Natural Environment Monitoring at Georgia Tech

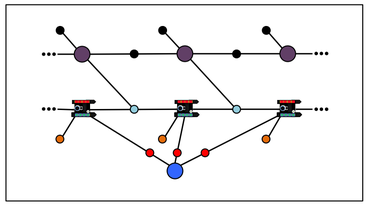
15 min

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

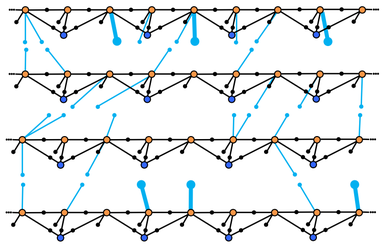
USV and Environment

Models

One Session



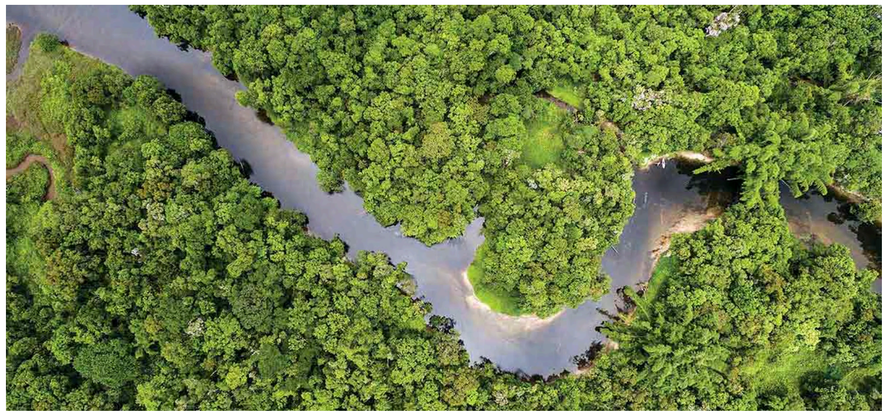
Multi-Session



Impact: Opportunities for new monitoring applications in natural environments

Griffith *et al.*; 2016; 2019

1. Introduction: 1. Visual Environment Monitoring

	Satellite views	Stationary cameras	Moving camera
			
Fidelity	✗	✓	✓
Spatial Coverage	✓	✗	✓
Continuous Time	✗	✓	✗ (On demand)

Griffith *et al.*; 2016; 2019

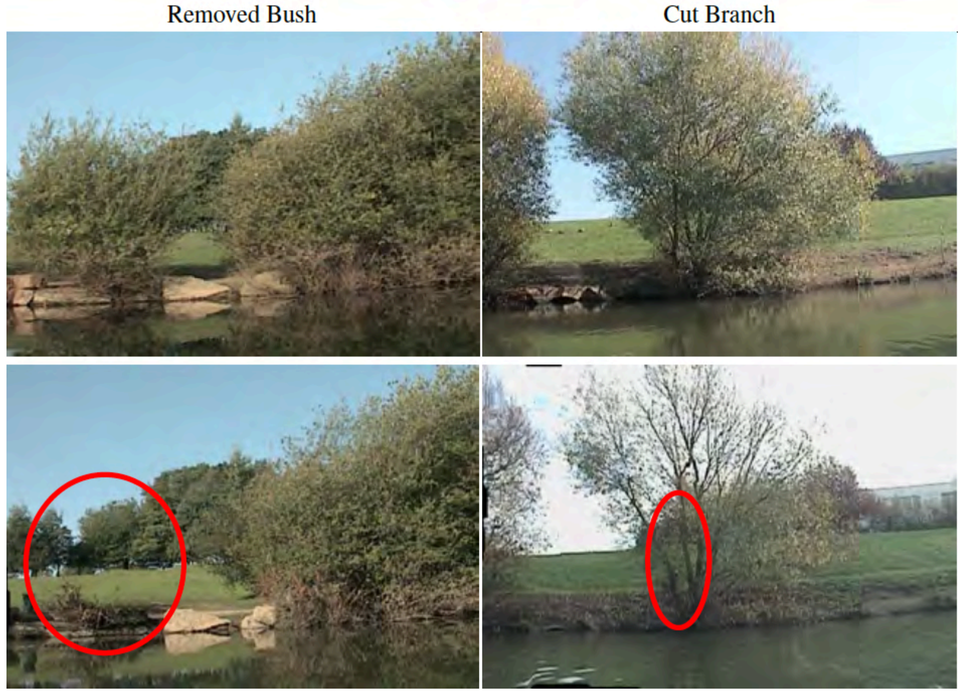
1. Introduction: 2. Desired Results

Time-lapses

Sequence 1: unaligned

Sequence 2: aligned

Changes

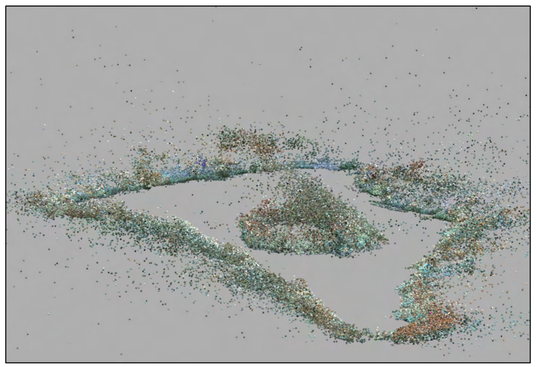


Griffith *et al.*; 2016; 2019

1. Introduction: 3. Direction

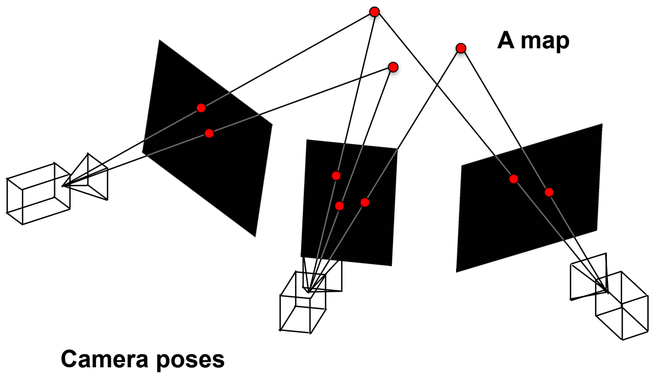
Exploit spatial information to achieve data association across seasons.

Geometry-based



(A point cloud)

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

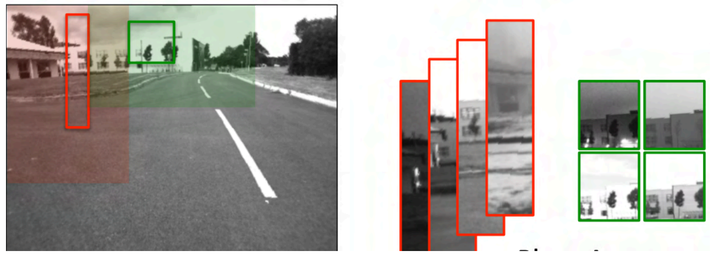


Appearance-based

Less robust

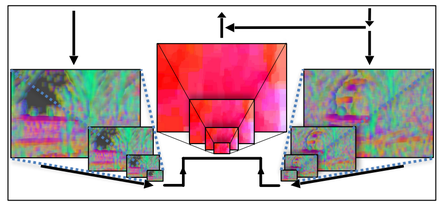
points

patches



Whole images

NetVLAD



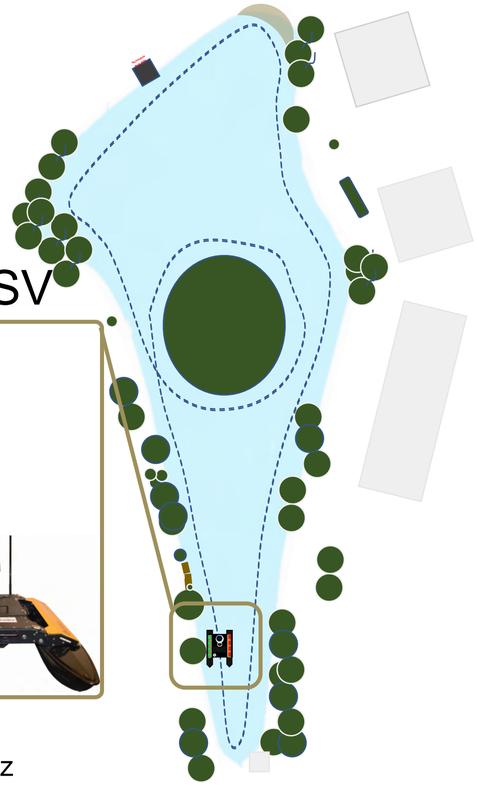
Dense image alignment

More robust

Griffith *et al.*; 2016; 2019

2. Dataset

Lakeshore environment



Kingfisher USV

- 704x480 images @ 10 Hz
- constant velocity
- GPS
- IMU

- 1 km perimeter

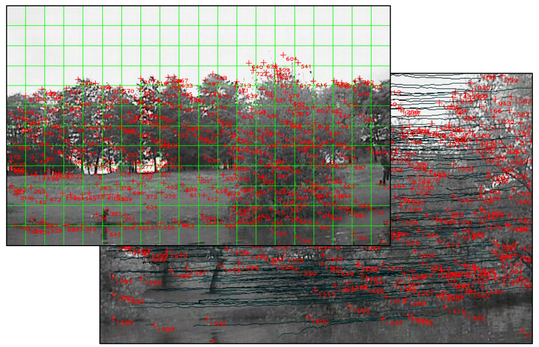
~Biweekly Surveys

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

Griffith *et al.*; 2016; 2019

3. SLAM: 1. Single-Session

Feature Extraction and Tracking



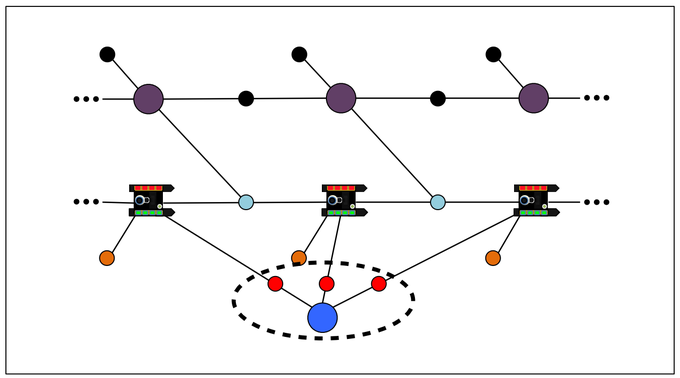
Grid

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

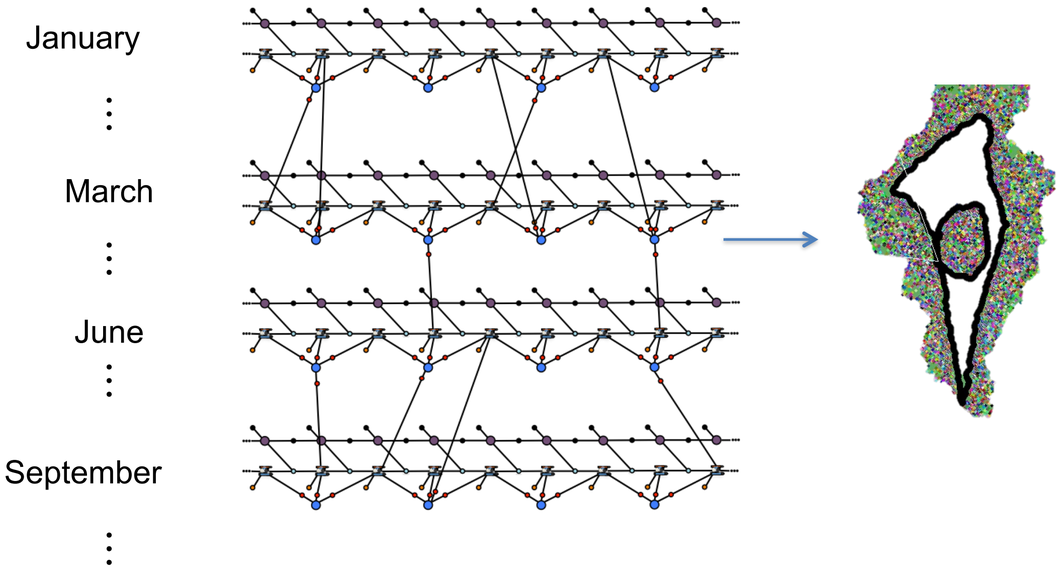
compute: 16 GB, two minutes

~3.5 pixels reprojection error

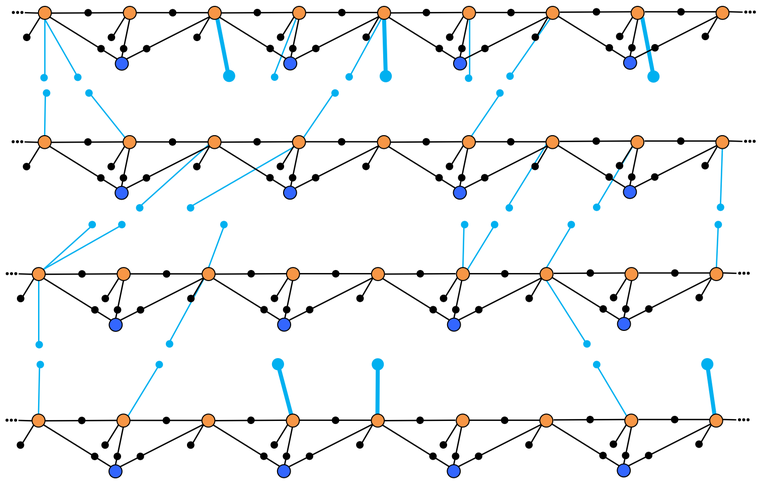
Griffith *et al.*; 2016; 2019

3. SLAM: 1. Multi-Session

Problem Representation



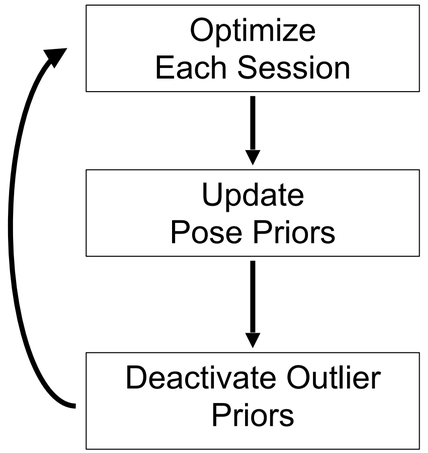
Factor Graph



Variables
- poses, SE3
- landmarks, R3

Inter-session loop closures
- across seasons
- same season

Subgraph Optimization Algorithm



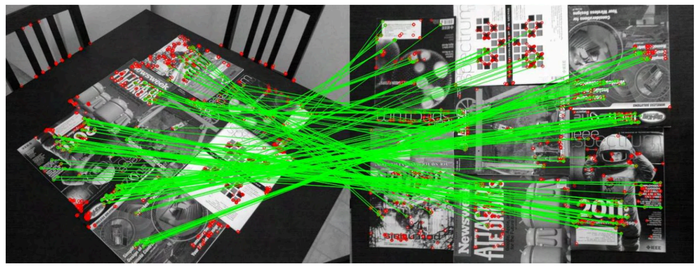
- Stopping criterion: 0.01 m med change
- ISLC outliers are explicitly removed each iteration, based on a reprojection error check

compute: 25 minutes per year of surveys

Griffith *et al.*; 2016; 2019

4. Loop Closures. 1. Data Association Across Surveys

ORB Local Image Features



SIFT Flow

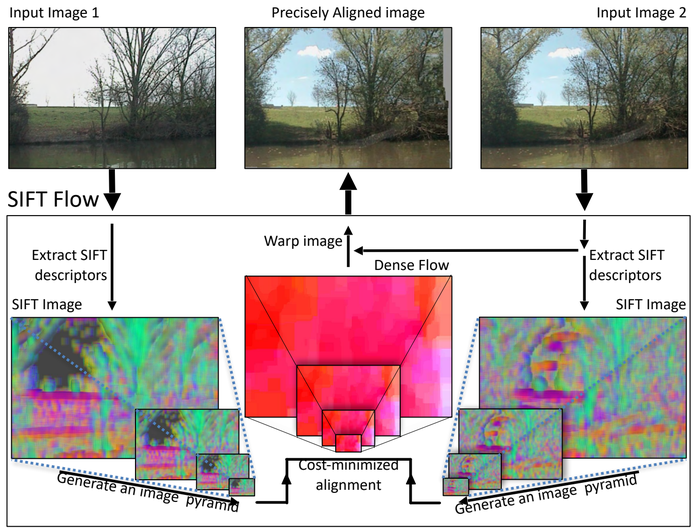
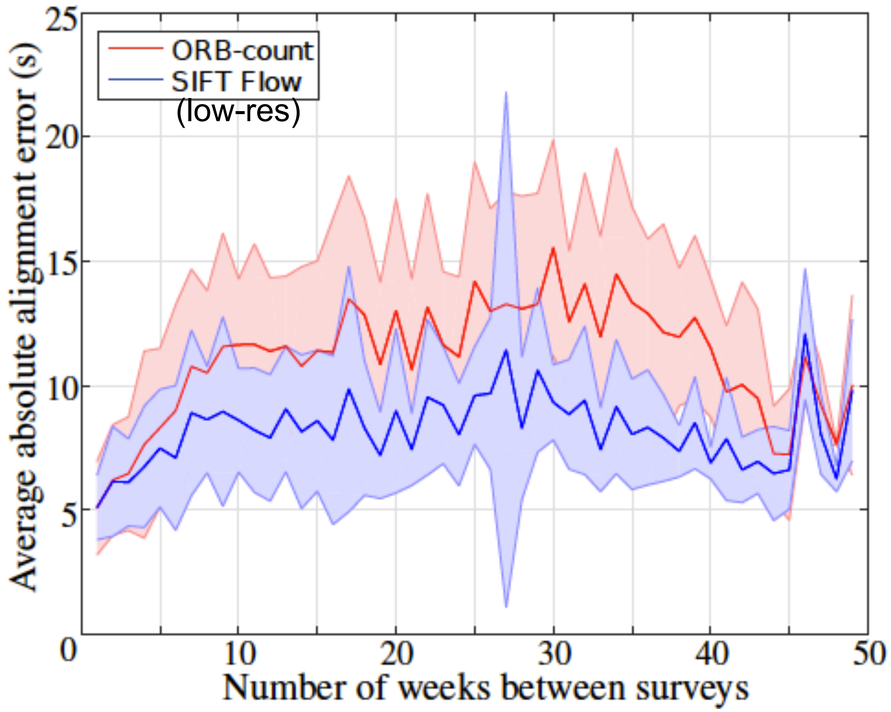


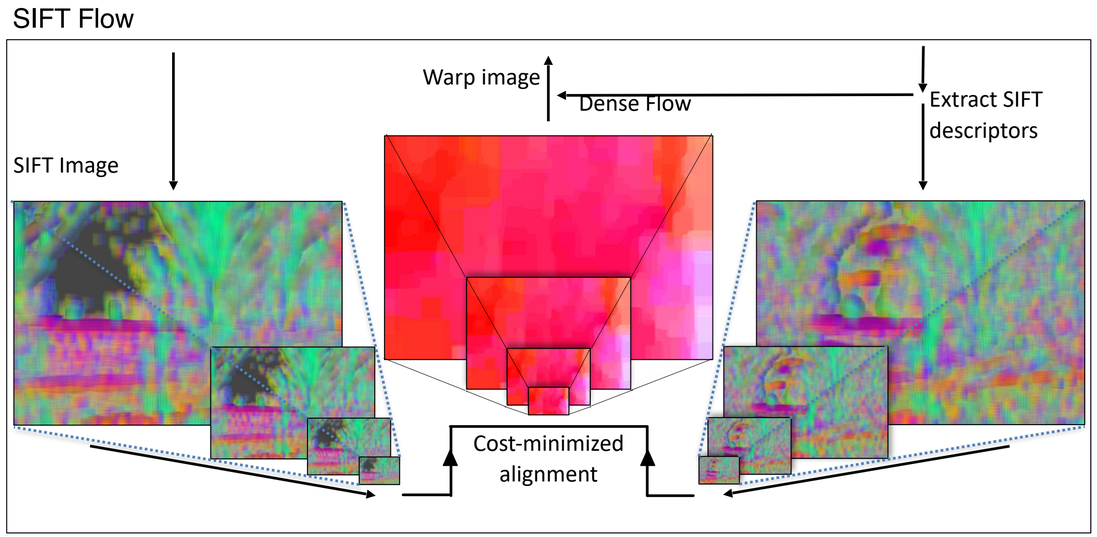
Image Retrieval Result



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

Griffith *et al.*; 2016; 2019

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

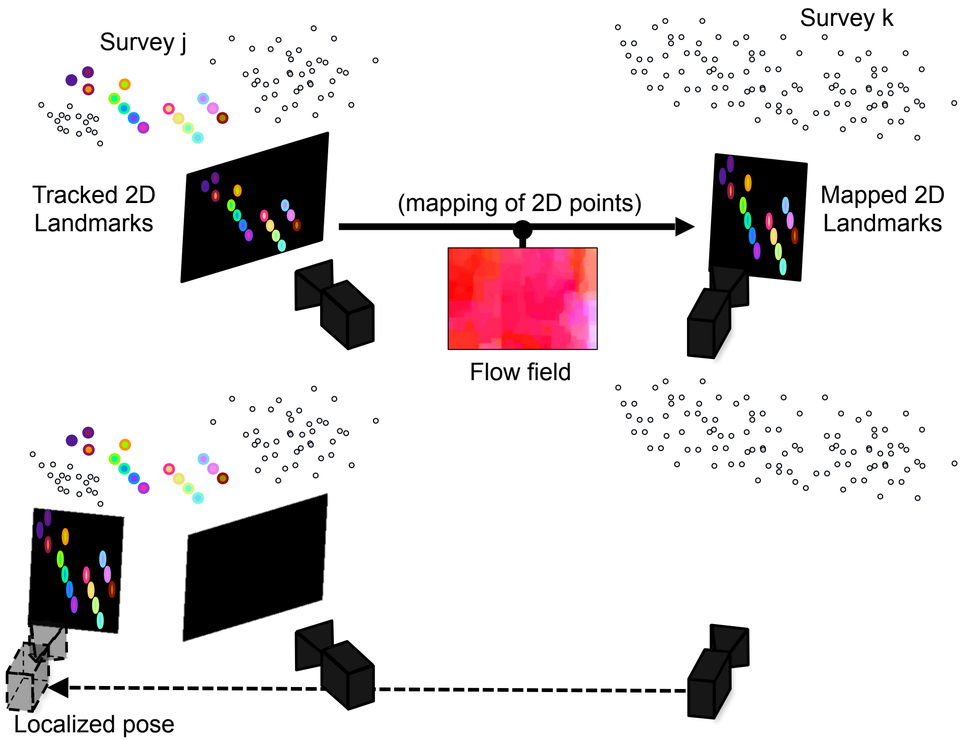
Projected map point hypothesis constraints

Unmatched pixels can be tightly constrained!

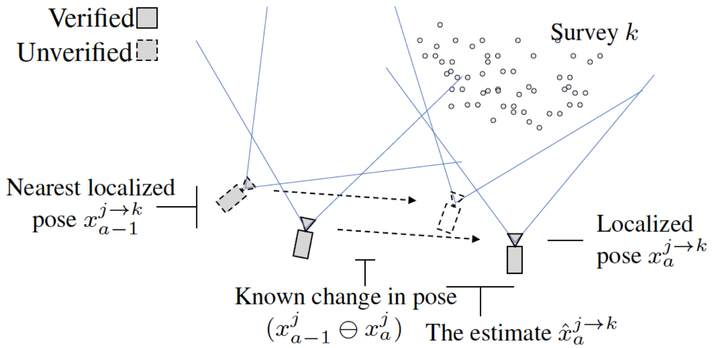
Griffith *et al.*; 2016; 2019

4. Loop Closures. 3. Loop Closure Search

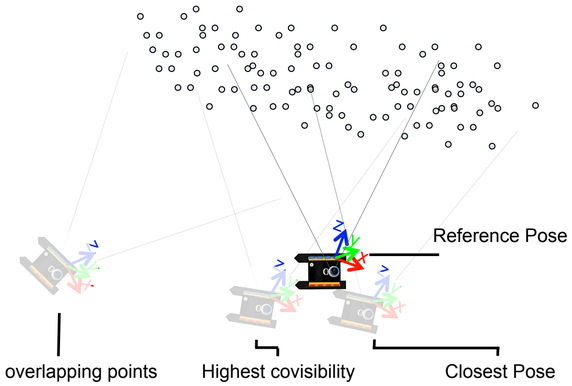
1. Acquiring Inter–Session Landmark Observations



2. Loop Closure Verification

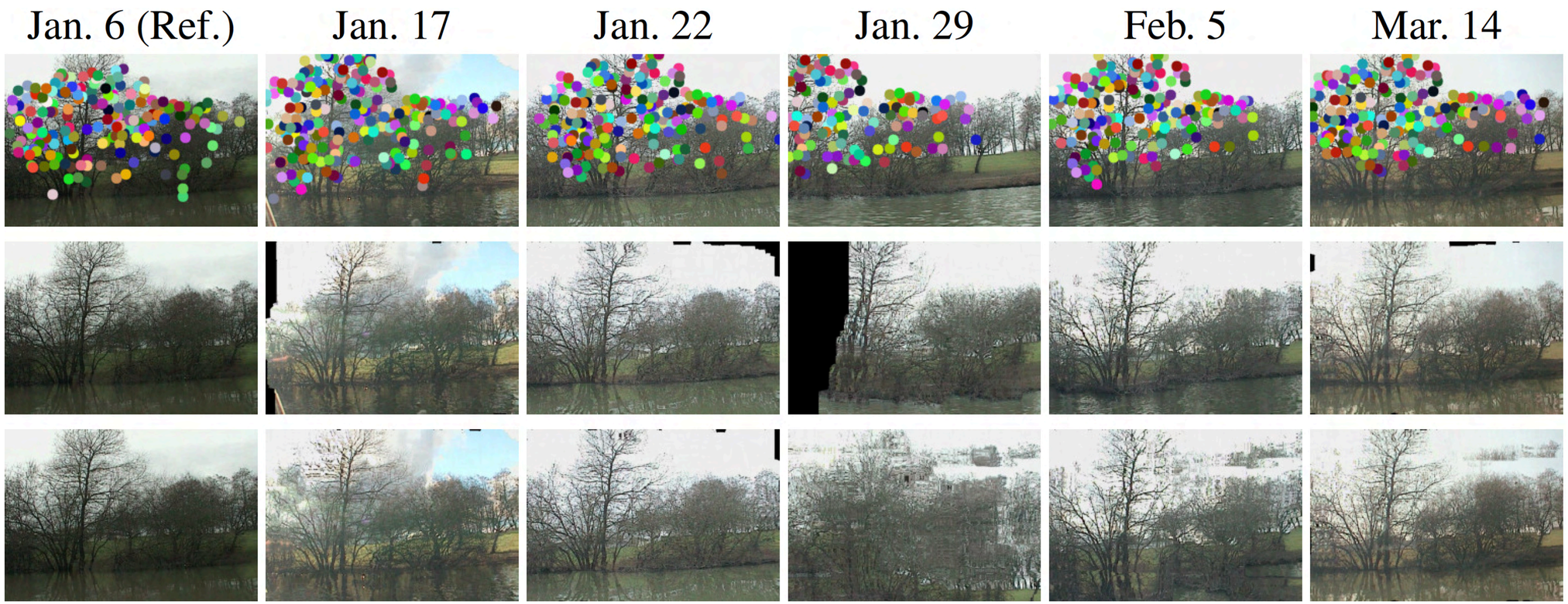


3. Viewpoint Selection (independent of appearance)



Griffith *et al.*; 2016; 2019

5. Evaluation: 1. Map-Centric Data Association



Griffith *et al.*; 2016; 2019

5. Evaluation: 2. Time-lapses

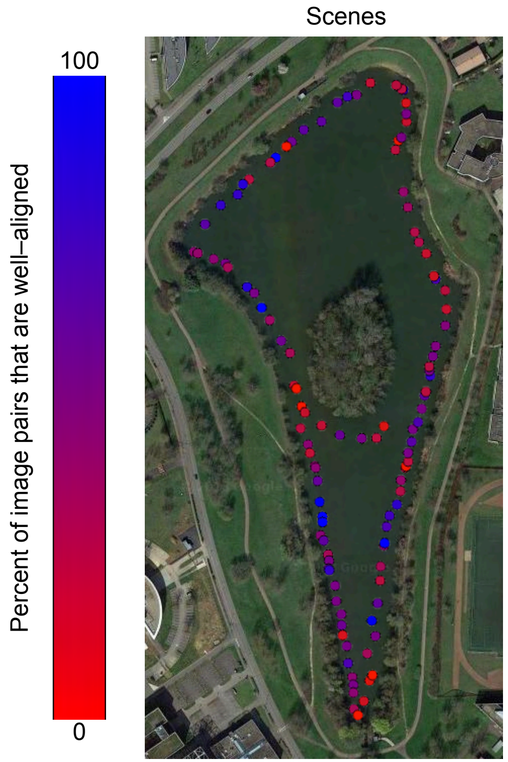
- Image sets were aligned and then hand–sorted into time–lapses
- Approximately a third included 20+ images (out of a max size of roughly 33).

Griffith *et al.*; 2016; 2019

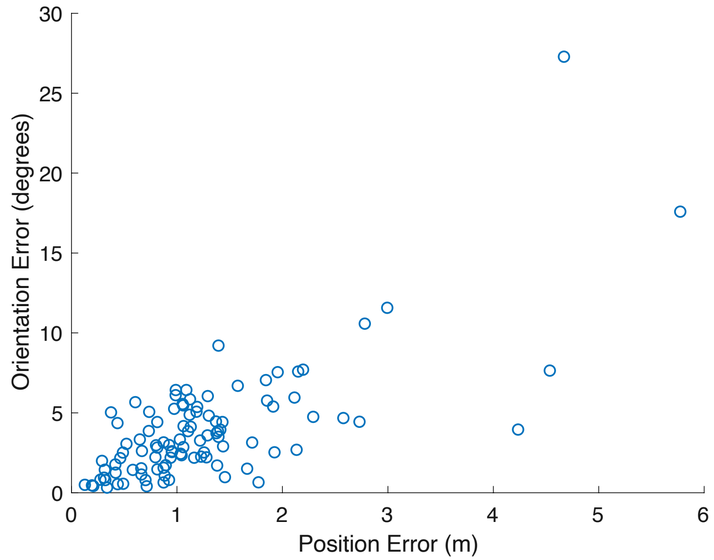
5. Evaluation: 3. Gauging the Errors

We could do better by improving SLAM

Length of time-lapses by scene



Pose error



Griffith *et al.*; 2016; 2019

Questions?