Environment Monitoring and Driving Assistance

Cédric Pradalier

July 8^{th}, 2014



Objectives of this talk

In General

- Describe our efforts to use autonomous mobility for environment monitoring.
- Suggest other applications of driver assistance.

Outline

Autonomous Lakeshore Monitoring

Conclusion

Autonomous Lakeshore Monitoring







S. Griffith



P. Drews



C. Pradalier

Challenges

1 of 4: Moving sensor in a natural environment



From S. Eddins, Matlab Image Processing Toolbox



From Pattern Recognition and Image Processing Group, VUT

Georgia Tech Lorraine

Challenges

2 of 4: Variation of Appearance in Natural Environments



From Churchill and Newman, 2013

Challenges

3 of 4: Navigation among other "intelligent" agents



Ducks



Swan

Challenges

4 of 4: Noice, uncertainty and incompleteness



Dirty Camera Dome



Sun glare



Non-smooth motion

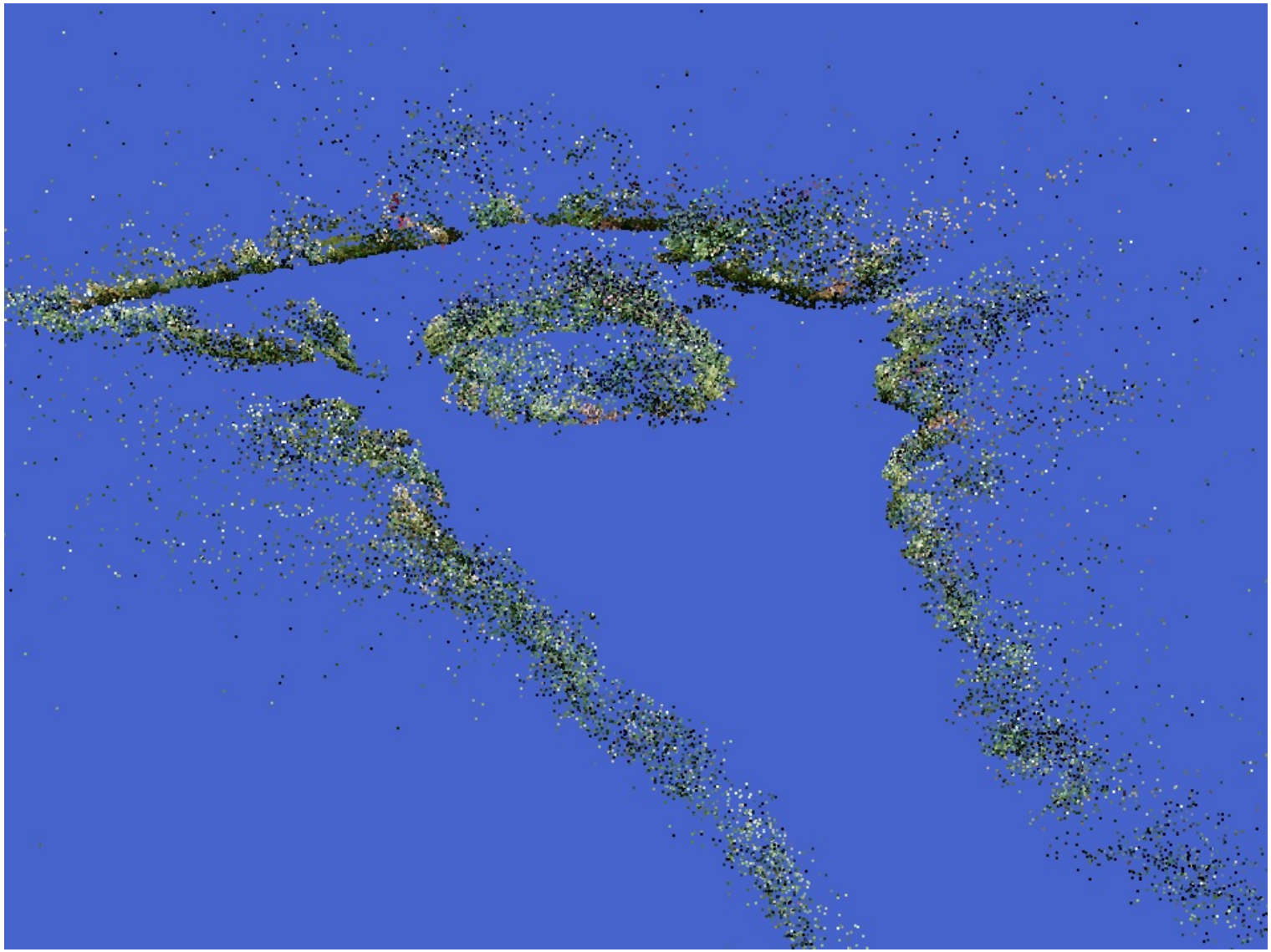


Seeds and pollen

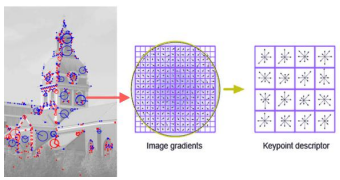
Research Question

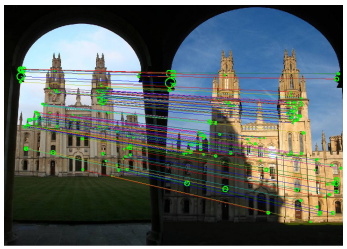
Is there a more stable characteristic of outdoor environment we can use as a starting place towards a full spatio-temporal model?

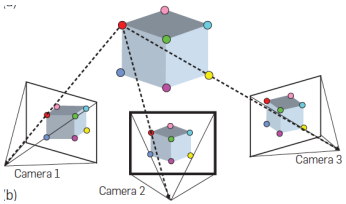
The Geometry of the Lakeshore

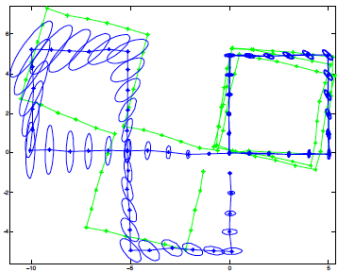


The Standard Visual SLAM Pipeline







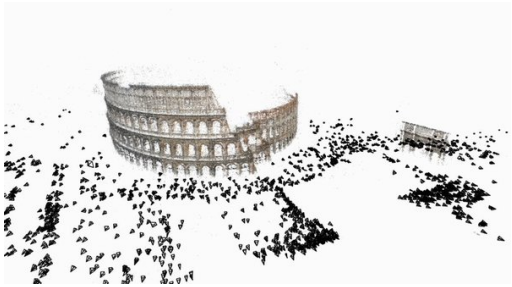


Feature Extraction → **Feature Matching** → **Triangulation** → **Optimization**

SIFT	Epipolar constraints	Hartley & Sturm	iSAM2
SURF	RANSAC	Kneip *et al.*	iLBA
BRISK	...	...	Ceres
BRIEF			ASLAM

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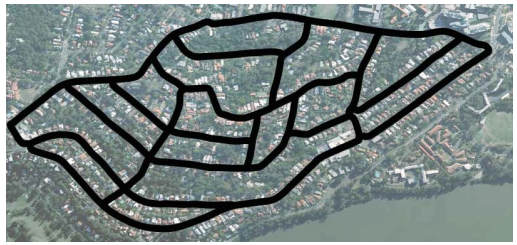
Outdoor Visual Mapping



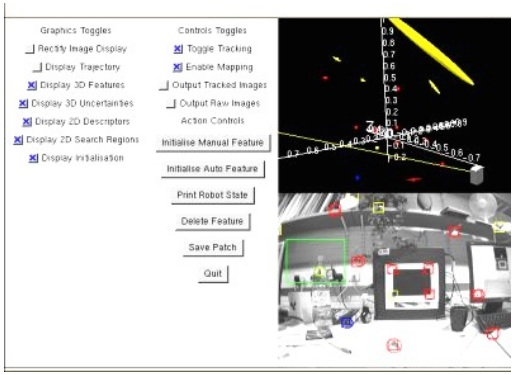
Agarwal *et al.*, 2011



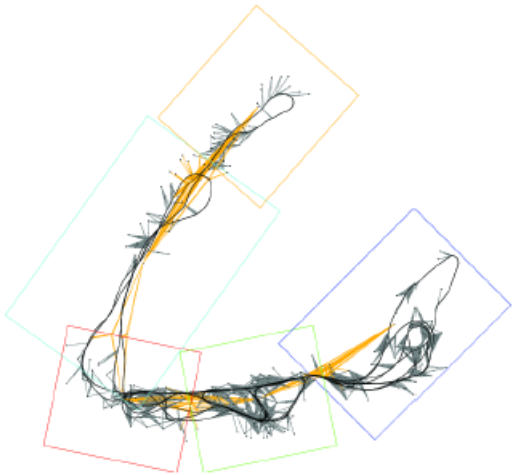
Nourani-Vatani *et al.*, 2010



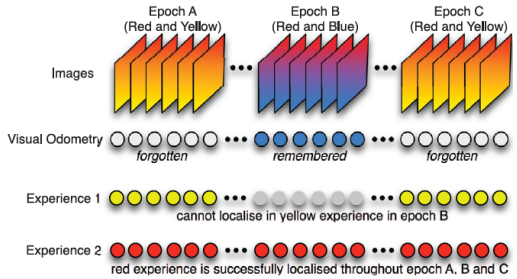
Glover *et al.*, 2011



Davison *et al.*, 2007



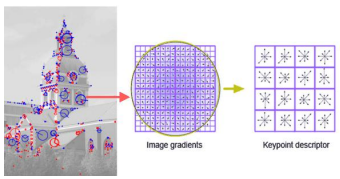
Ni *et al.*, 2007

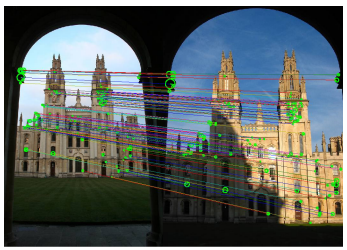


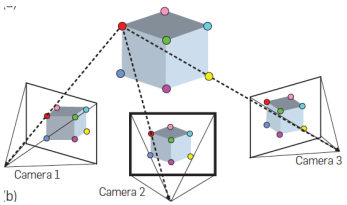
Churchill and Newman, 2013

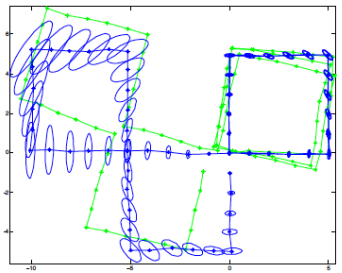
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Our Visual SLAM Pipeline









Feature Extraction → **Feature Matching** → **Triangulation** → **Optimization**

Lucas-Kanade

Epipolar constraints
RANSAC

Hartley & Sturm

iSAM2
Smart Factors

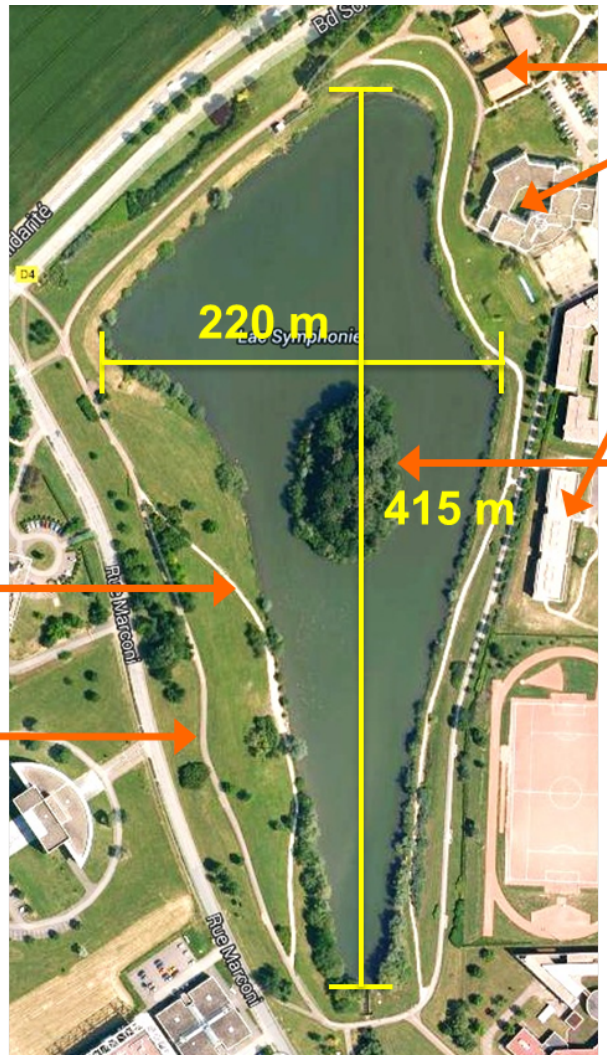
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The Lakeshore Environment



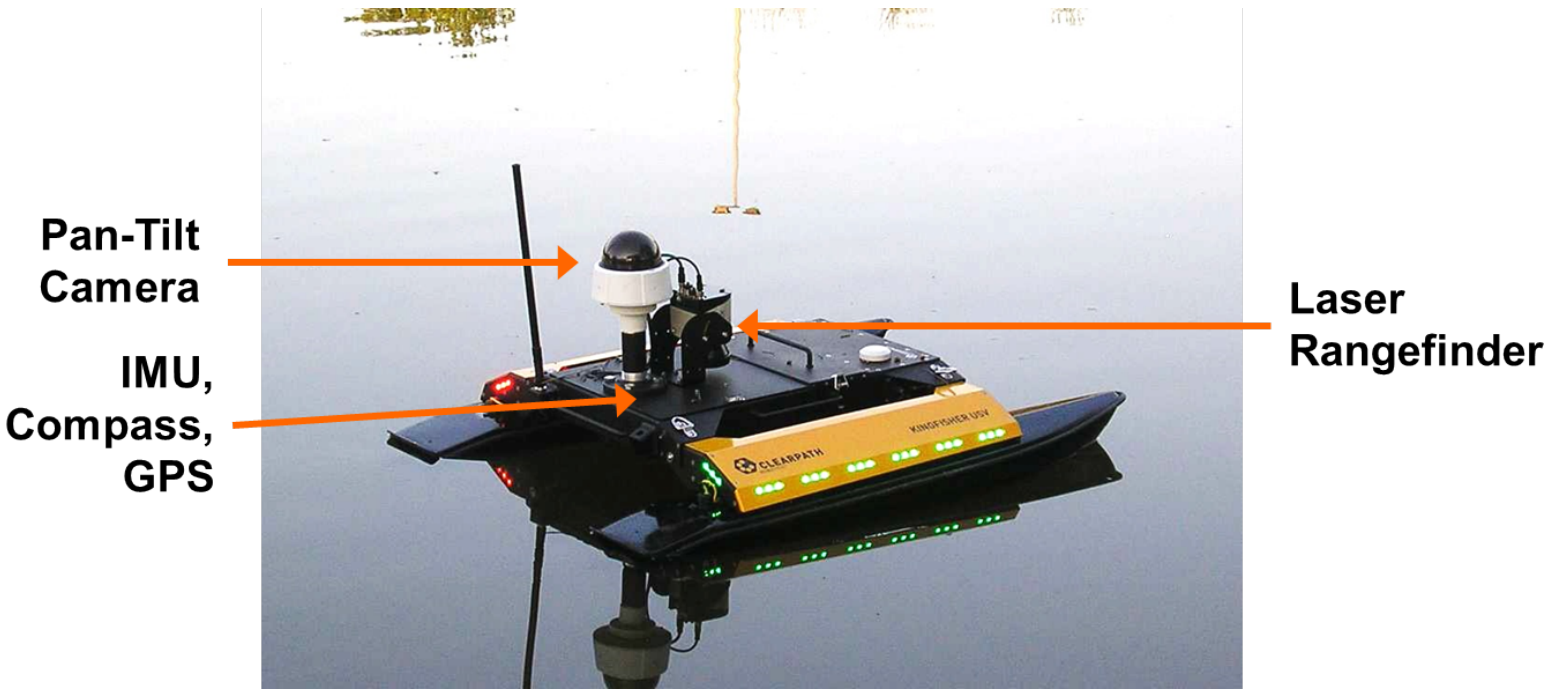
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Lac Symphonie



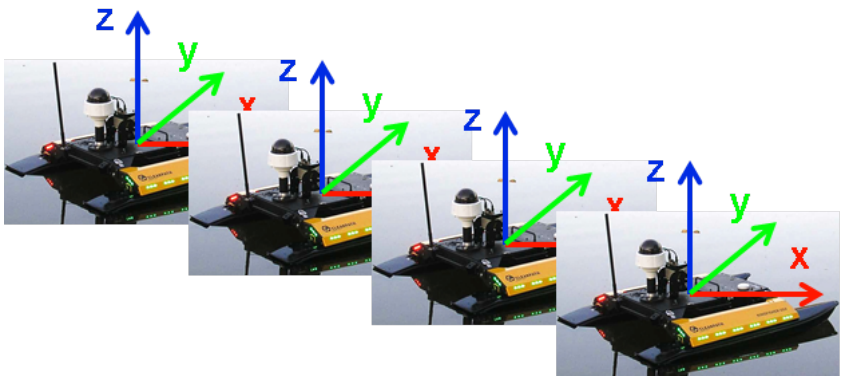
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Kingfisher from Clearpath-Robotics



Data Collection

Boat Poses



- Position from GPS
- Orientation from IMU/Compass
- Approx. constant speed: 0.5m/s

Images



- 704 x 480 color images
- 10 FPS
- Light JPEG compression

Example of the monitoring route



Camera's Point of View



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Natural Scene Variation Across Surveys



Comprehensive Dataset

30 surveys collected since Aug. 18th, 2013

1,100,000+ images

Every second week in average

SIFT Feature Matching

Same survey

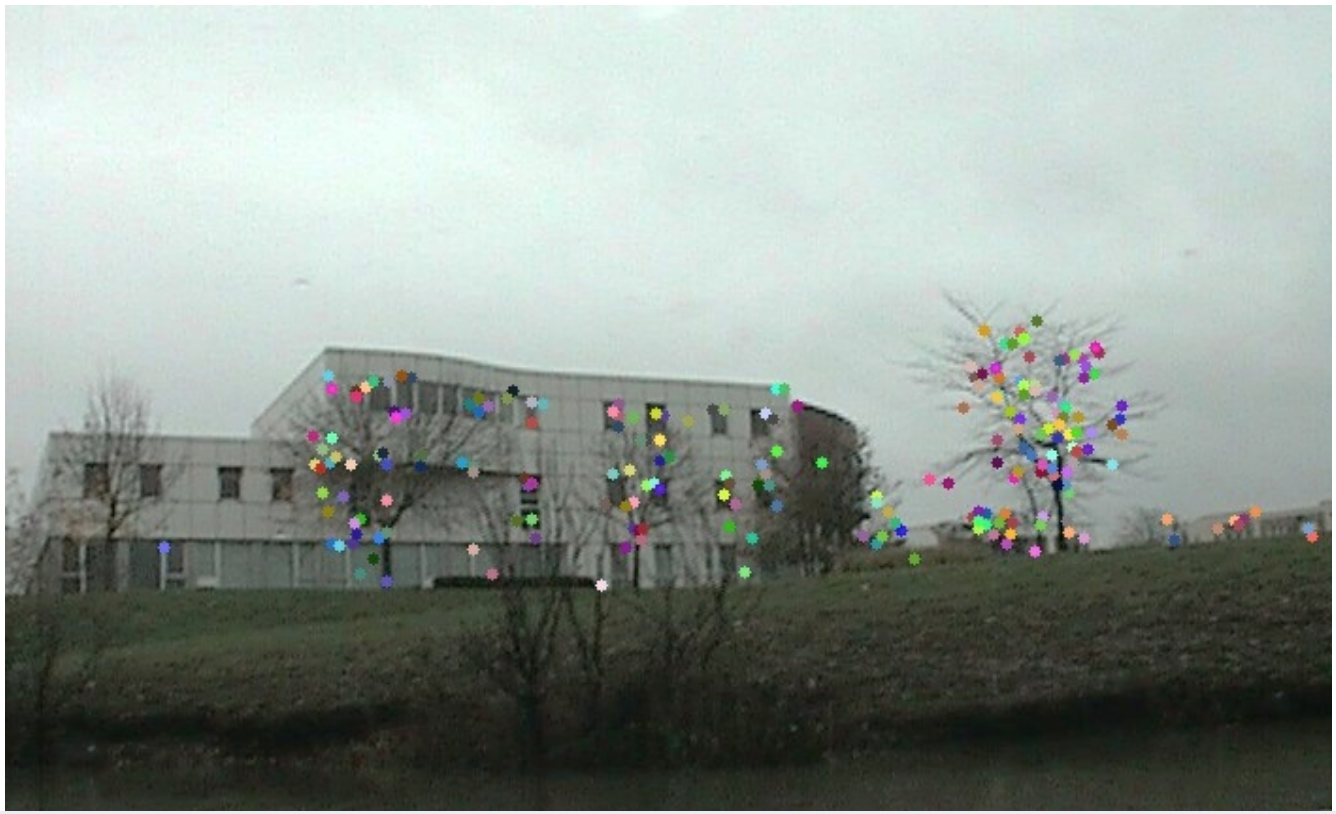
- Sparse set of features.
- Spatially unbalanced.



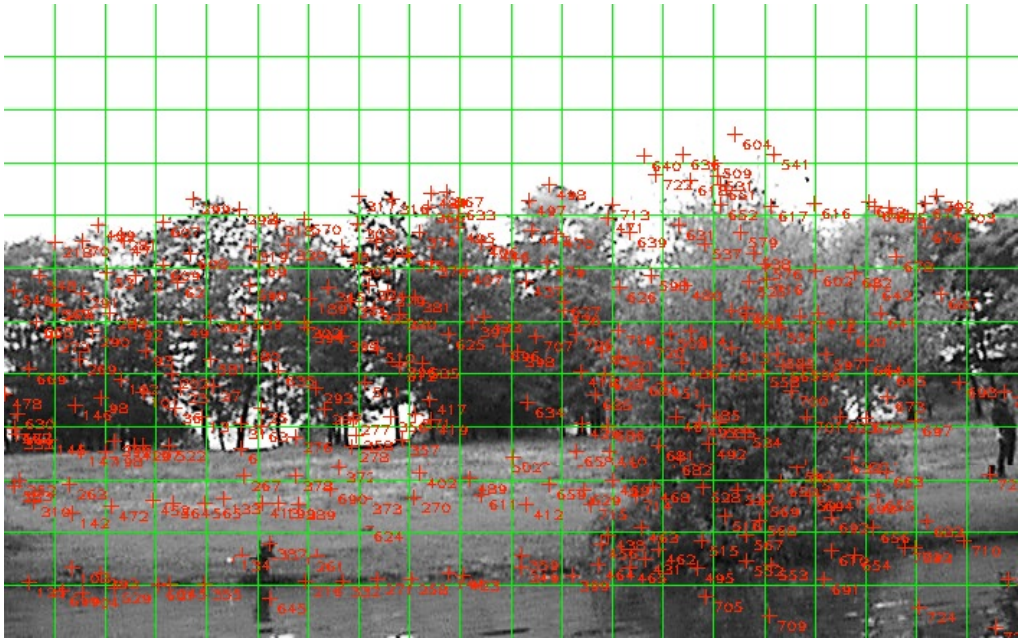
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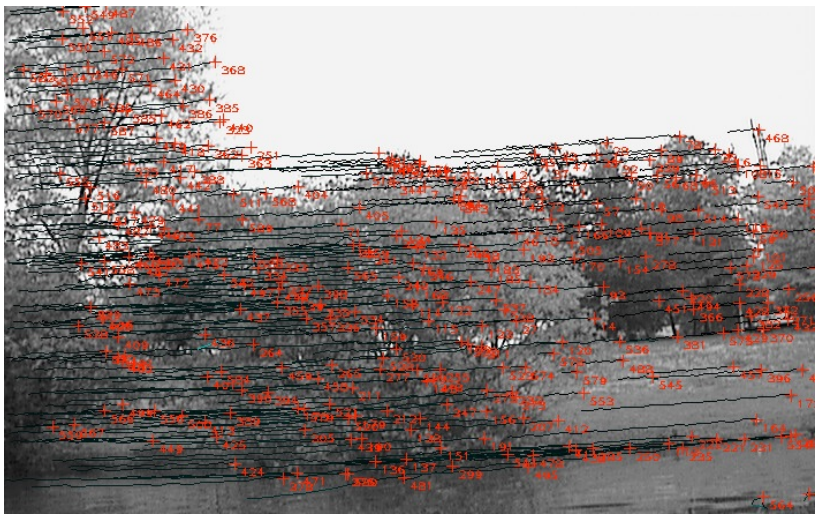
Lucas-Kanade Tracker

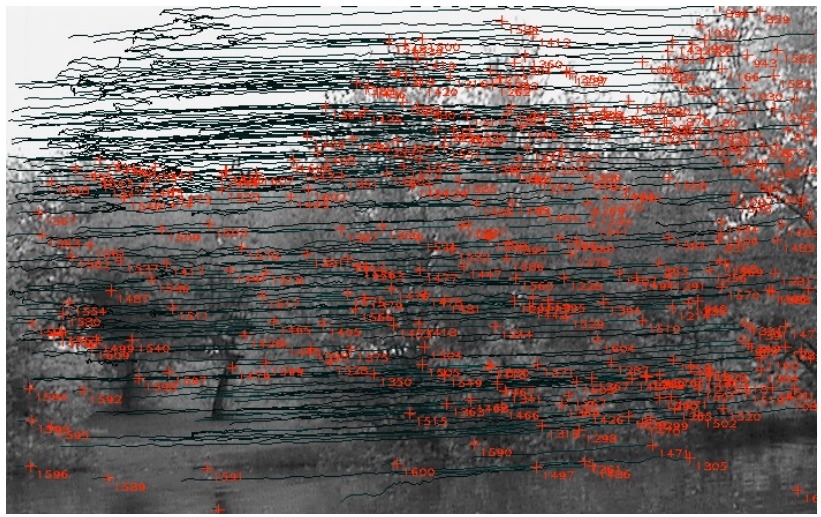


- Divide image into a grid (e.g. 12x20)
- Start tracking new features only in empty cells.

$\Longrightarrow$ Dense and Fast.

Feature tracks





- Reliable and stable feature tracking over long image sequences.
- Good scene coverage.

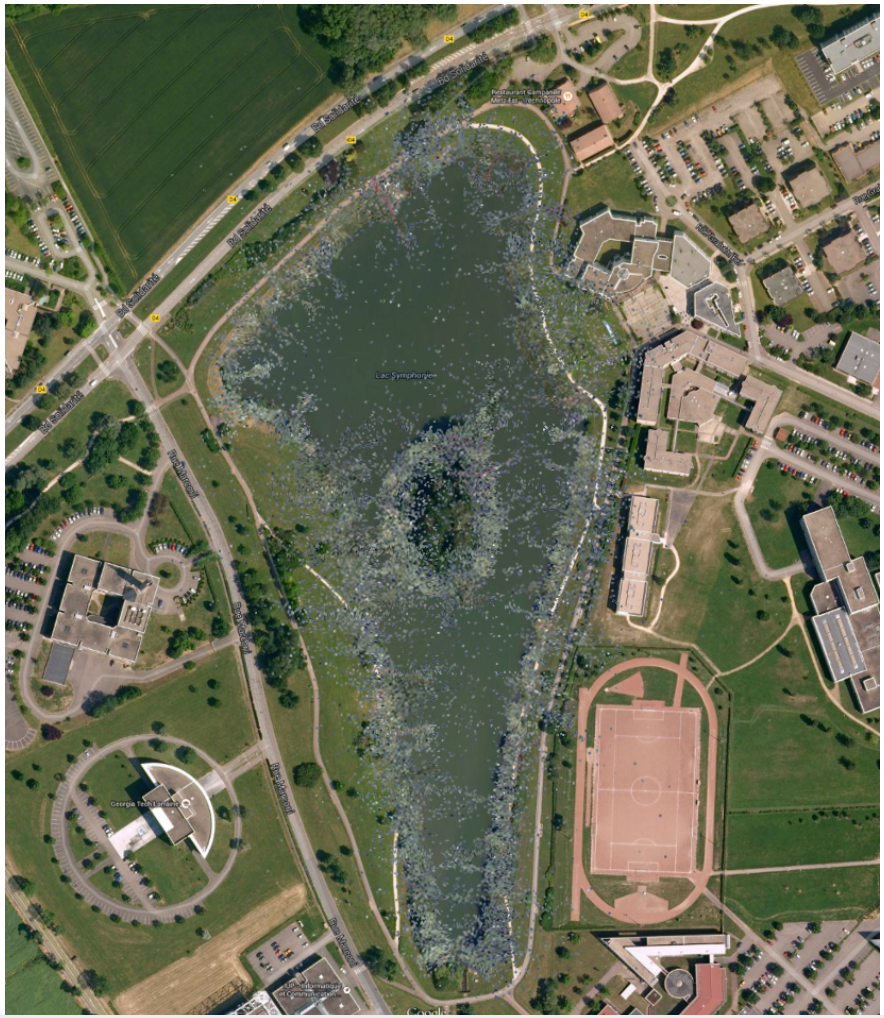
Initial Estimates of 3D feature positions

Based on the output of the KLT tracker



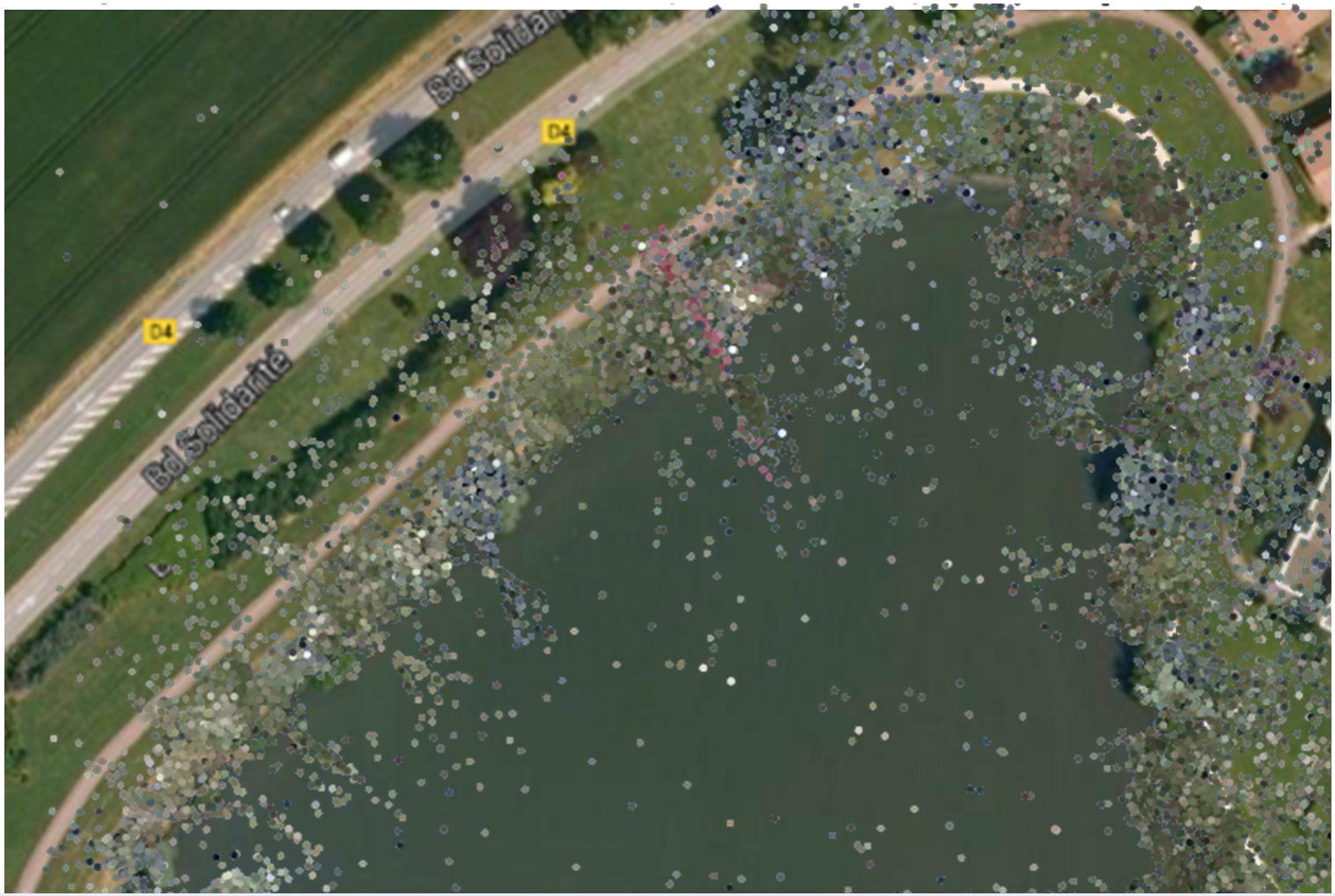
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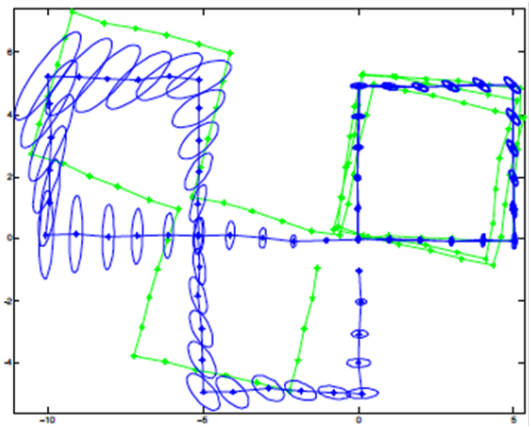


Initial Estimates of 3D feature positions

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Optimization

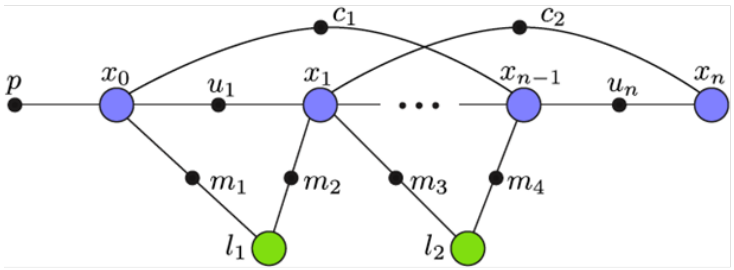


- Adjust the landmark positions and the robot poses to reduce the noise in the initial estimates.
- Minimize the total reprojection error between the observed and the predicted points.

Image from Dellaert 2012, example from Ed Olson.

iSAM2: Incremental Smoothing and Mapping

Kaess *et al.*, 2012



SLAM Factor Graph



Bayes tree data structure

- A factor graph is used to capture dependences among the different constraints to be optimized.
- Once converted into a Bayes tree, this method can perform fast, incremental optimization.

Image from Kaess et al. 2012.

Smart Factors

Carlone *et al.*, 2014



- The Schur complement is used to decompose the optimization problem into subproblems.
- All the observations for a particular landmark are encapsulated by a single smart factor.

Image from Carlone et al. 2014.

Optimized 3D feature positions



Optimized 3D feature positions



Optimized 3D feature positions



Current work: inter-survey alignment



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Conclusions on Environment Monitoring

- Outdoor environment are challenging for predominant data association techniques.
- A geometric model of the lakeshore may provide a basis for acquiring a model that accounts for natural variation of appearance.
- KLT improved our ability to capture 3D structure.

Outline

Autonomous Lakeshore Monitoring

Conclusion

Conclusion

- Still a lot to do for outdoor, visual mapping and navigation.
- World-wide, converging efforts towards mapping and estimation tools.
- Still some space for interesting robotic applications.

Thank you for your attention

