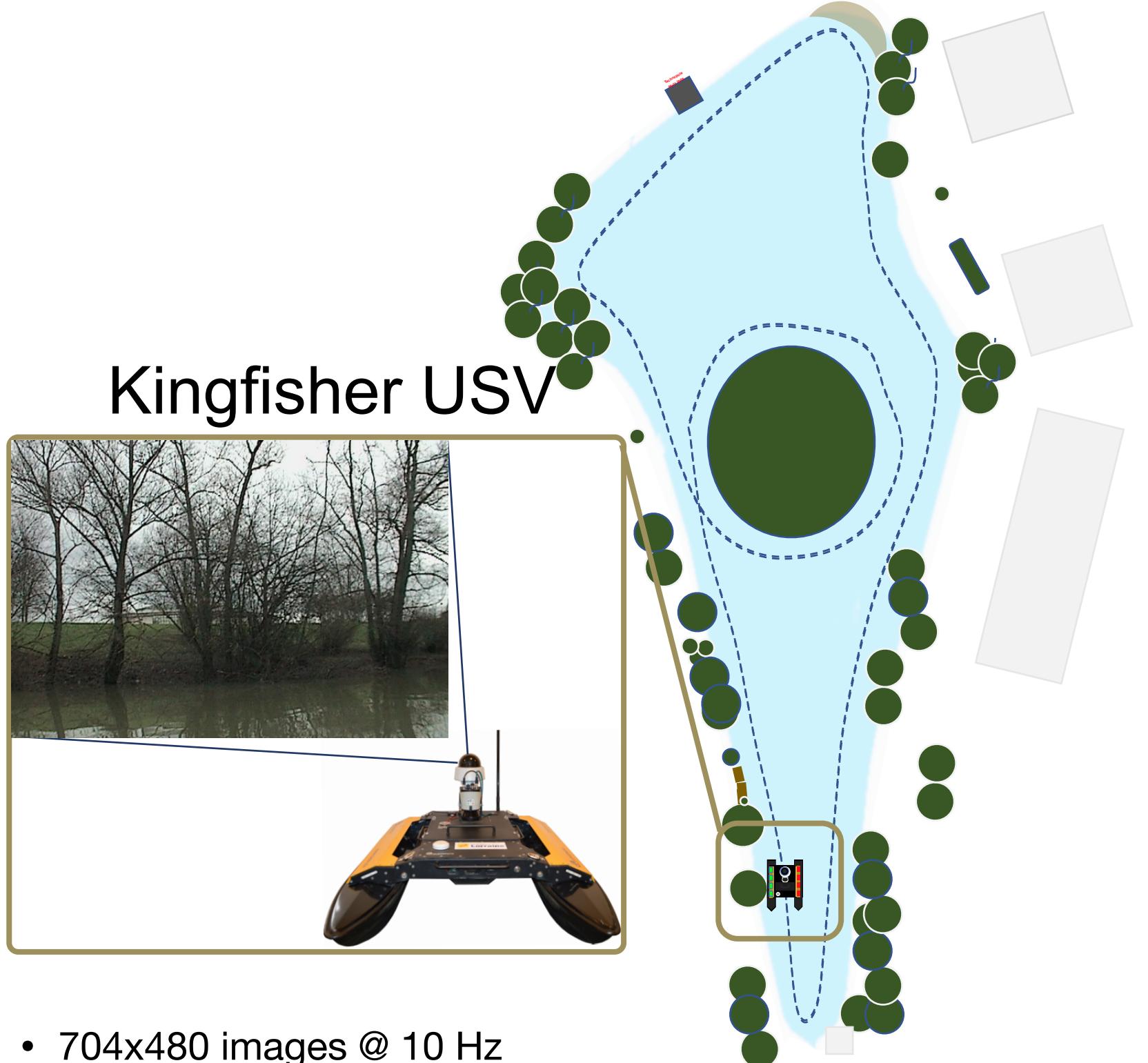
Dense image alignment  
More robust

NetVLAD



# 2. Dataset

Lakeshore environment



- 704x480 images @ 10 Hz
  - constant velocity
  - GPS
  - IMU
- 1 km perimeter

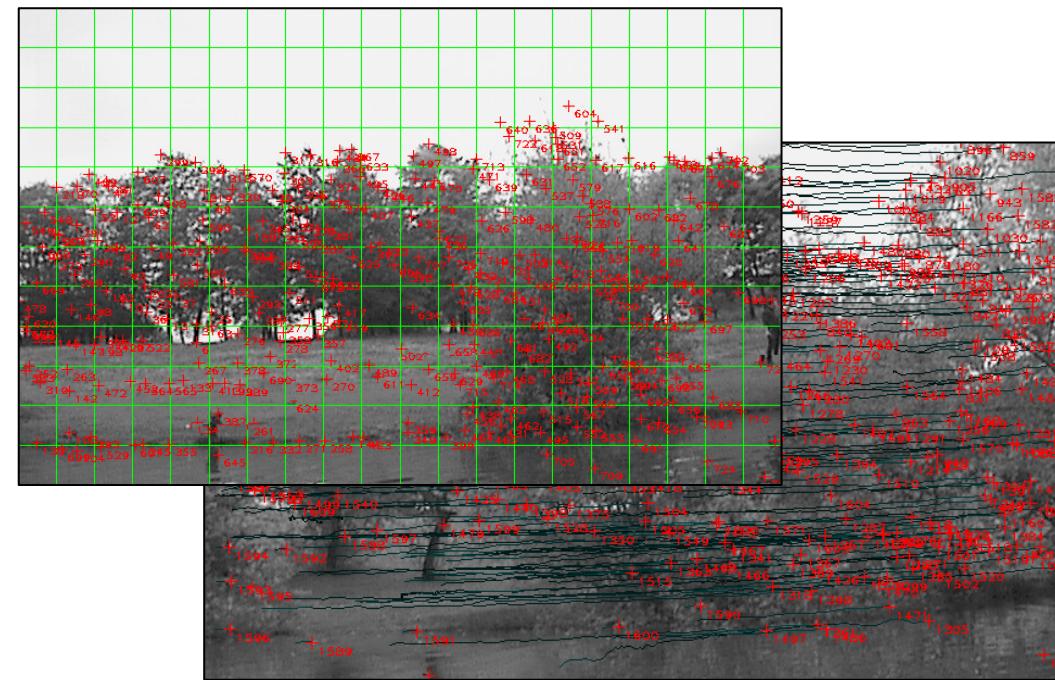
~Biweekly Surveys



- 30+ per year
- 4 years
- 120+ surveys

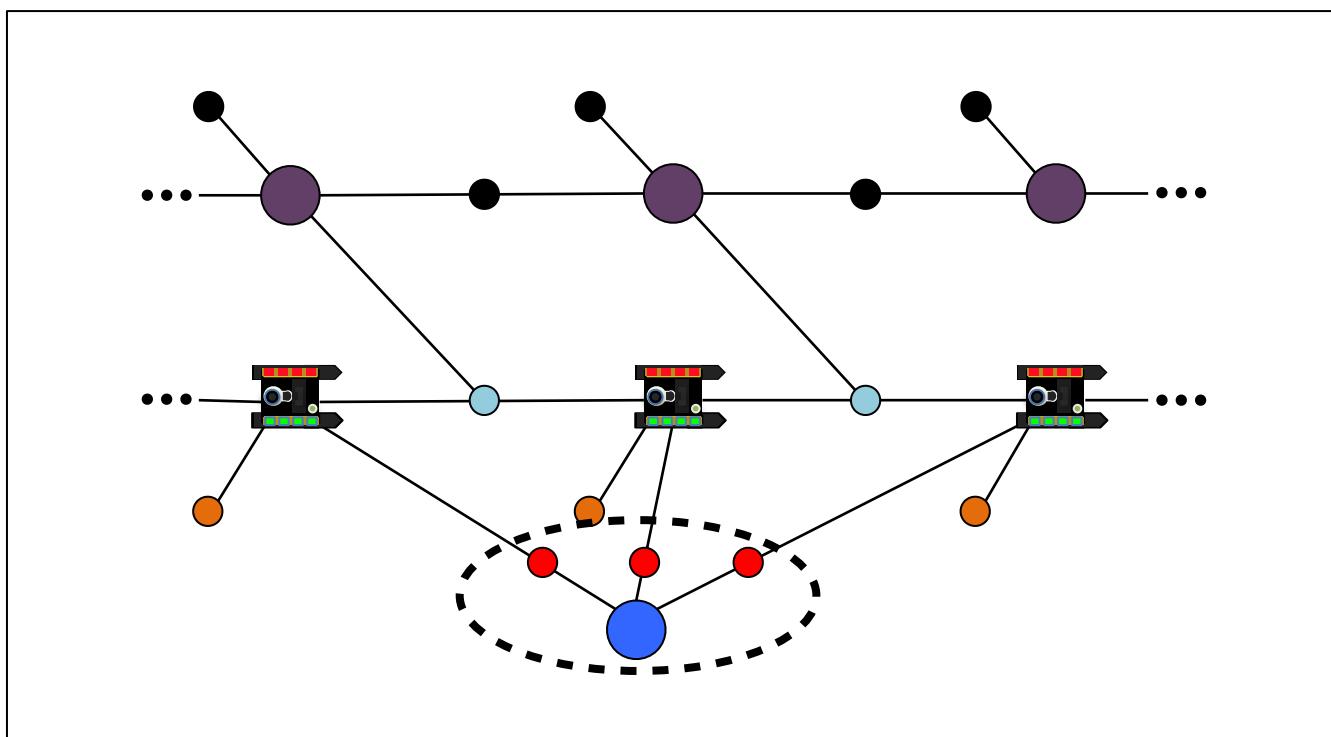
# 3. SLAM: 1. Single-Session

## Feature Extraction and Tracking



Grid  
Harris corners  
Kanade–Lucas–Tomasi feature tracker  
300 features per image

## Factor Graph



### Variables

- velocity, R3
- camera pose, SE3
- landmark, R3

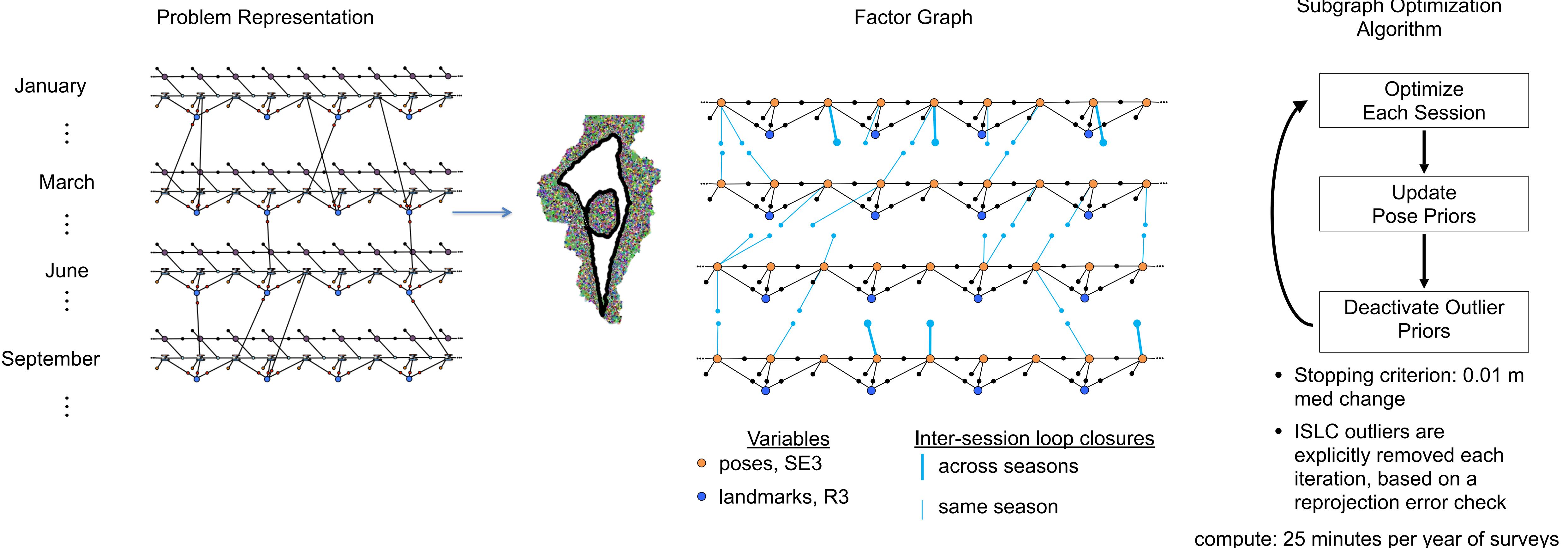
### Factors

- yaw rate
- constant velocity
- GPS prior
- 3D-2D projection
- “Smart” factor

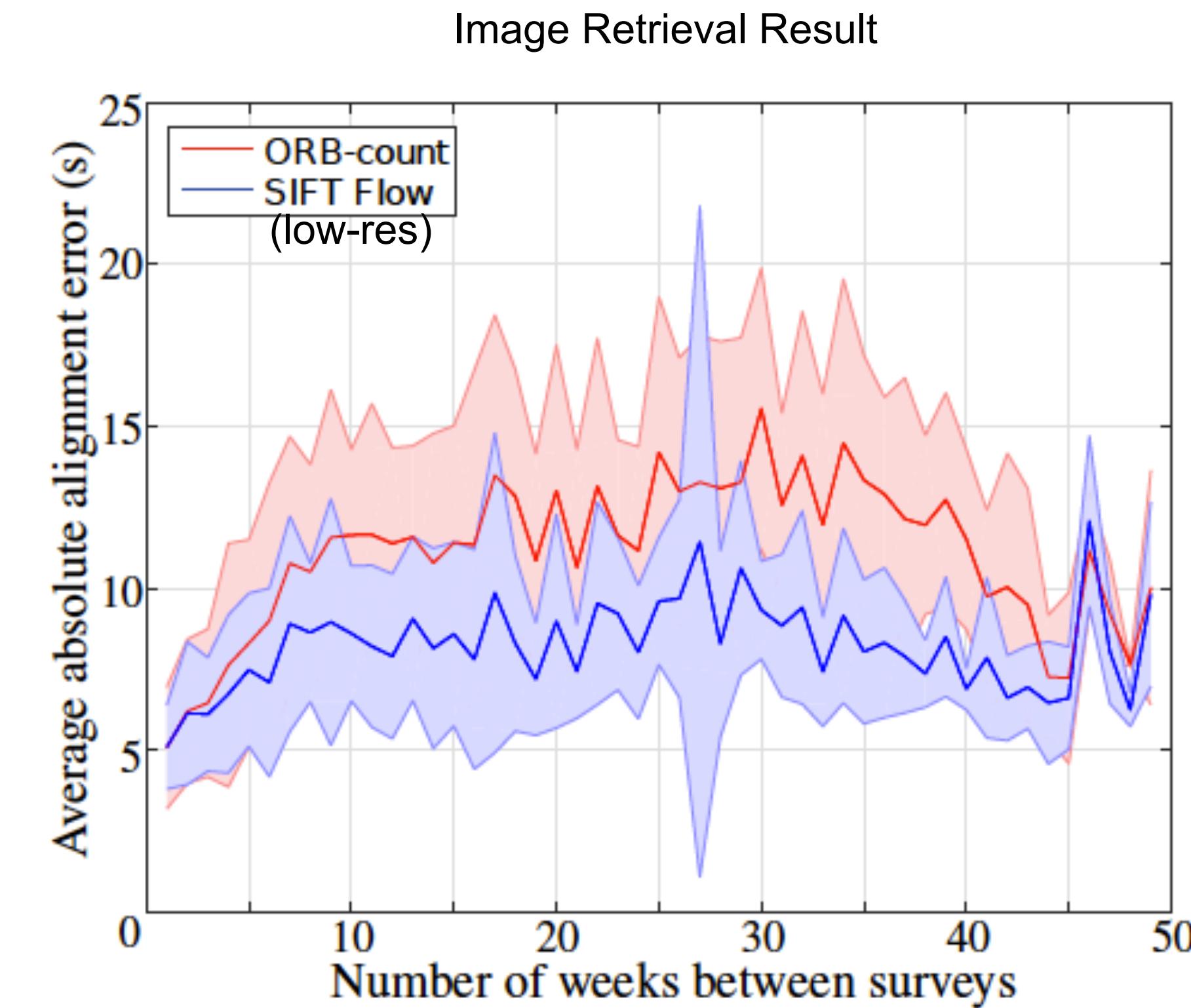
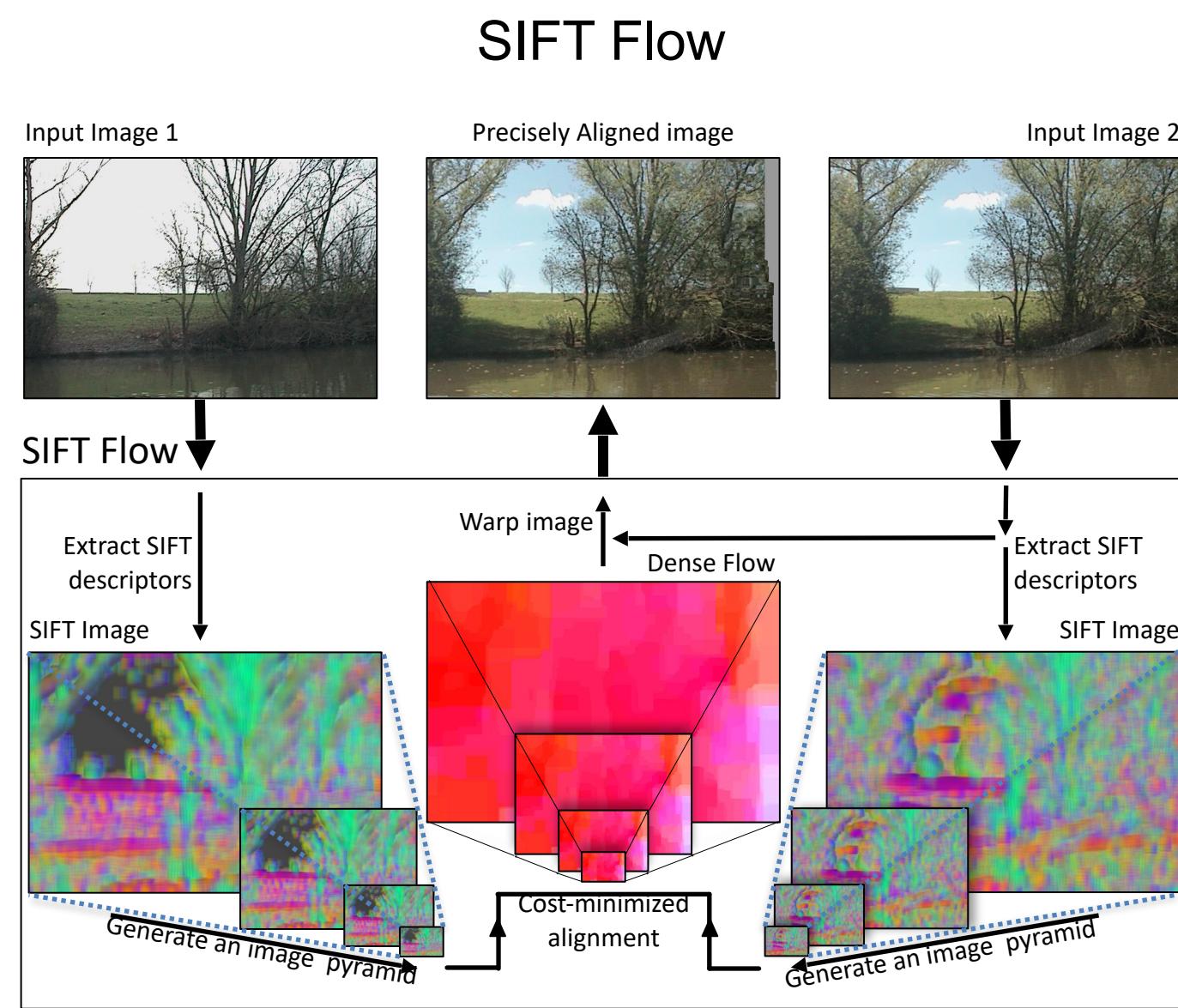
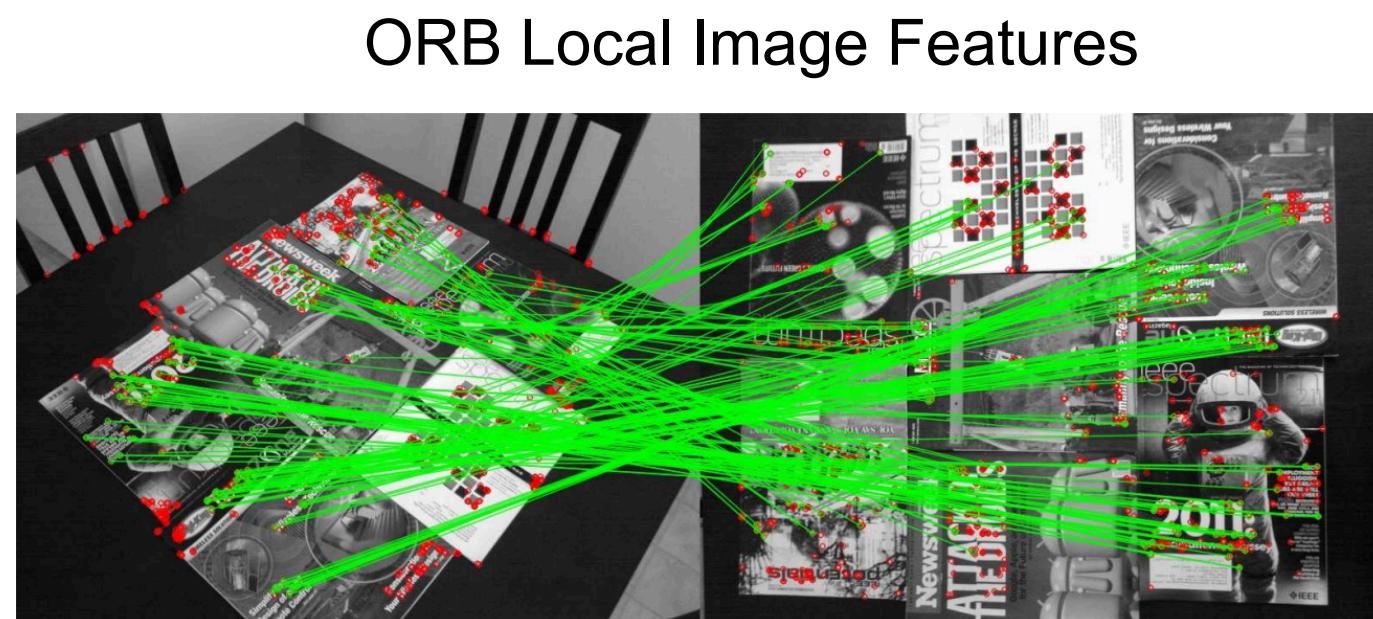
## Result

~3500 keyframes  
~100,000 map points  
compute: 16 GB, two minutes  
~3.5 pixels reprojection error

# 3. SLAM: 1. Multi-Session

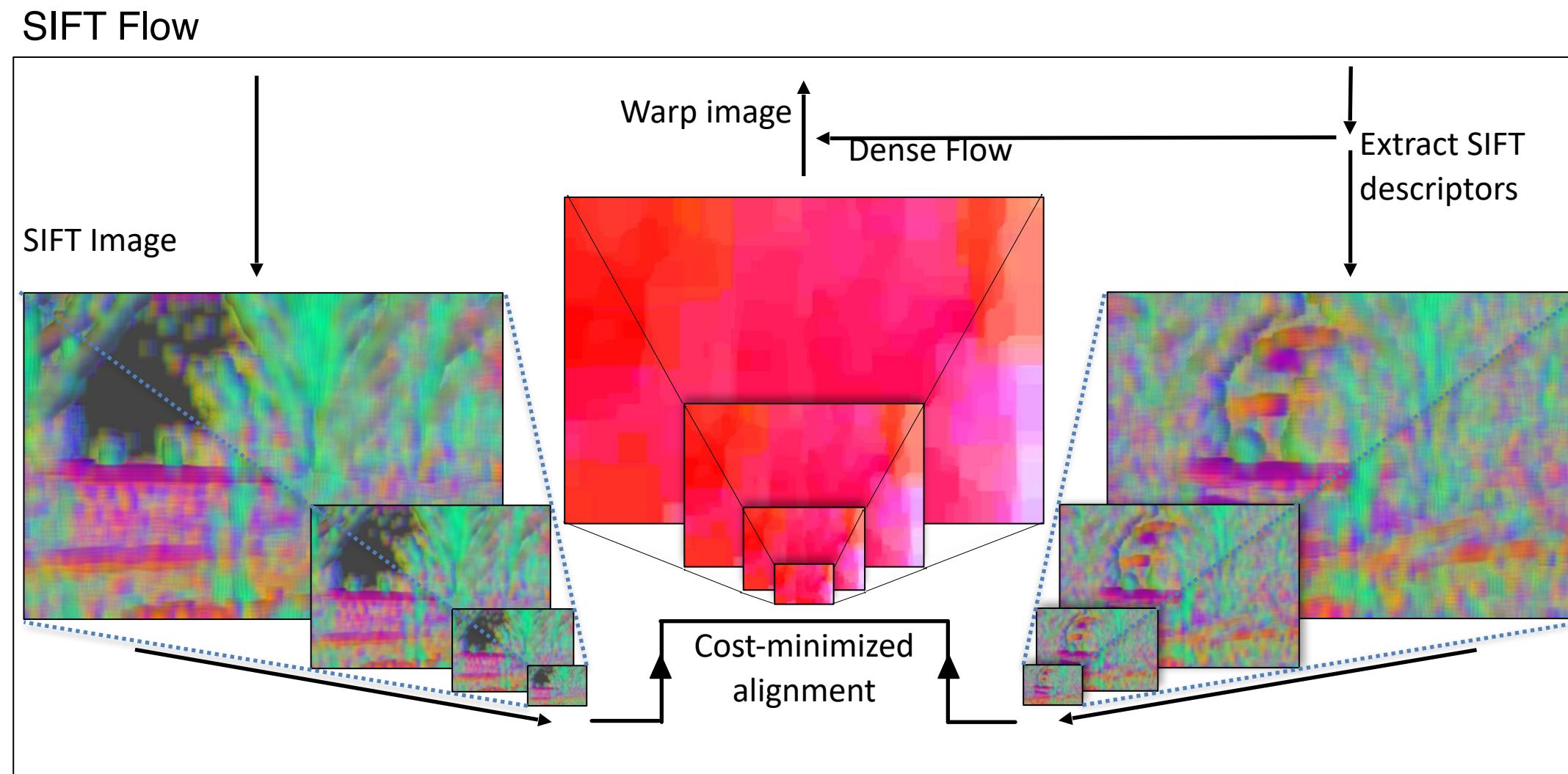


# 4. Loop Closures. 1. Data Association Across Surveys



- Images were more often the same scene using SIFT Flow (low-res)
- Appearance lacked matching power after 2-3 months

# 4. Loop Closures. 2. Extensions to SIFT Flow



## SIFT-Flow Constraints

Data term

Regularization term

Smoothness term

Coarse to fine  
alignment

## Added Alignment Constraints

Alignment verification check

Epipolar line constraints

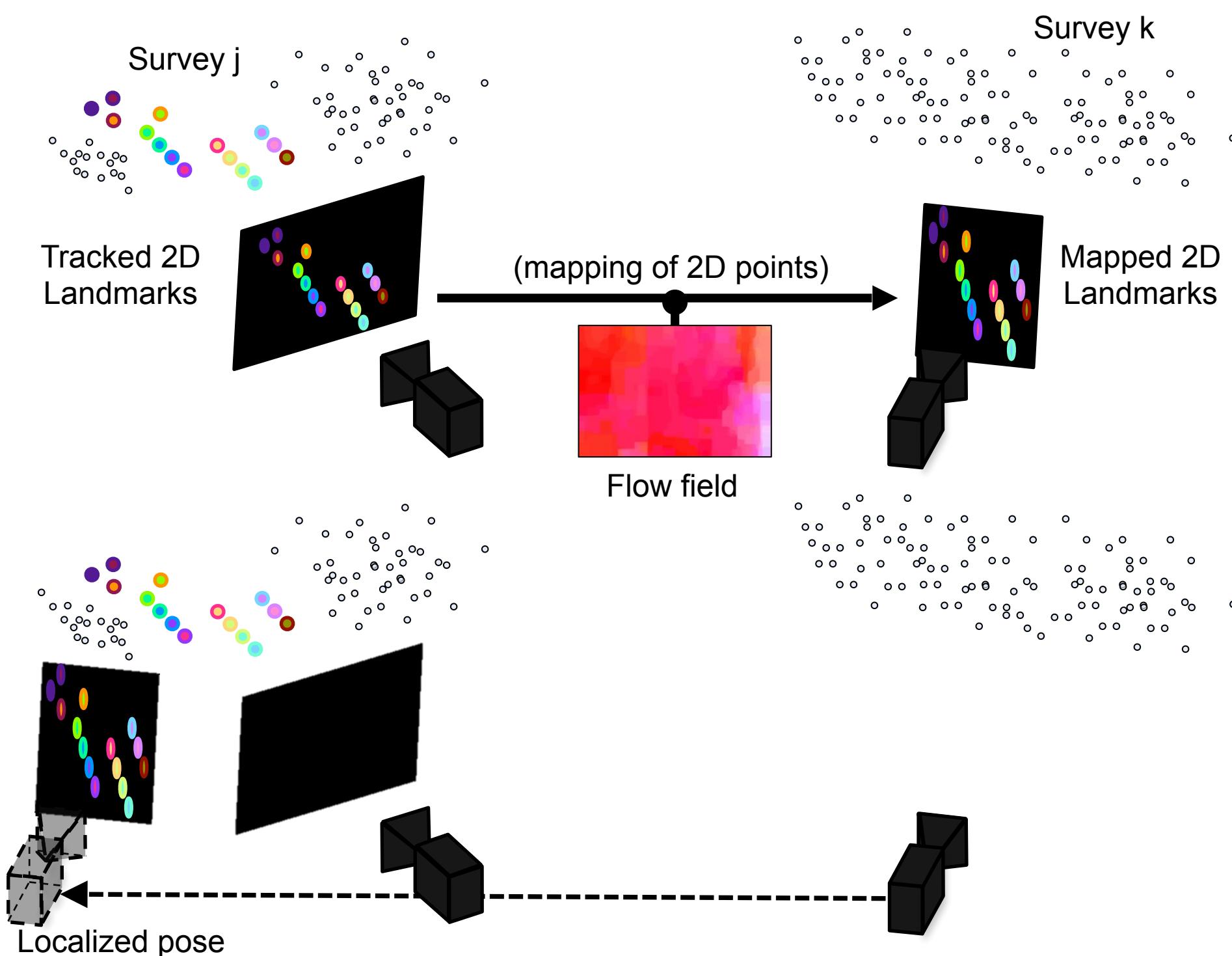
Forward-backward  
match constraints

Projected map point  
hypothesis constraints

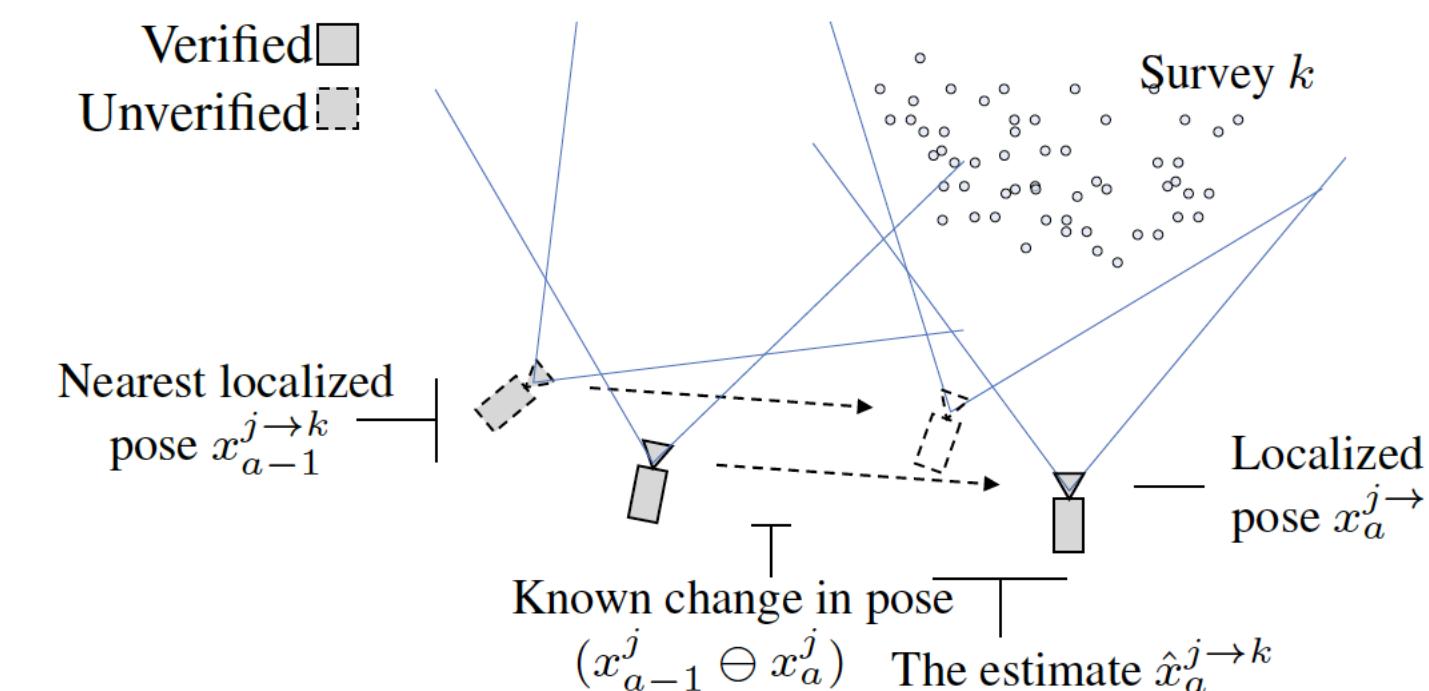
Unmatched pixels can be tightly constrained!

# 4. Loop Closures. 3. Loop Closure Search

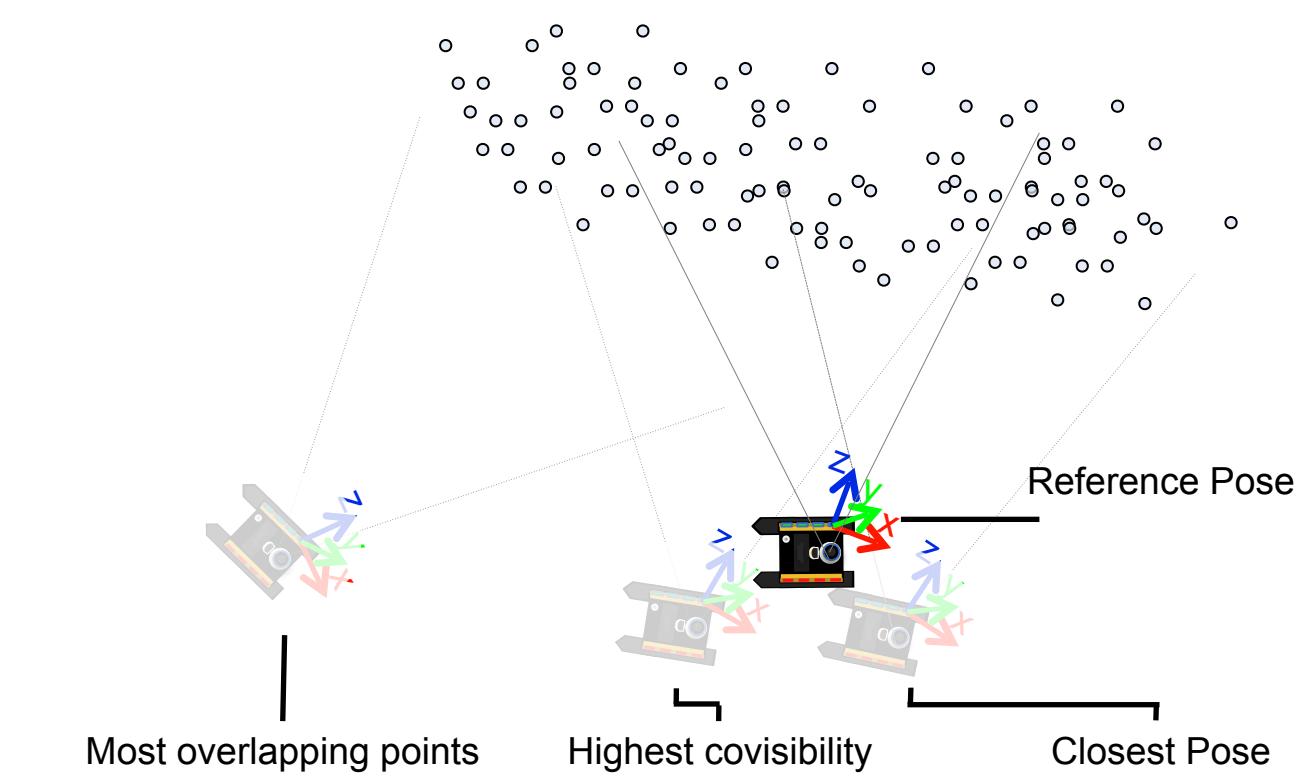
## 1. Acquiring Inter-Session Landmark Observations



## 2. Loop Closure Verification

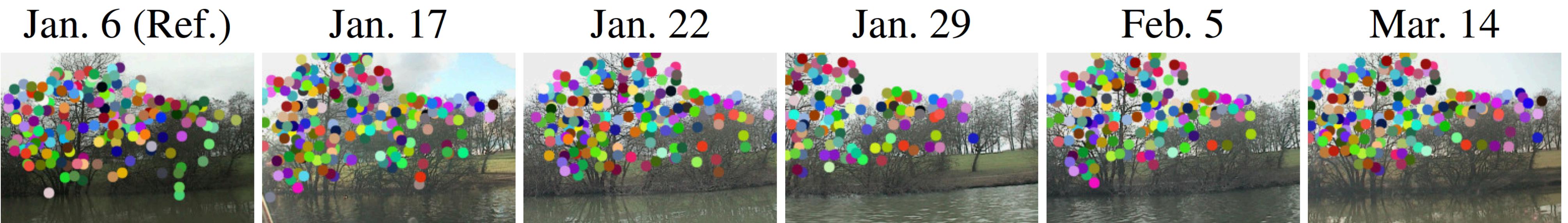


## 3. Viewpoint Selection (independent of appearance)



# 5. Evaluation: 1. Map-Centric Data Association

Map points



SIFT Flow +  
Extensions



SIFT Flow



# 5. Evaluation: 2. Time-lapses

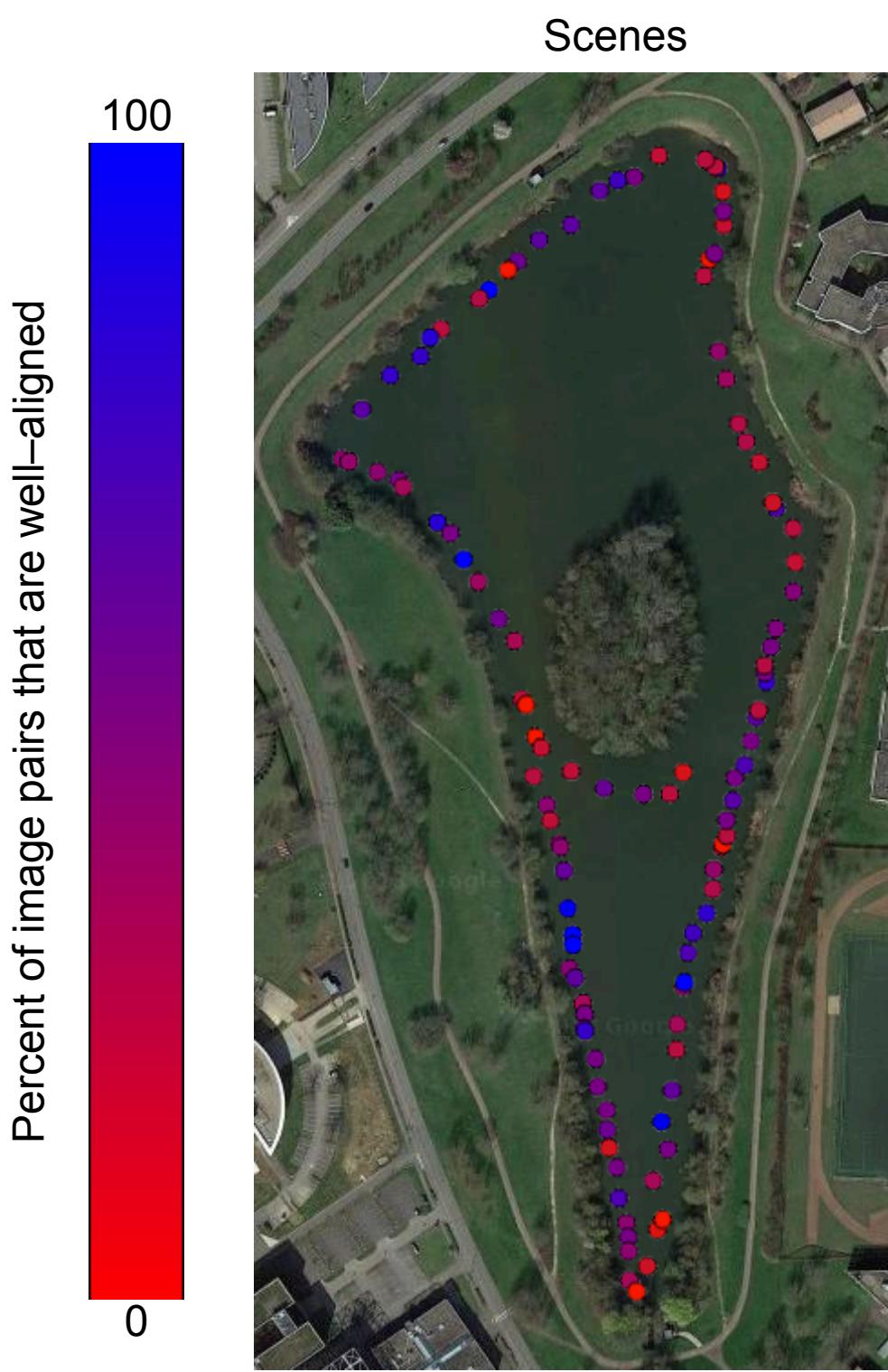


- Image sets were aligned and then hand-sorted into time-lapses
- Approximately a third included 20+ images (out of a max size of roughly 33).

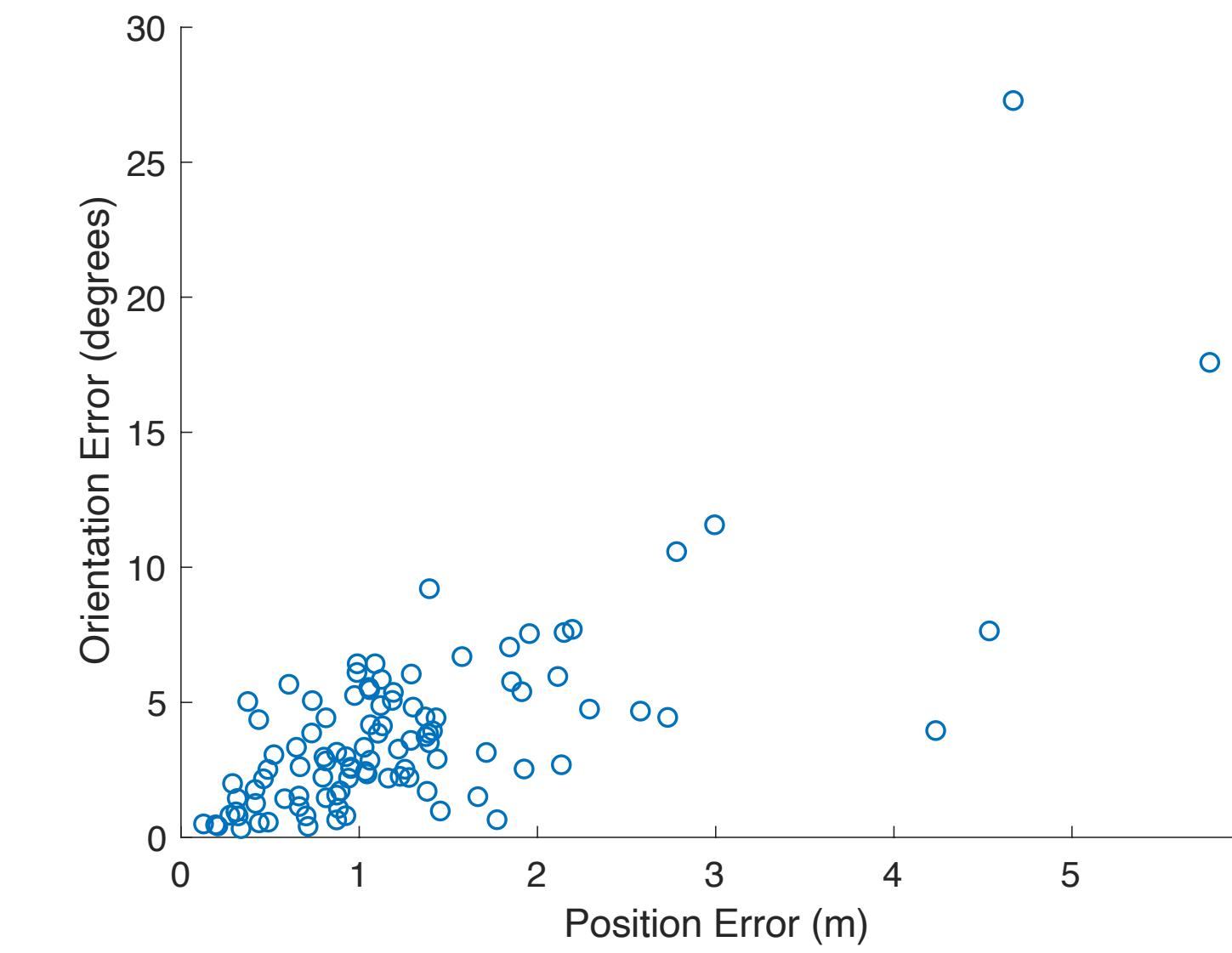
# 5. Evaluation: 3. Gauging the Errors

*We could do better by improving SLAM*

Length of time-lapses by scene



Pose error



# Questions?