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A Robust Graph-based Framework for Building Precise Maps from Laser Range Scans

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Introduction

- Preparing mobile robots for industrial environments:
  - Requires precise position estimates
  - Setting of artificial markers is inconvenient
- Localization quality depends on:
  - Accuracy of sensors used
  - Computational power
  - Accuracy and resolution of prior map
- Requirements of a SLAM framework:
  - Robust in the presence of repetitive structures
  - High scalabilty for application in large scale environments
  - High precision of final map

Overview

- State-of-the-art graph optimization based methods used
- Use of feature based SLAM
  - Scales well with larger map sizes
  - Allows efficient map matching
- Perceptual aliasing poses a challenge
  - Limited observation space of 2D range scans
  - Industrial environments: high number of repetitive structures
- Decouple pose and map optimization
  - Estimate pose graph topology first
  - Map optimization based on correct pose graph

Framework Overview

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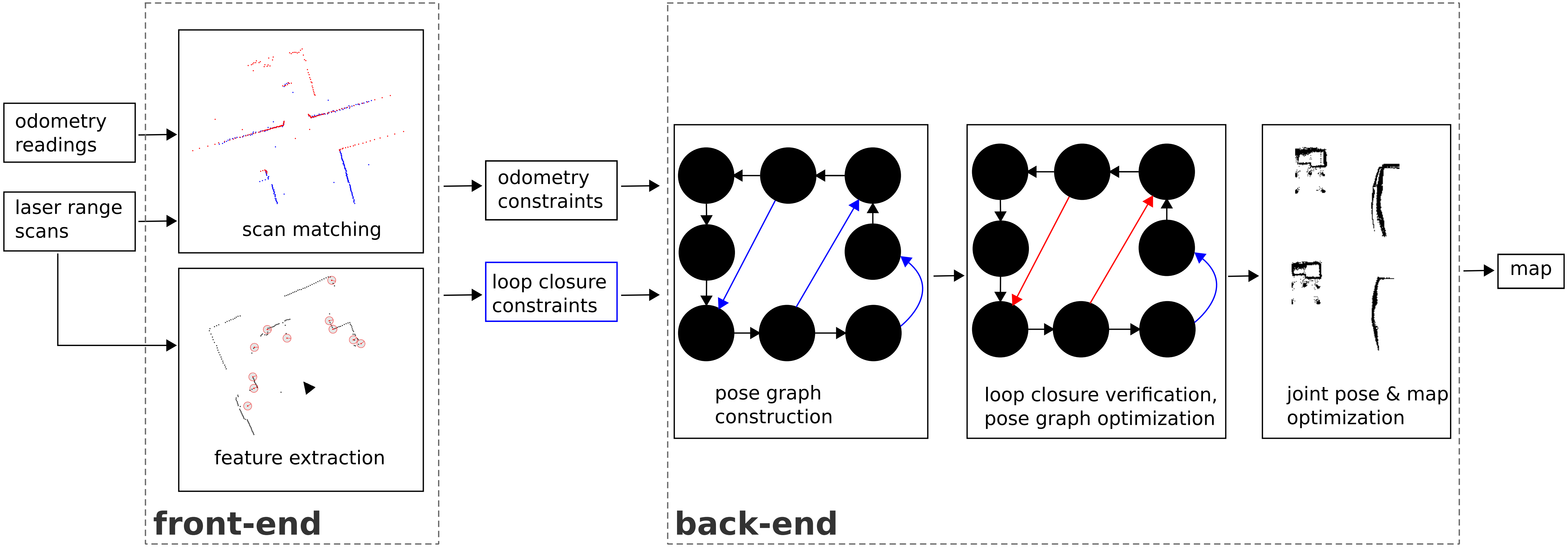
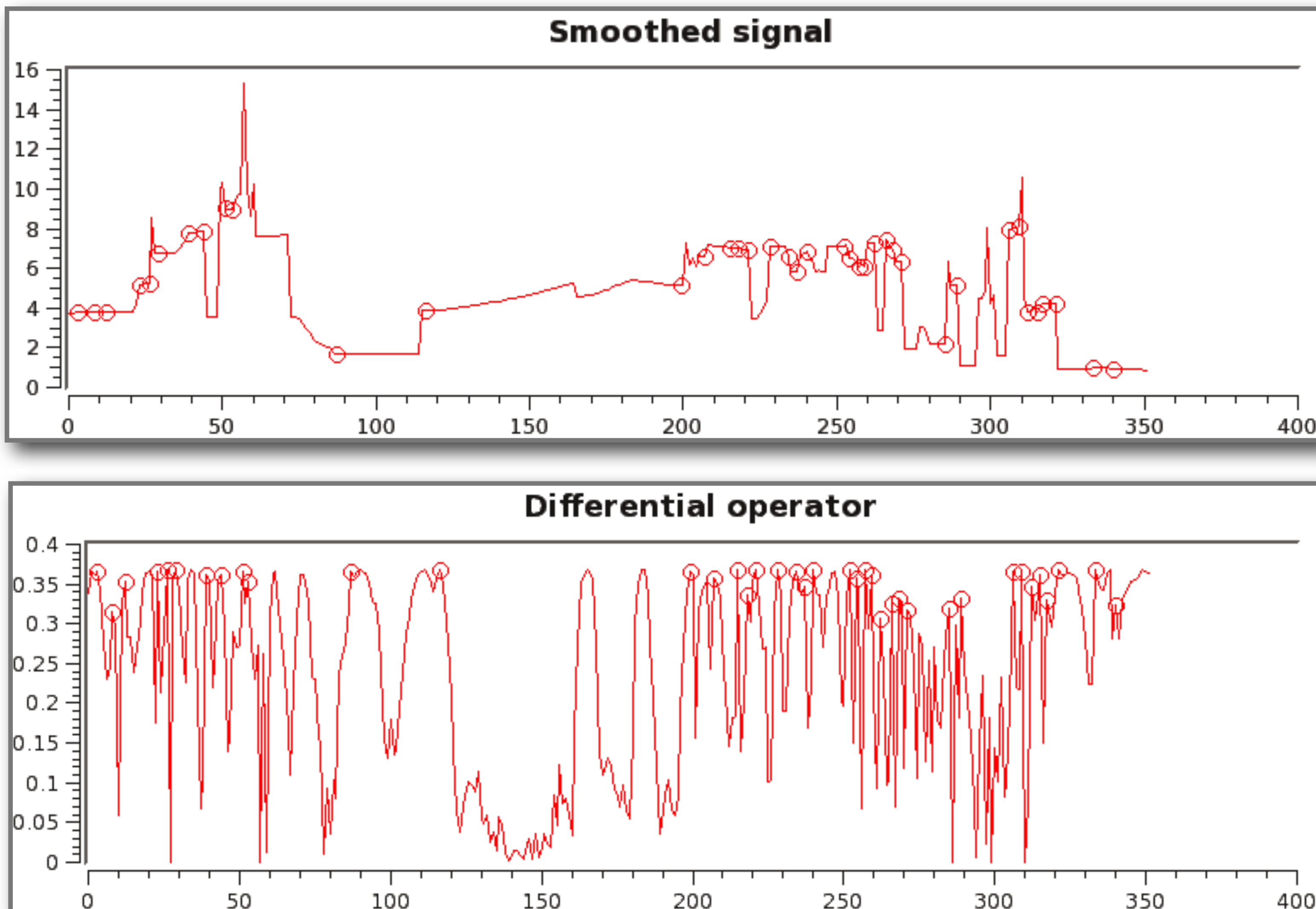
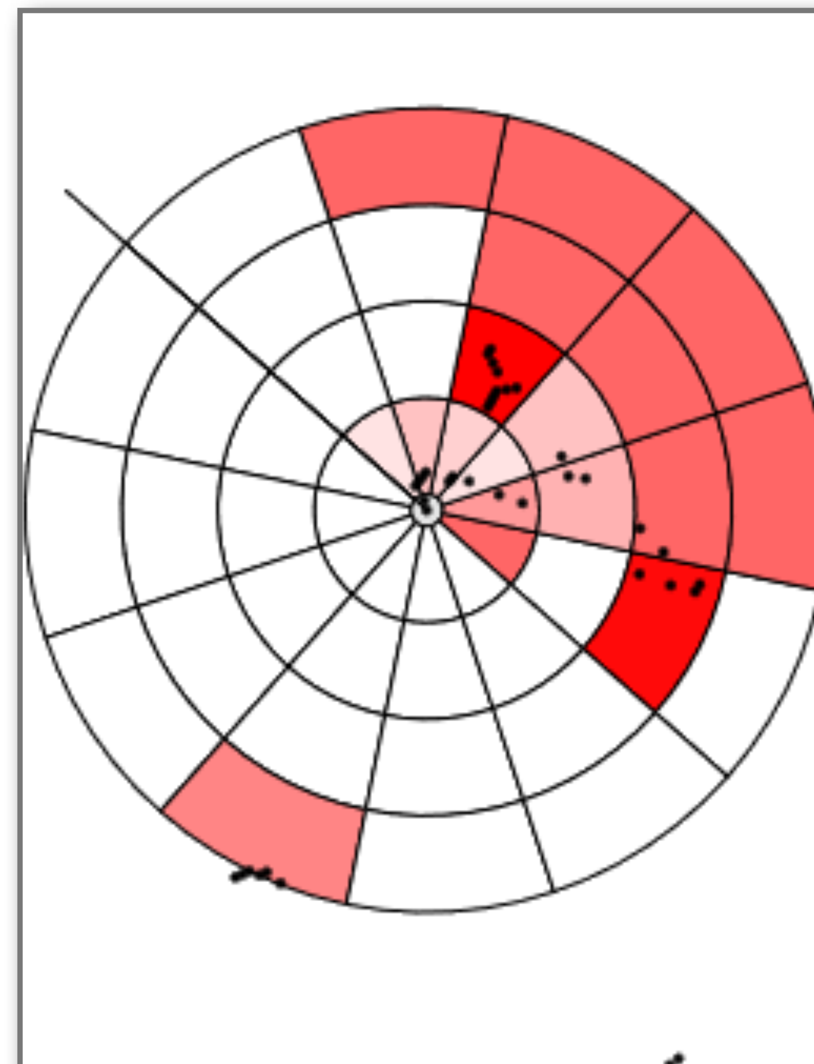


Front-End: Feature Extraction

- Extraction of FLIRT interest points (Tipaldi et al., ICRA ’10)

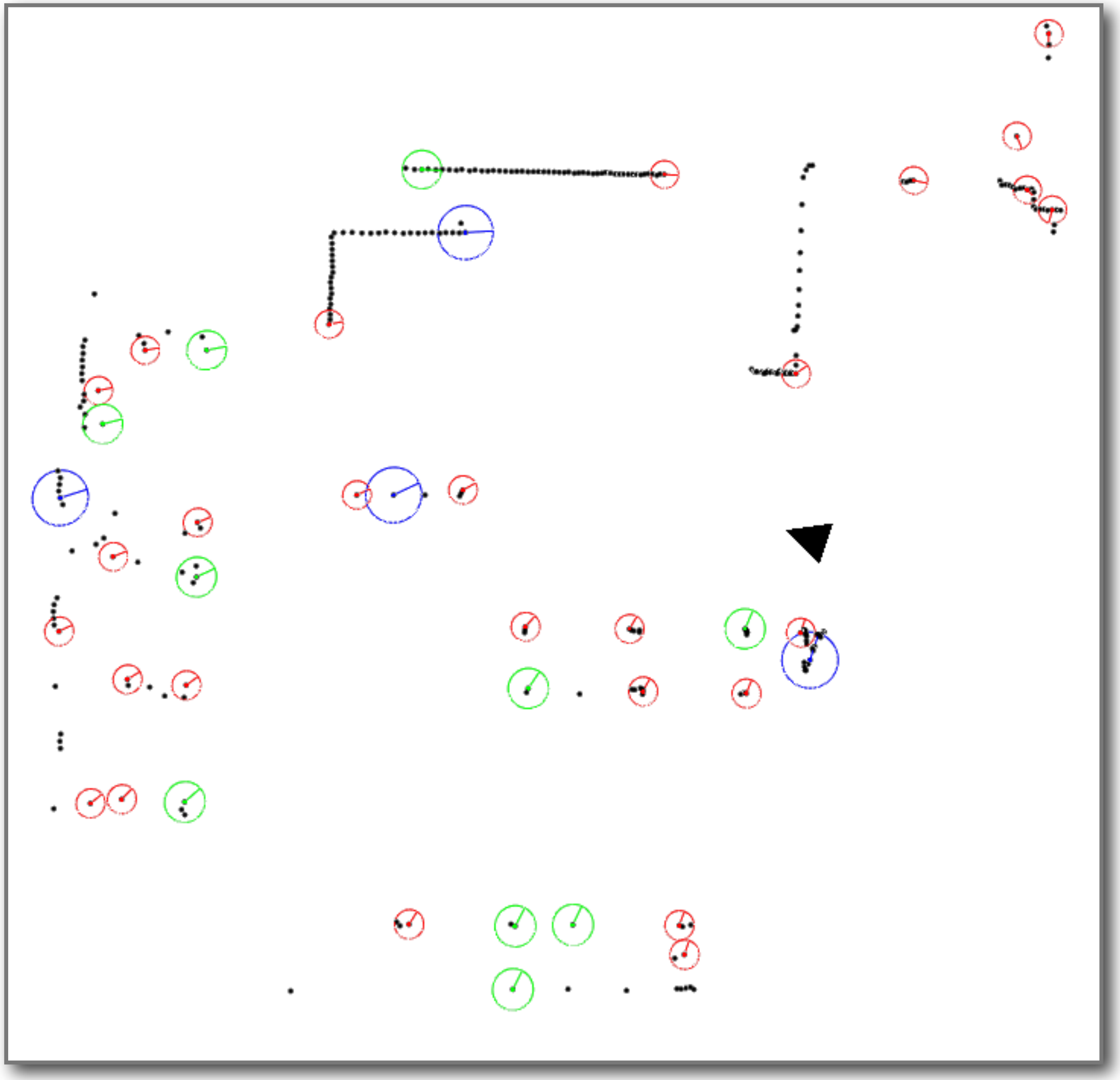


Features extracted from smoothed range readings



Beta grid describing local surroundings

Front-End: Feature Extraction



Example: Features detected, colors indicating scale

Front-End: Loop Closure Detections

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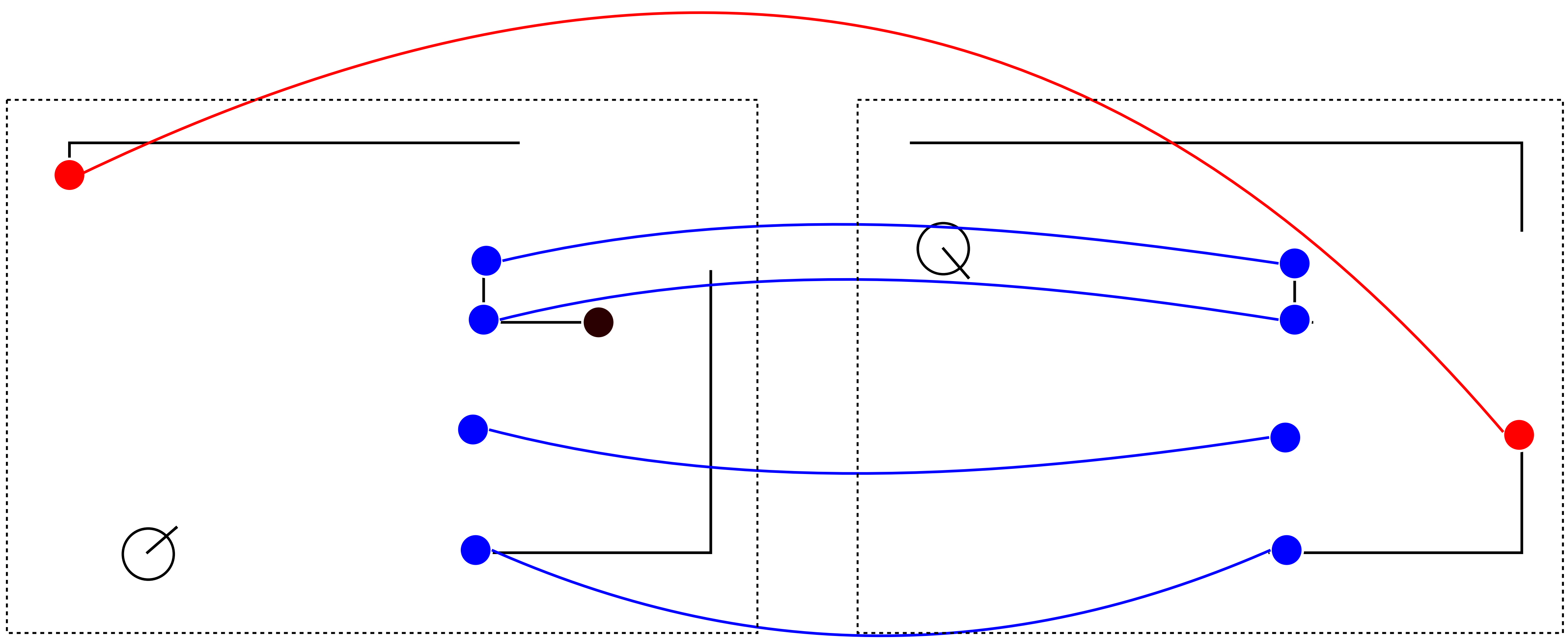
- Match features of reference & observed scans
  - RANSAC based outlier rejection
  - Estimation of rigid transformation of feature sets
  - Minimize point wise reprojected error



Matching feature sets; blue: inliers, red: outliers

Back-End: Pose Graph Optimization

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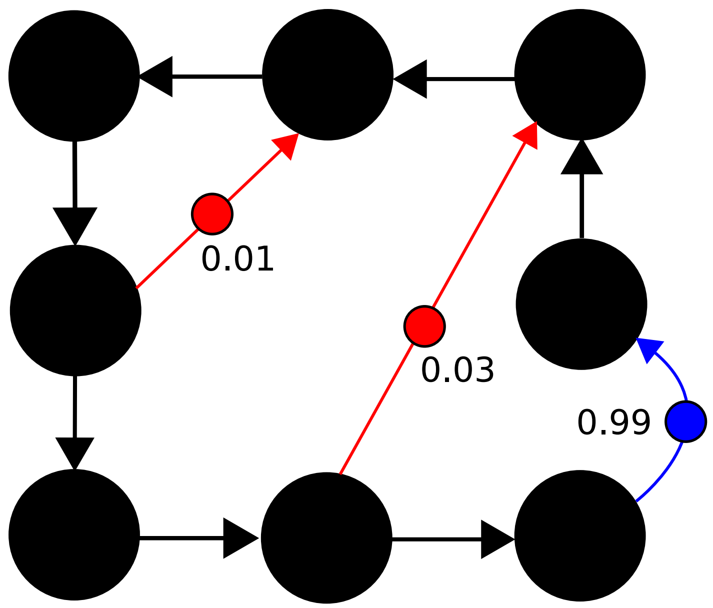
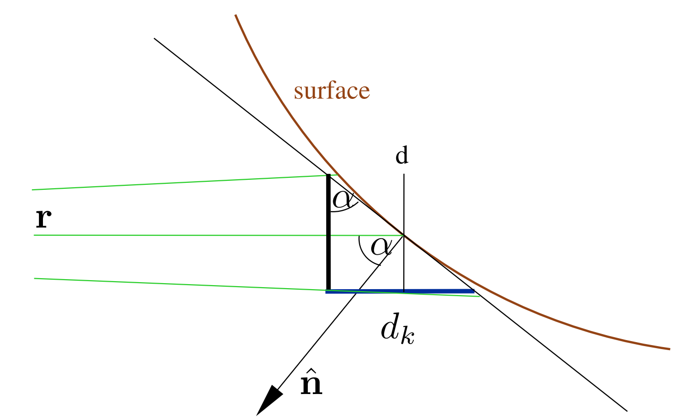
- Switchable Constraints (Sünderhauf et al., IROS ’11):
  - Loop closure incorporation is subject to optimization
  - Loop closure constraints can be “switched off”
  - Joint optimization of odometry & loop closure constraints
- Switch priors: Confidence provided by front-end
- Different switch functions possible
- Research Lines:
  - Latif et al.: Robust Loop Closing over time (RSS ’12)
  - Agarwal et al.: Max Mixture (RSS ’12), Dynamic Covariance Scaling (ICRA ’13)



Back-End: Map Optimization

- Based on Sparse Surface Adjustment (Ruhnke et al., ICRA '11)
- Assumption: Given pose graph is topologically consistent
- Advanced Sensor Model incorporates:
  - Incident angle w.r.t. surfaces
  - Conic shape of beam
- Data Association: laser beams are assigned surface patches
- Jointly optimize robot poses and laser measurements (range & direction)



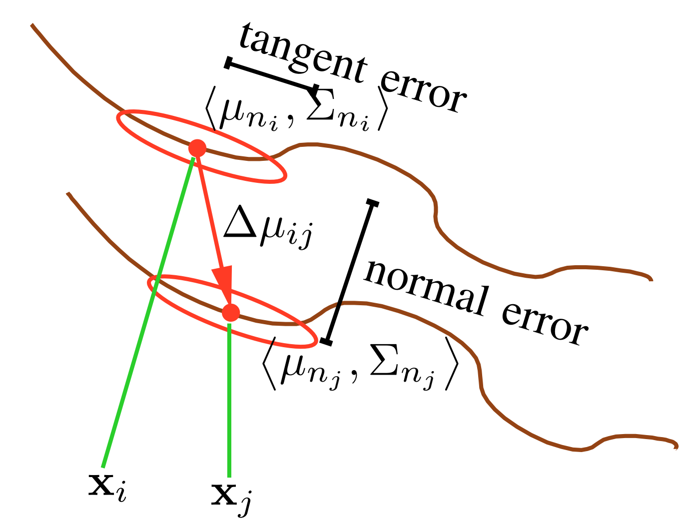


Image courtesy by Ruhnke et al.

Experiments

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SCITOS G5 operating in a warehouse

Experiments: Robust optimization

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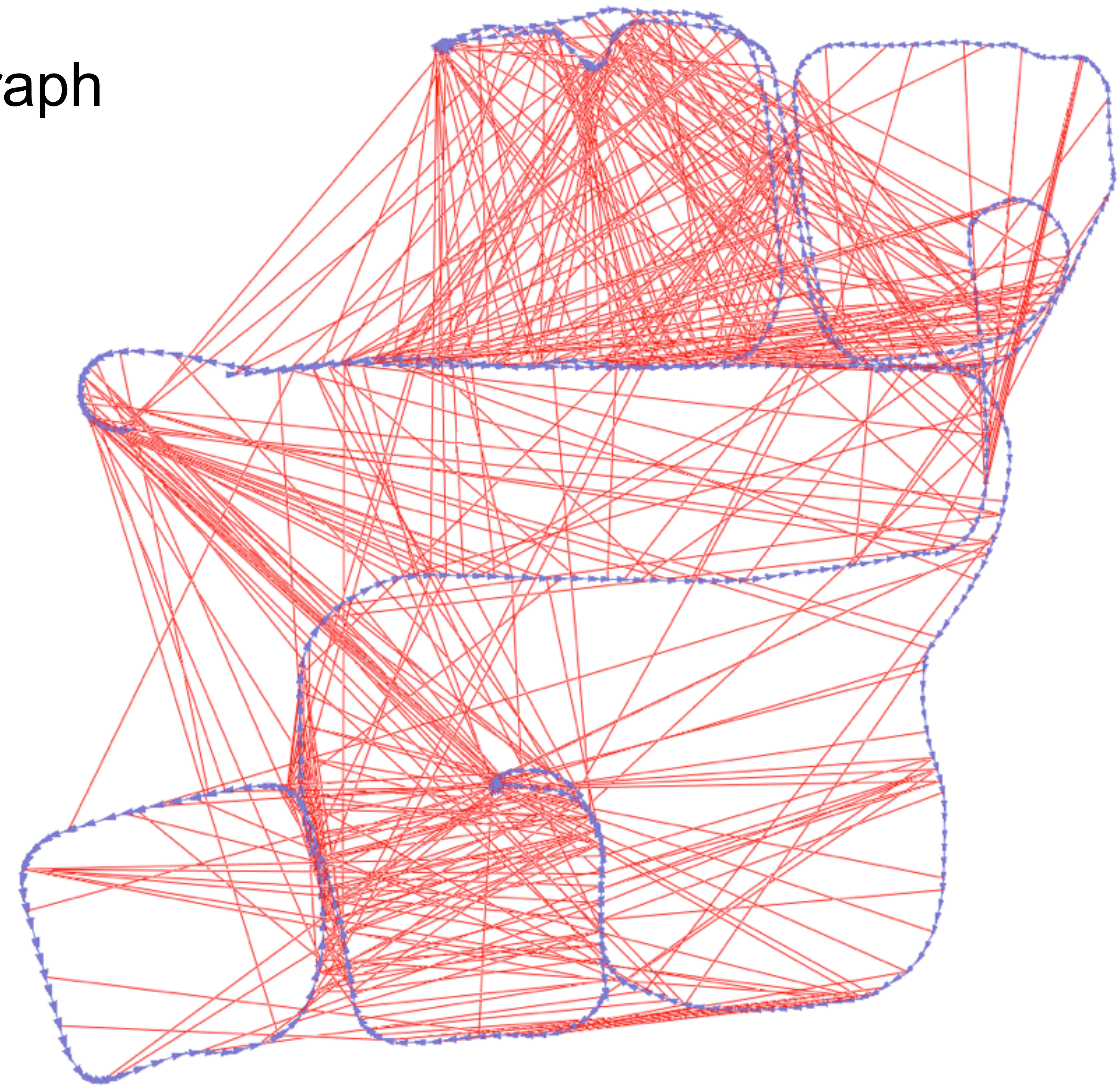
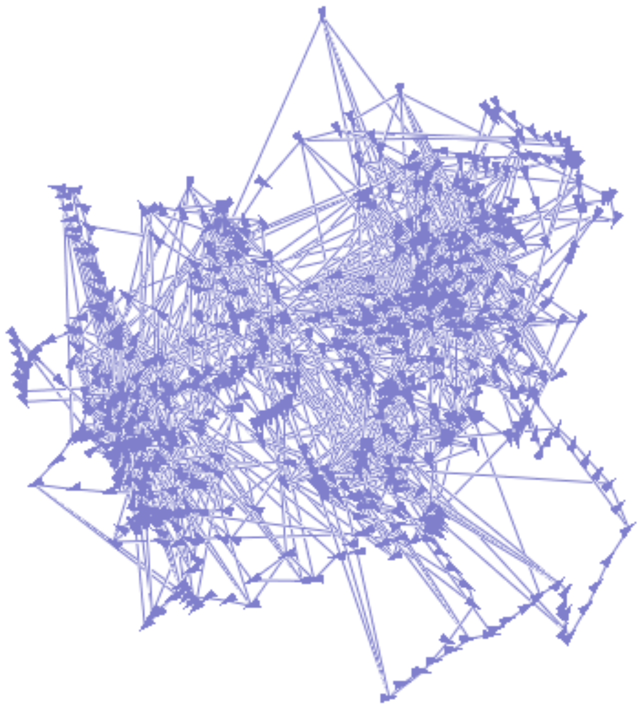
Initial Pose Graph



Experiments: Robust optimization

Nonrobust optimization



Experiments: Robust optimization

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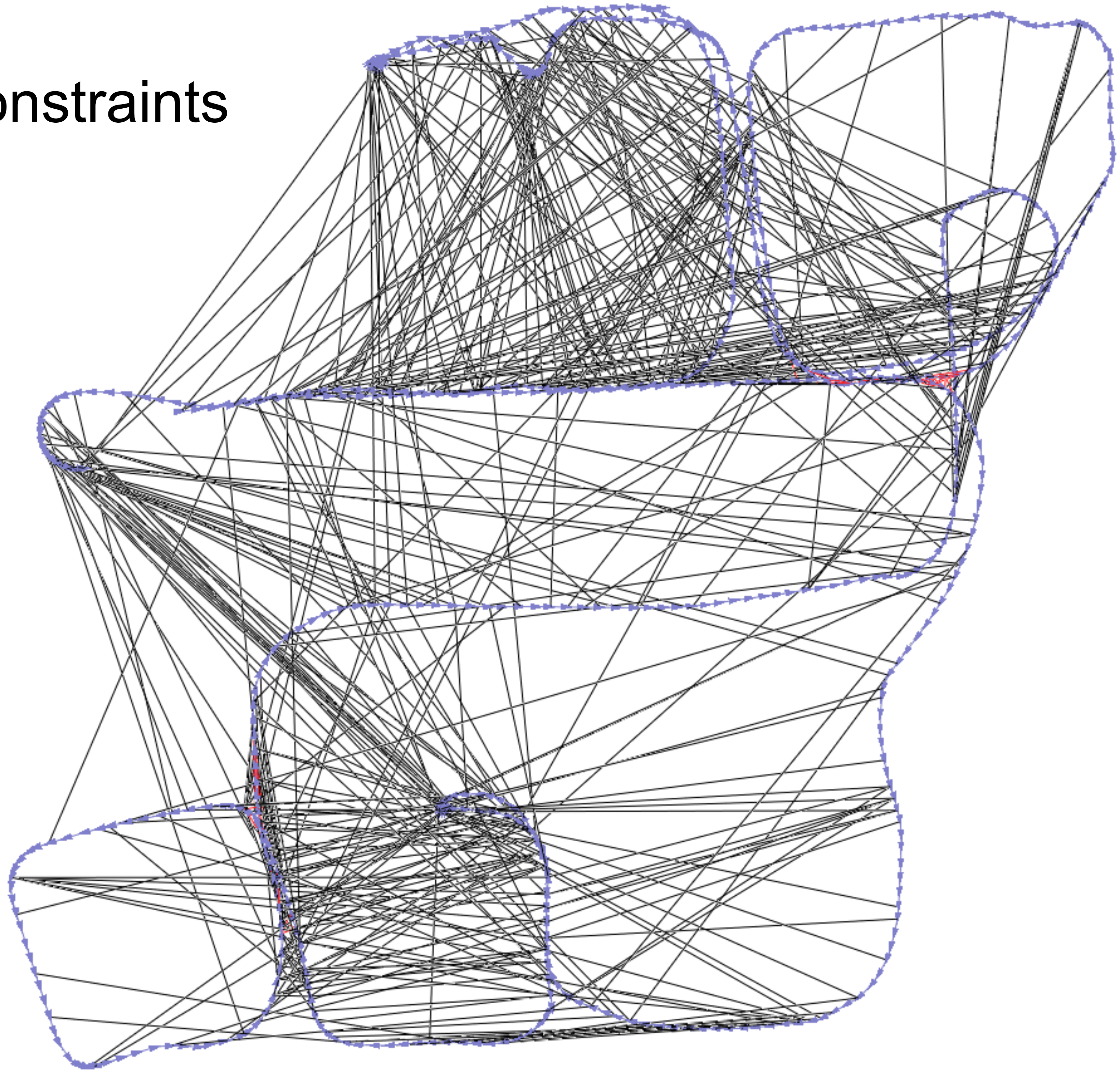
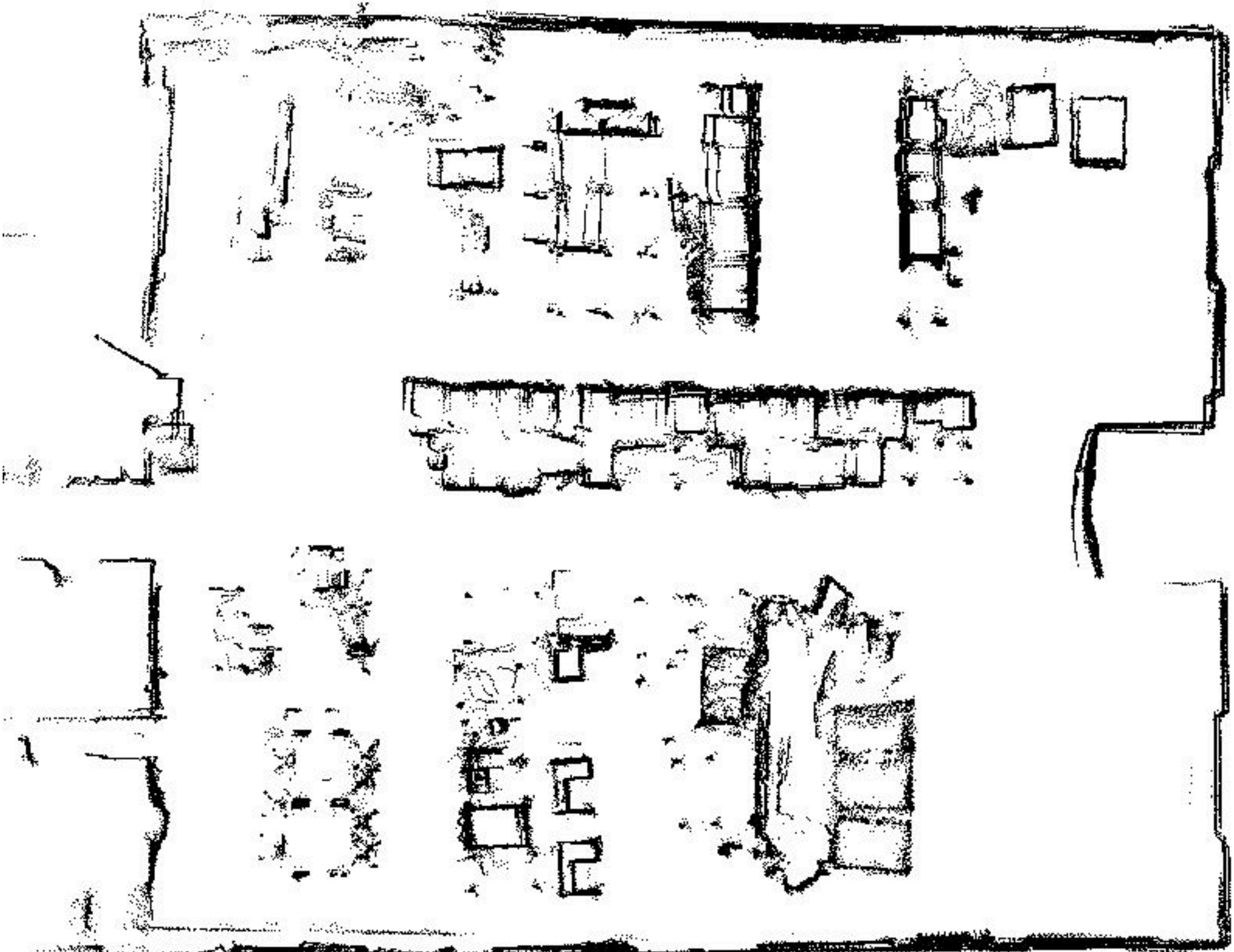
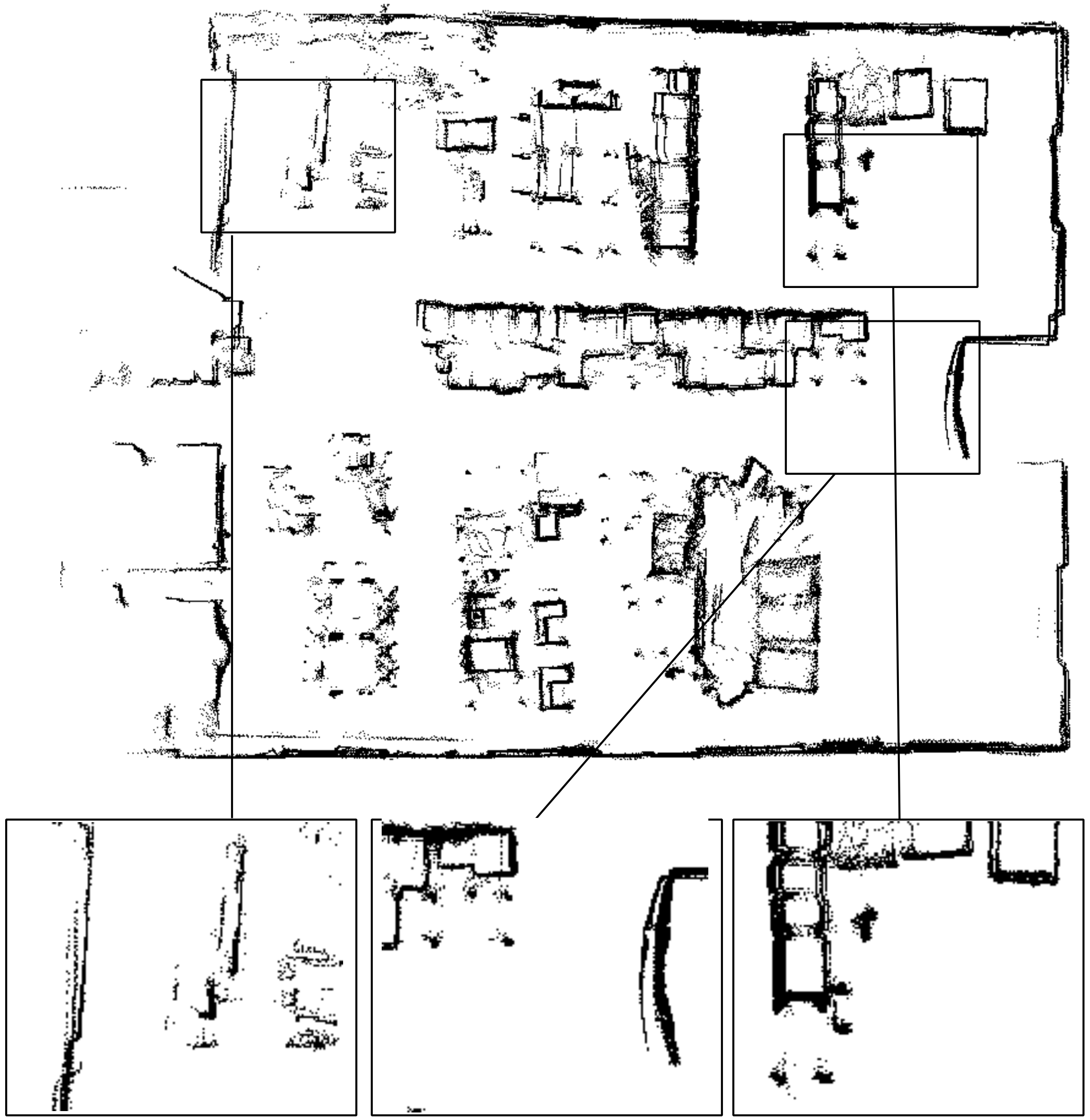
Switchable Constraints

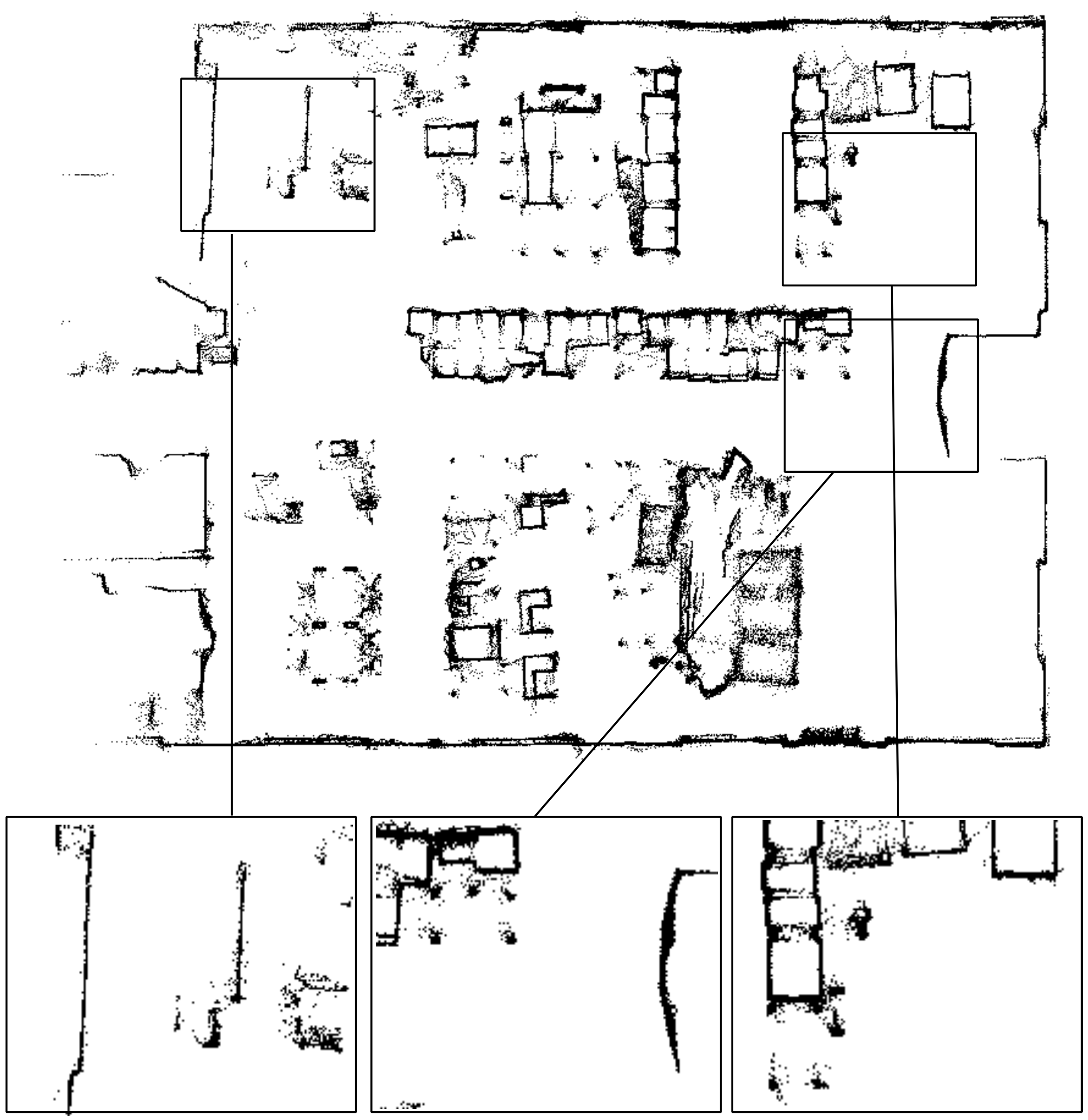




Experiments: Mapping Results (I)



No Optimization



Optimization using SSA

Experiments: Mapping Results (II)

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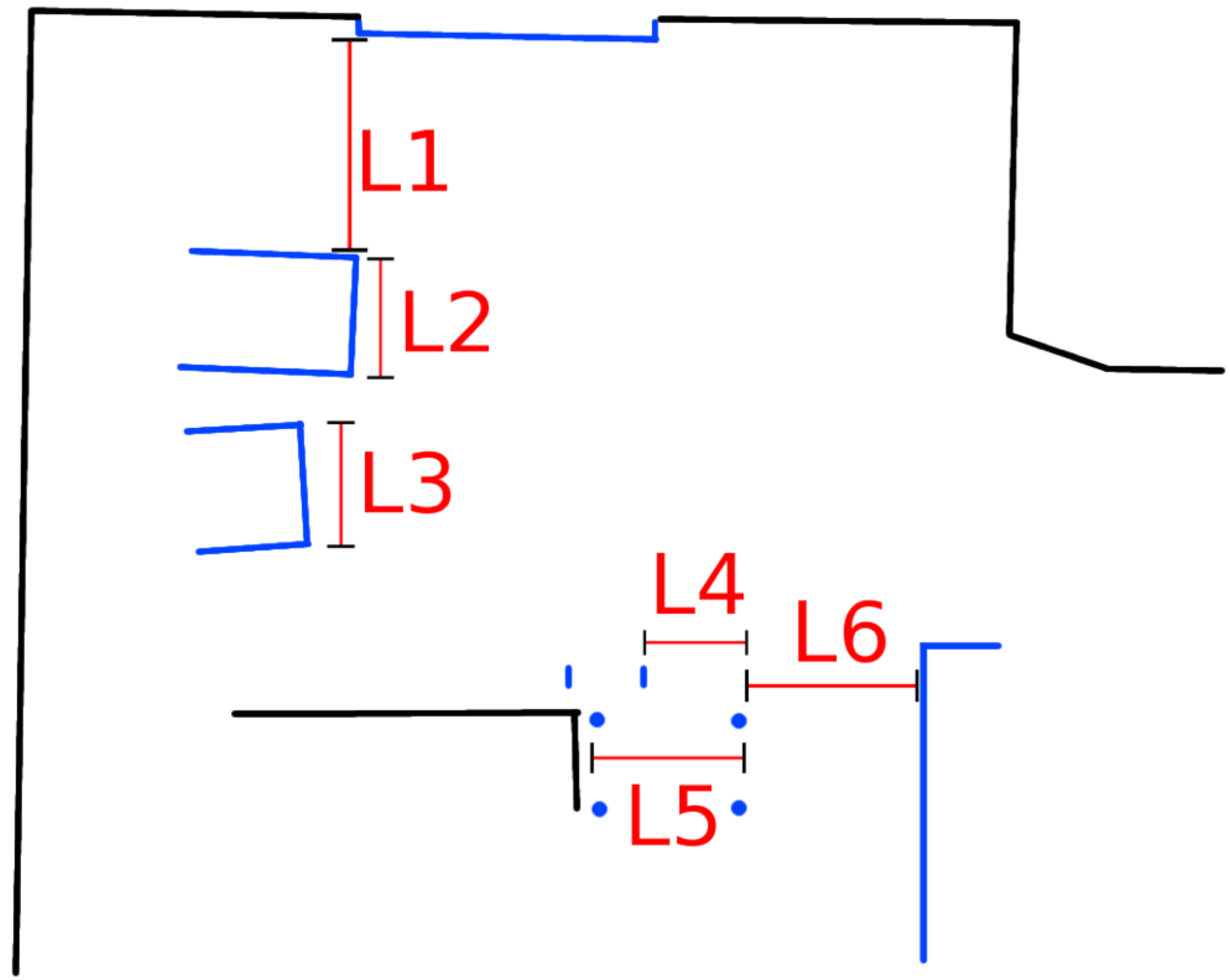
	GT [mm]	Δ[mm]
L_1	1490.0	49.24
L_2	762.0	47.05
L_3	791.0	40.82
L_4	650.0	8.34
L_5	892.0	39.48
L_6	1206.0	20.04
$\mu(L)$	-	**34.16**
$\mathrm{Var}(L)$	-	**26.64**



Experiments: Mapping Results (II)

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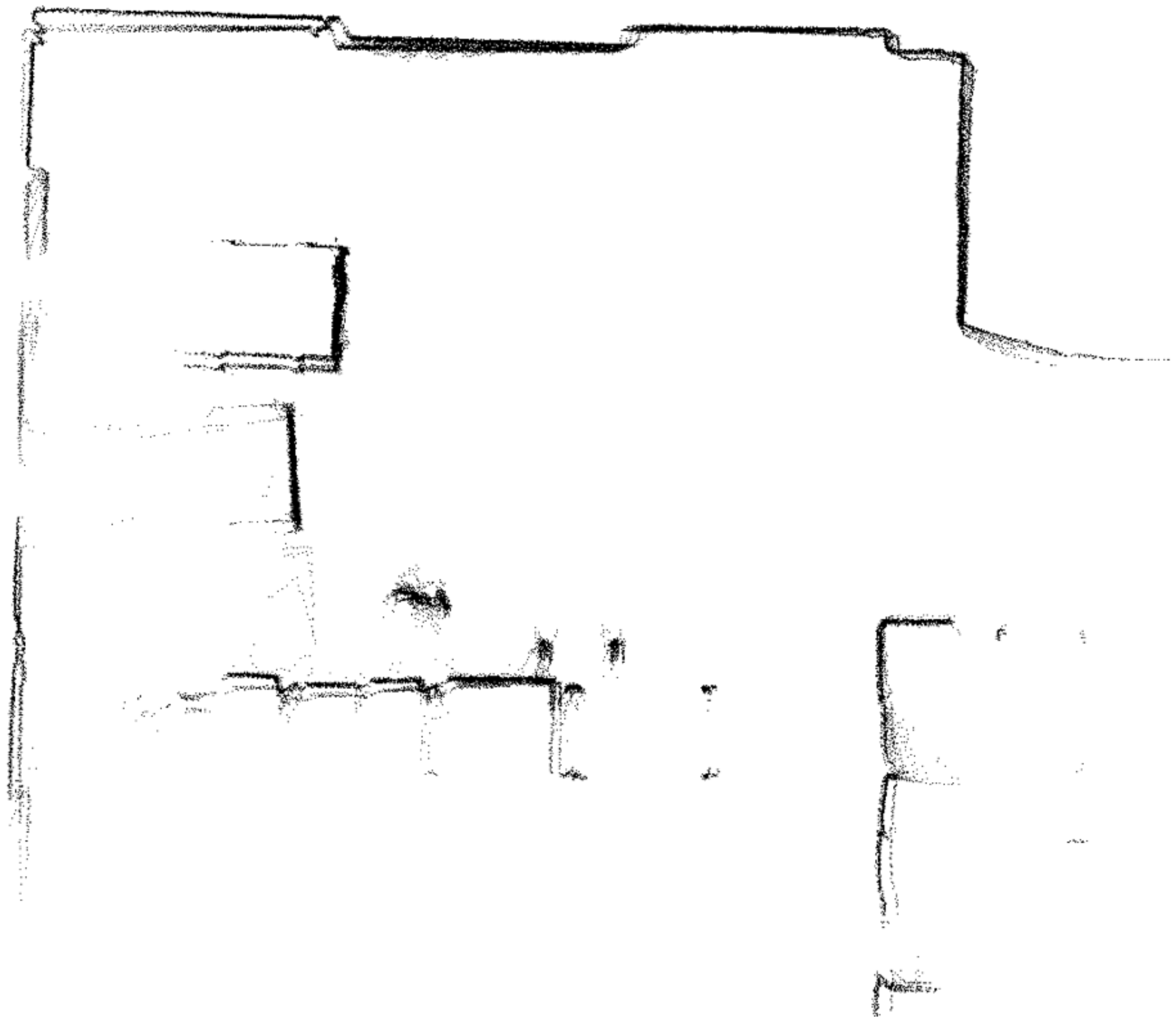
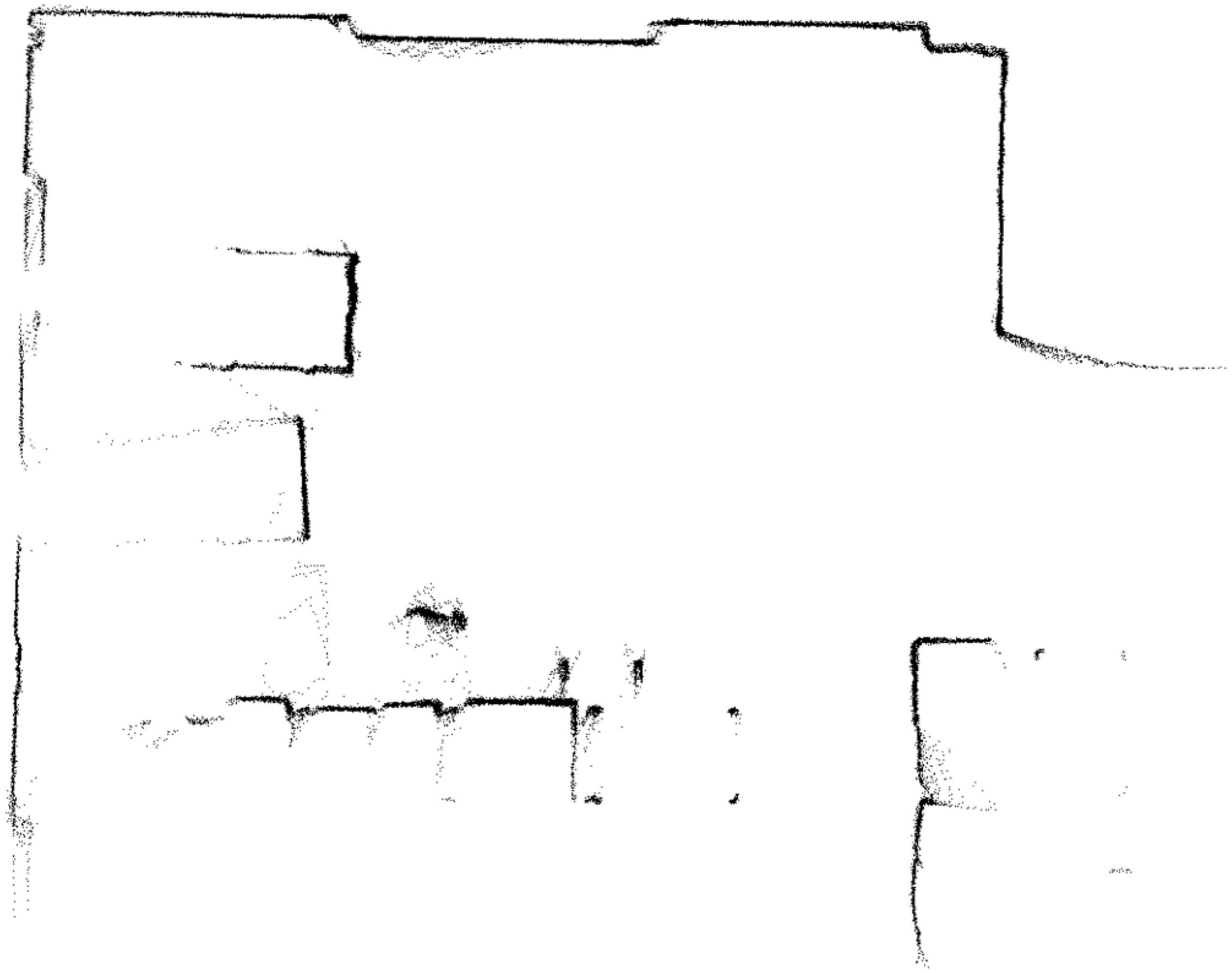


No Optimization



Optimization using SSA

Experiments: Mapping Results (II)

SCITOS G5 operating in a warehouse

Conclusion & Future Work

- Framework is able to generate accurate maps
  - Front-end: FLIRT allows efficient place recognition
  - Pose graph: Robust optimization necessary
  - SSA: Promising results, particularly for large surfaces
- Finding the right representation for localization
  - Low resolution global occupancy grid map
  - High resolution submaps in workspaces
- Coping with dynamic change occuring over time
  - Dynamic Occupancy Grid Maps (Meyer-Delius et al., AAAI ’12)