# Distributed Real-time Cooperative Localization and Mapping

## Using an Uncertainty-Aware Expectation-Maximization Approach

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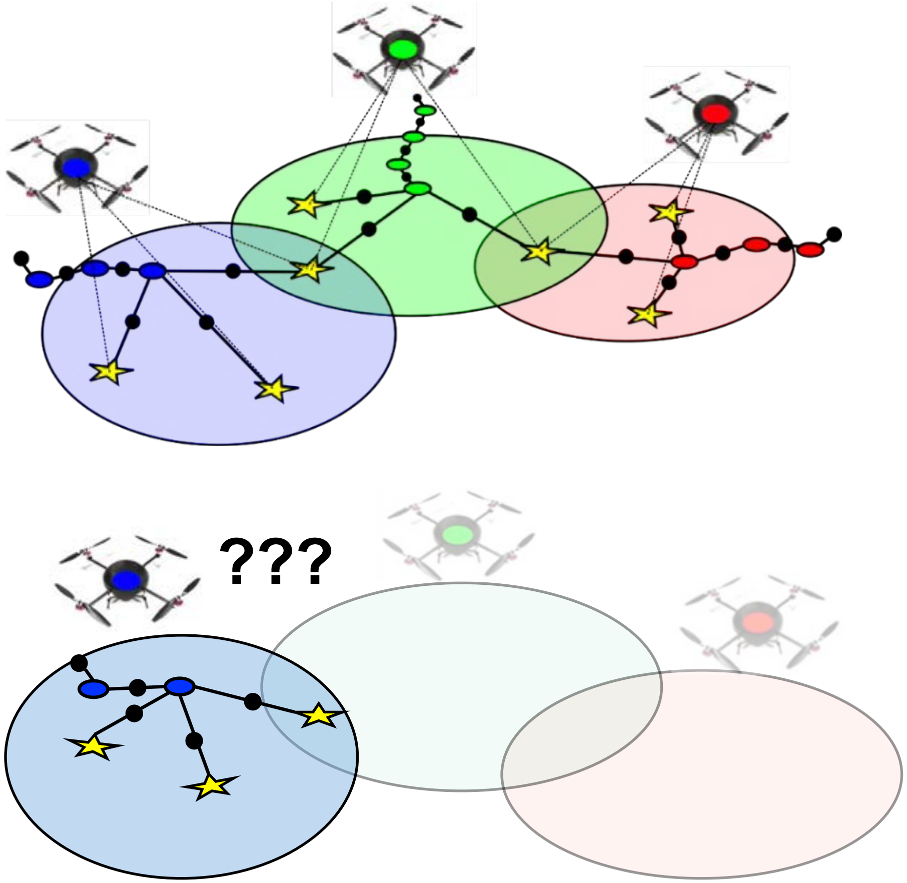
# Distributed Mapping

Efficient to explore large area by deploying multiple robots.

**Challenges**

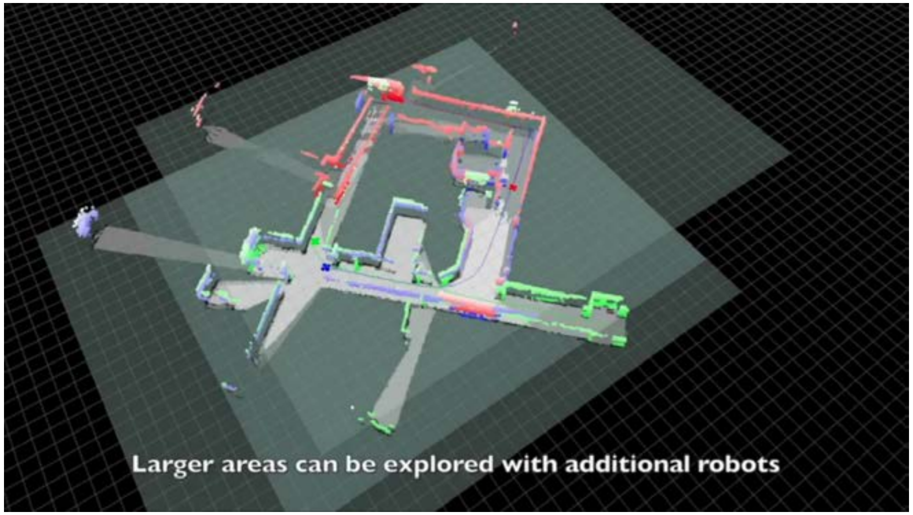
- Imperfect measurements.
- Asynchronously mapping: No rendezvous / direct views.
- No artificial landmarks.
- Failure of communication or even a robot.



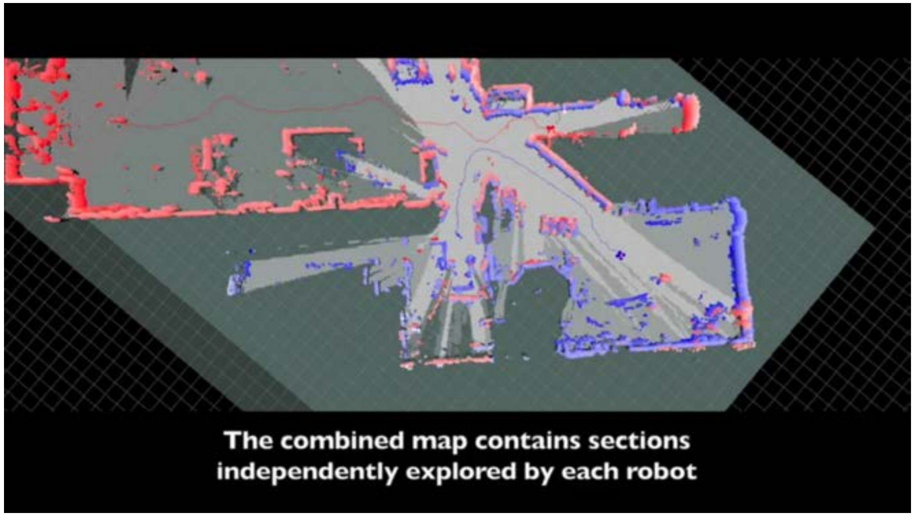
*Credit: Alex Cunningham and Frank Dellaert,* Large-scale experimental design for decentralized SLAM, SPIE 2012

# Our Work

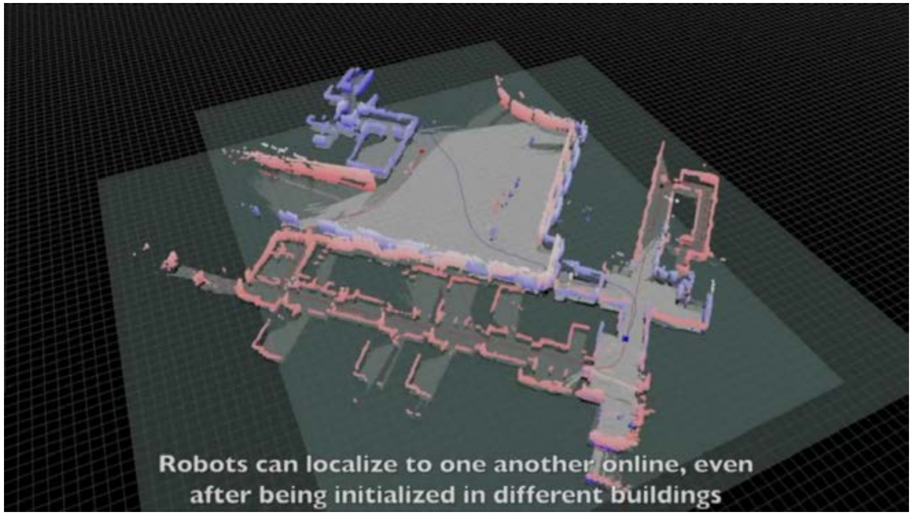
- Distributed approach.
- Only base on natural features.
- No direct measurement needed between robots.
- Online and Real-time.



3 robots indoor


The combined map contains sections independently explored by each robot

2 robots indoor


Robots can localize to one another online, even after being initialized in different buildings

2 robots indoor+outdoor

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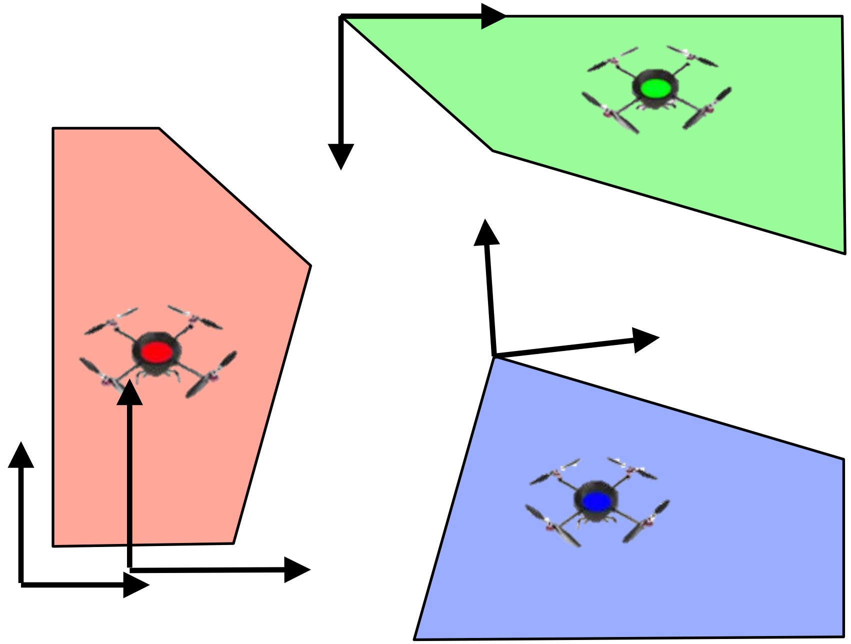
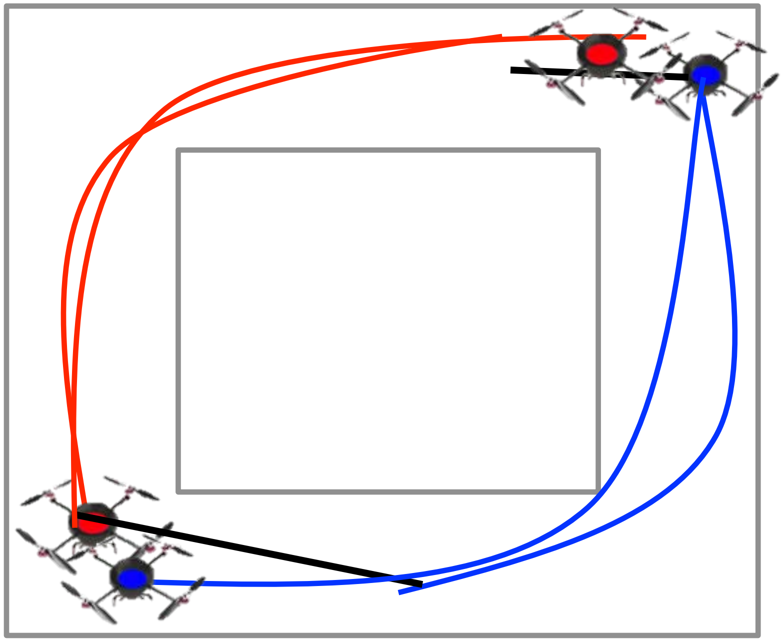
# Approach

- An EM approach to build a common reference.
- An EM approach to find correct loop closures between robot.





### Robustness

Multi Indoor/outdoor datasets validated

### Efficiency

Run 10~20Hz onboard

### Accuracy

~1m in ~100m size map

### Scalability

Up to 6~8 drones (current setting, limited by Network capacity)

### Conclusion

We have a distributed / fast / robust approach to solve multi-robot SLAM problem.

## Thanks!

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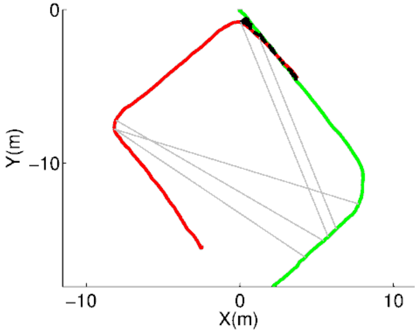
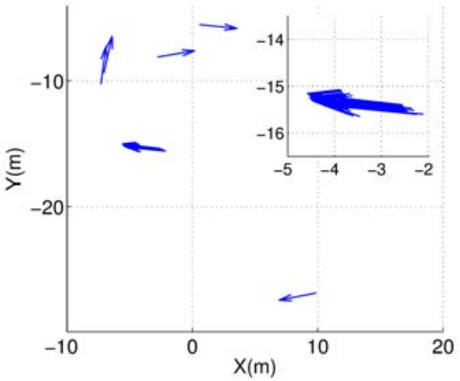
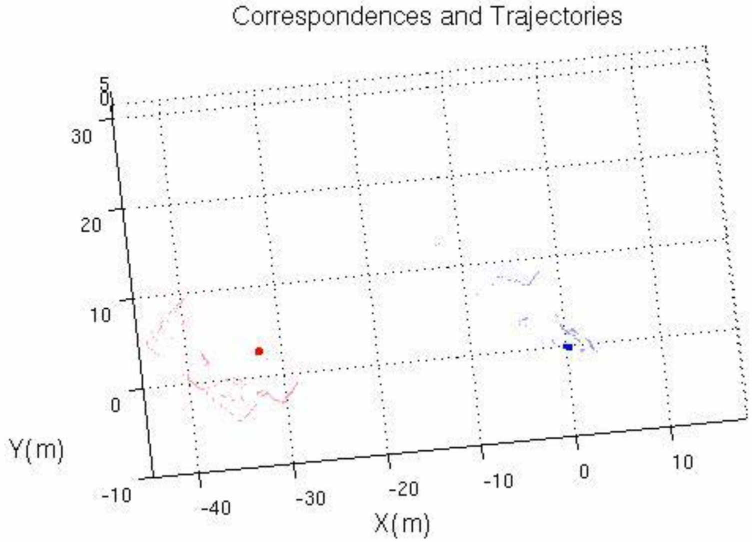
# Backup Slides

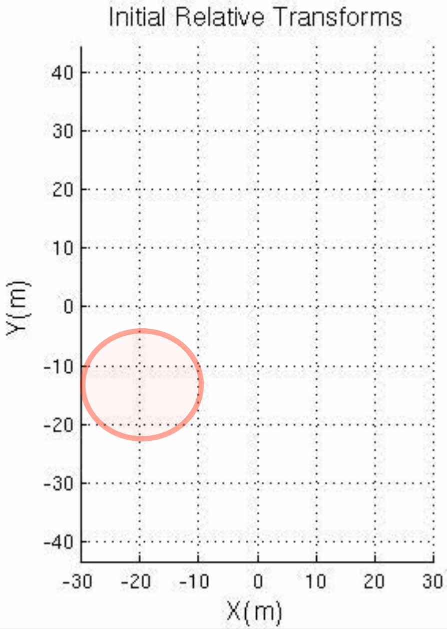
# Build Common Reference Frame

- Multi-robot correspondences: Loop closure between robots.
- Inliers have similar *initial relative poses*: cluster and optimize use EM.
- *Measurement aliasing* rejected by hypothesis selection



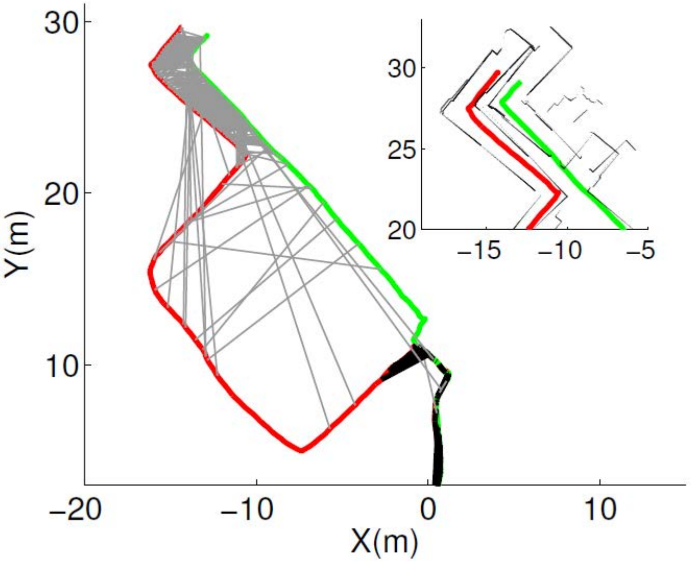


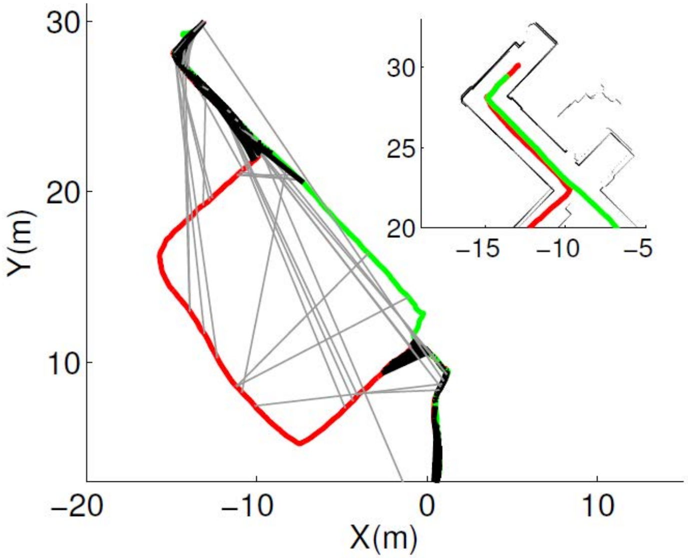




# Uncertainty Aware Approach

- Drift of odometry causes the failure to identify inlier correspondences.
- Let the EM approach aware the uncertainty of current poses, accept more biased correspondences if uncertainty is large.

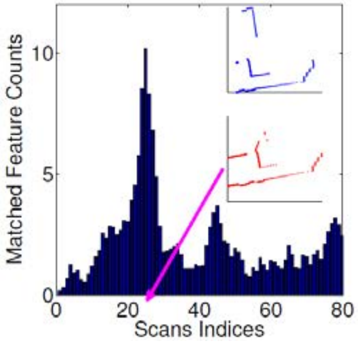


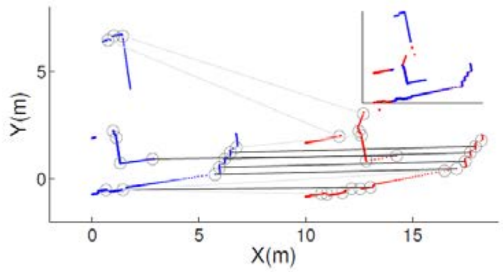


# Real-time Implementation on Robot

## Frontend

- Bag-of-Word + RANSAC based loop closing, using FLIRT 2D laser features
- Average runtime ~10ms when ~1e3 scans are indexed.





## Backend

- iSAM2 incremental optimizer.
- UKF-based mapper.

## Hardware

- CMU Quadrotor platform
- 2D laser scanner + IMU
- 1.86GHz Intel Core 2 Duo CPU