Parameter Optimization for Loop Closure Detection in Closed Environments

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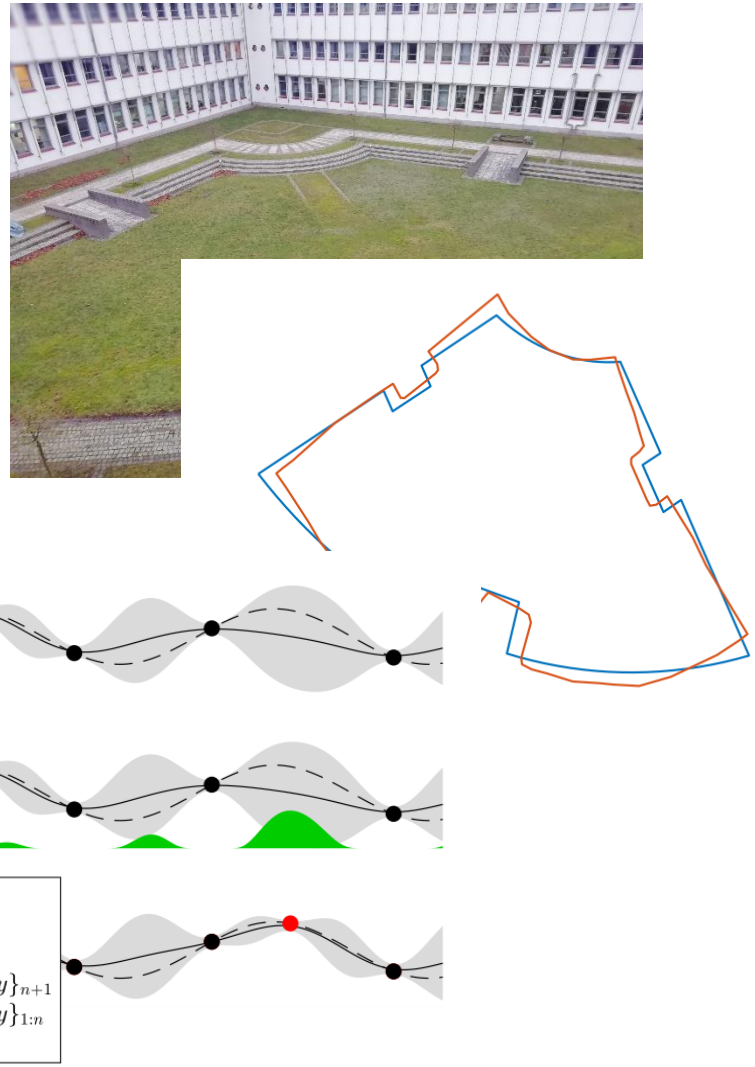
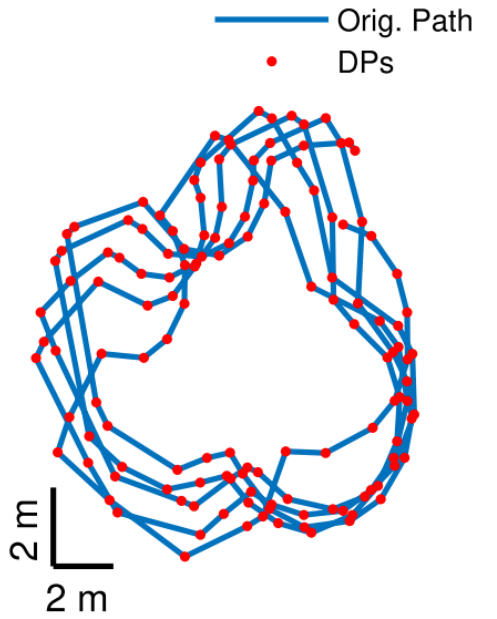
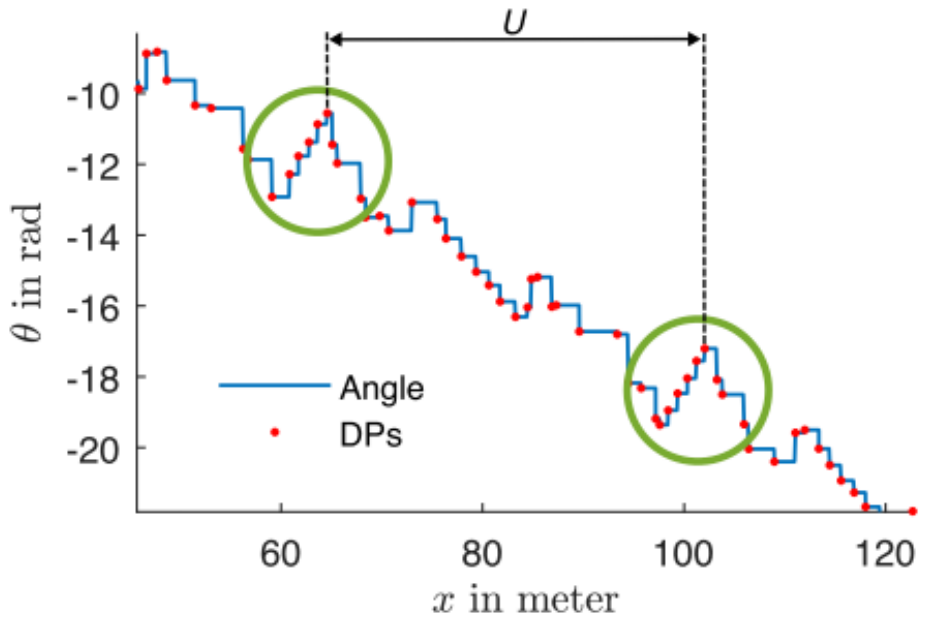
Motivation

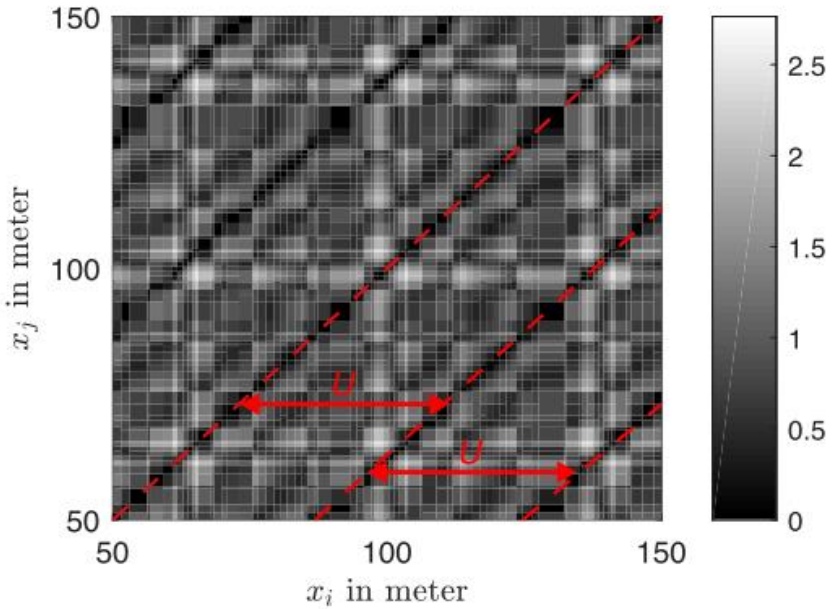
- Mapping algorithms require fine tuning of many parameters to work efficiently
- For truly autonomous systems, the robot must learn required parameters automatically, e.g. by exploring the environment
- Proposed:
  Parameter optimization for closed environments
- Requirements:
  Wall following, several boundary line traversals



Loop Closure Detection







- Boundary line traversals
- Orientation function with pose graph vertices
- Comparison error

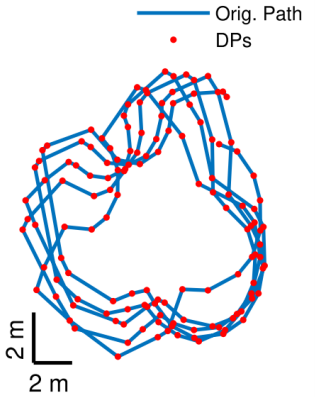
Meta-Parameter Learning – Idea

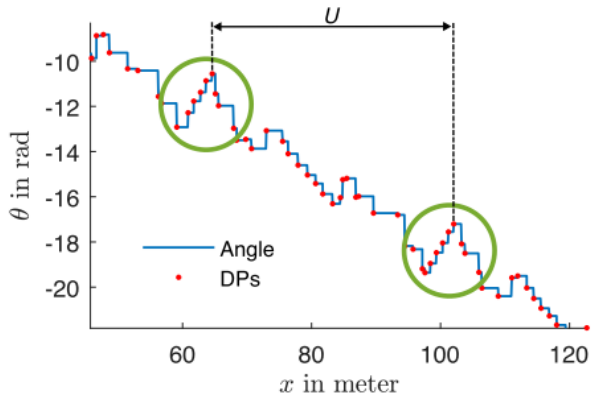
Let the odometry error be Gaussian with

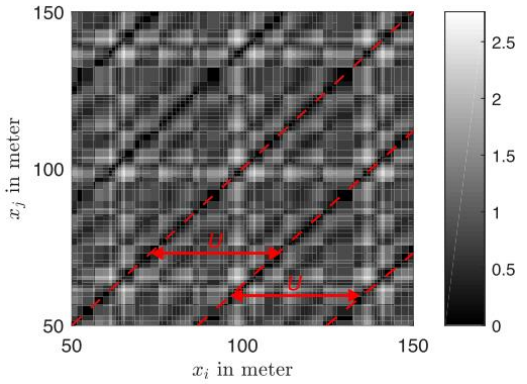
$$\boldsymbol{\epsilon} \sim \mathcal{N}(\mathbf{0}, \boldsymbol{P})$$

then the length U of a traversal along the complete boundary line measured between any boundary line vertices is also Gaussian

$$u \sim \mathcal{N}(\mu_U, \sigma_U)$$







Meta-Parameter Learning – Gaussian Mixture Model

$$u \sim \mathcal{N}(\mu_U, \sigma_U)$$

Learn Gaussian Mixture Model based on the distances between loop closing pairs

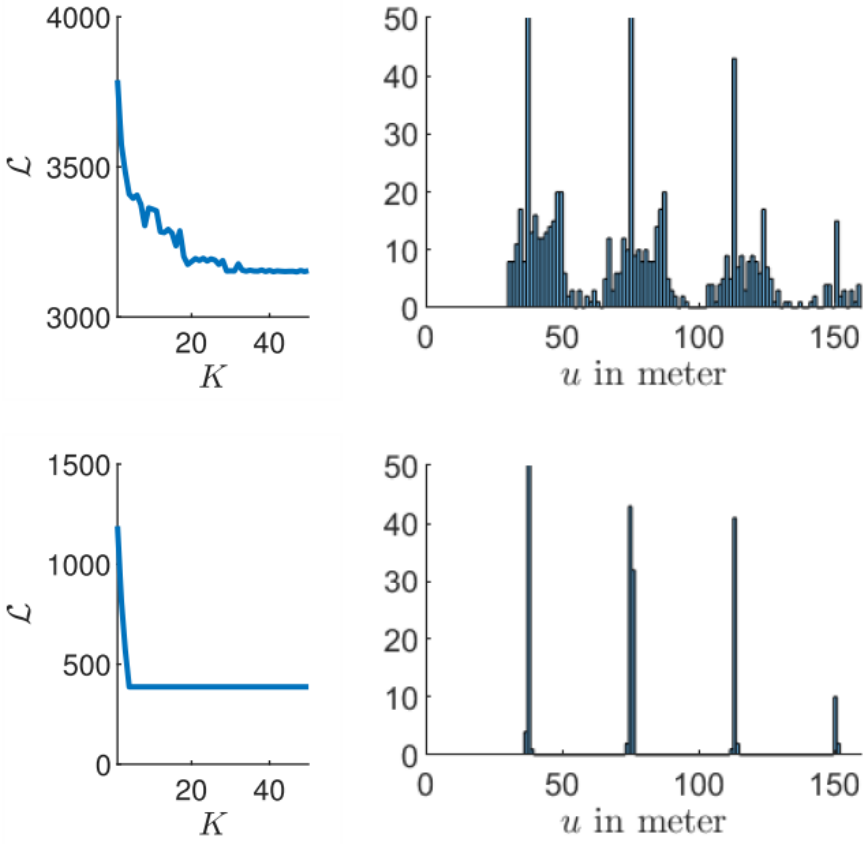
$$p(\boldsymbol{u}) = \sum_{k=1}^{K} \pi_k \mathcal{N}(\boldsymbol{u}|\mu_k, \Sigma_k)$$

and use the negative log likelihood

$$-\mathcal{L} = -\ln p(\boldsymbol{u}|\boldsymbol{\pi}, \boldsymbol{\mu}, \boldsymbol{\Sigma})$$

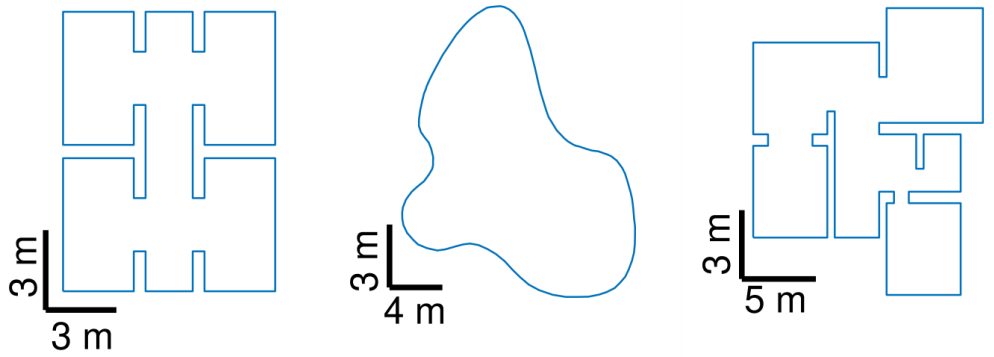
for the cost function together with the number M of found loop closures

$$c(\boldsymbol{\theta}) = -\mathcal{L} - \log(M)$$

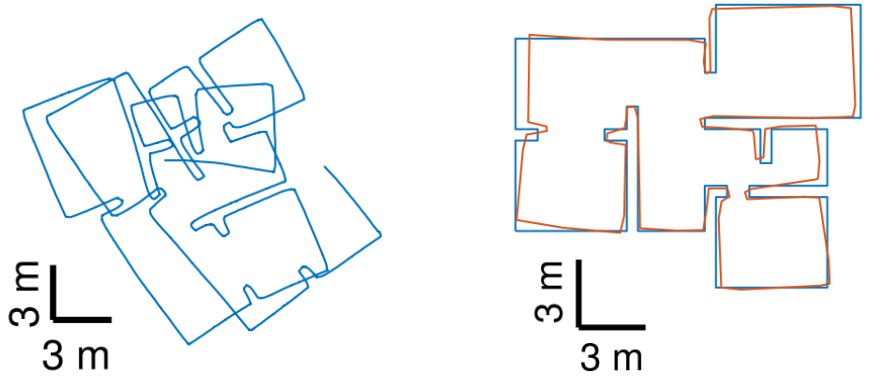


Evaluation – Simulation

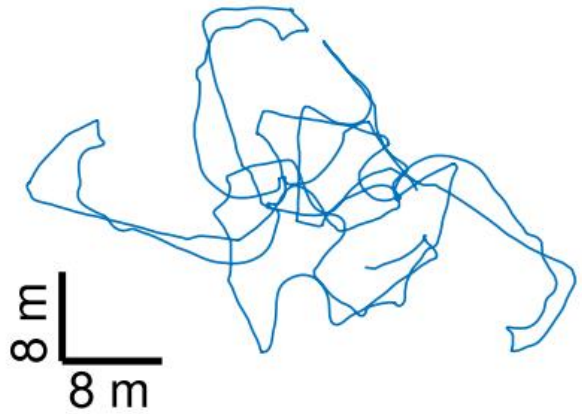
- Three different maps, with different sizes and shapes
- For each environment, the learning algorithm learned meta-parameters which led to accurate map estimates
- Map accuracies have been in the same region or better than with hand-adjusted parameters

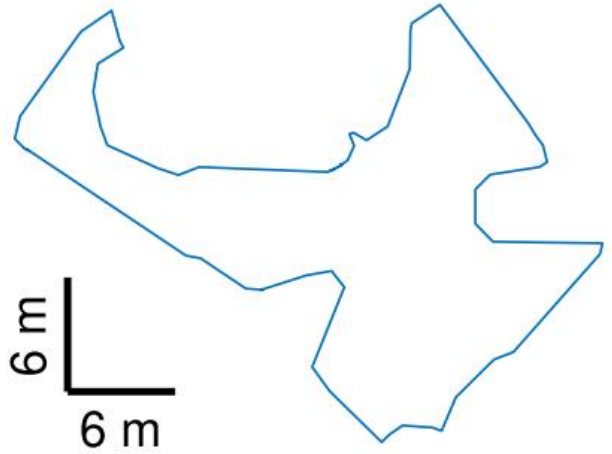


(a) Map 1 (b) Map 2 (c) Map 3



Evaluation – Garden Environment





Conclusion & Future Work

- Mapping with learned meta-parameter leads to accurate map estimates of the closed environments
- Meta-Parameter learning enables robot to be truly autonomous
- Test appproach onto different mobile robots, e.g. robots equipped with LiDAR and cycling inside a building

Thank you for your Attention