Calibrating Lidars in structured environments

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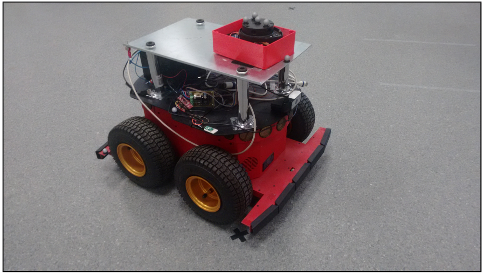
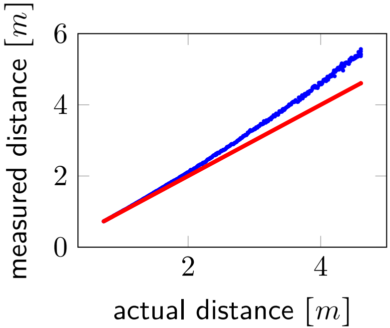
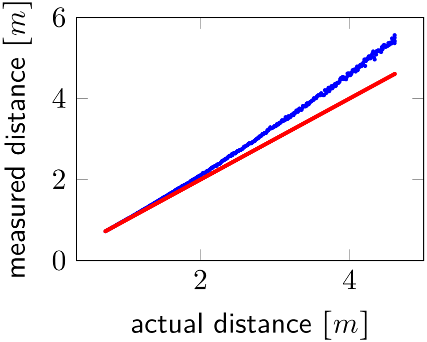
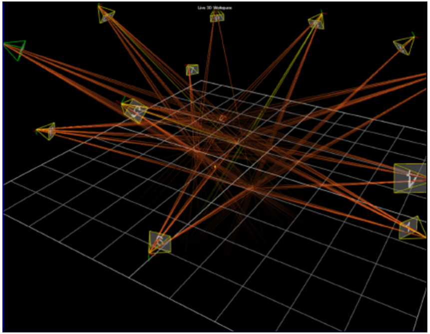
Calibration: an essential task in robotics





How is calibration usually done?





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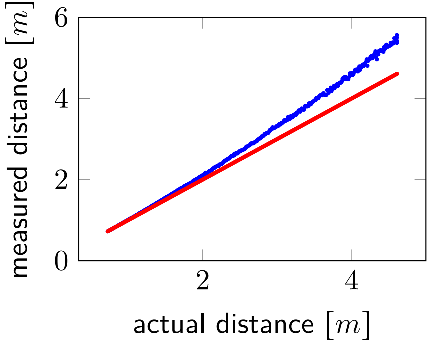

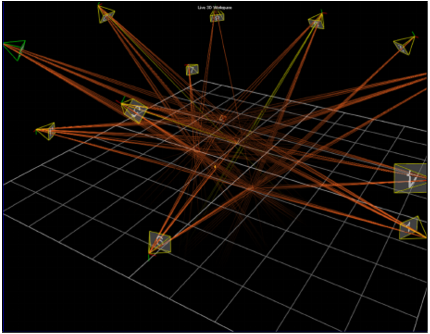

DRAWBACKS:

- really expensive
- set up is time consuming

Aim

assume the surrounding environment to be structured:

how can we transform this info into calibration strategies?

Problem Formulation

Algorithms

Results

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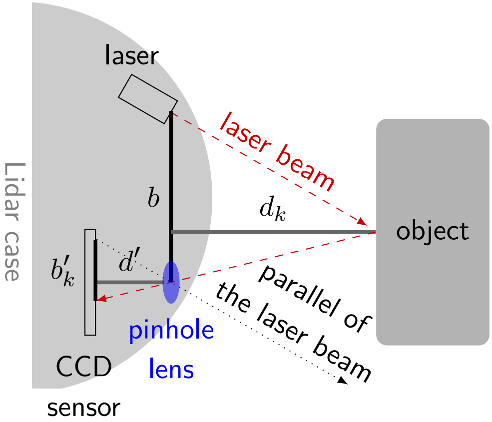
Example of a typical sensor



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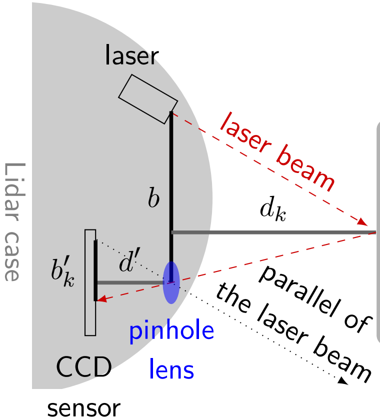

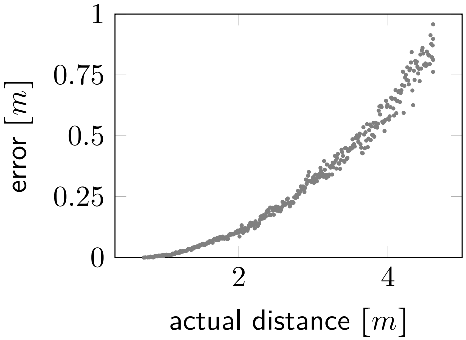

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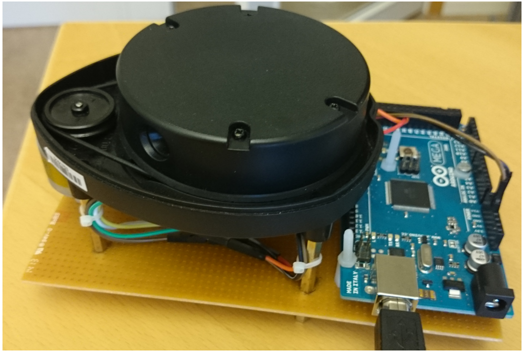

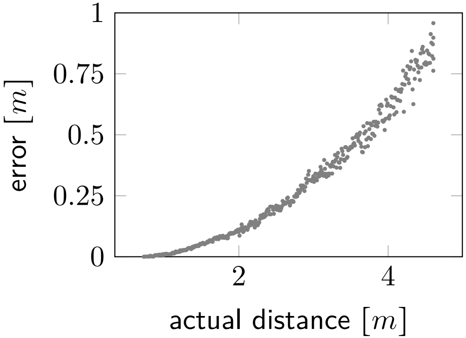

Problem formulation: modelling

Assumptions

- no access to groundtruth
- robot moves on flat areas
- environment does not change

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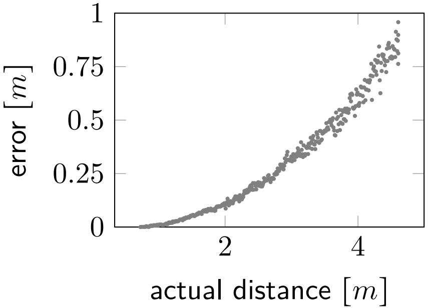
Our model of the sensor readings:

$$r_k = \underbrace{\sum_{i=0}^{n} \alpha_i d_k^i}_{\text{bias}} + \underbrace{\sum_{i=0}^{n} \beta_i d_k^i e_k}_{\text{noise}}$$

our problem: estimate the α_i's and β_i's



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Landmarks-based algorithms

Landmarks = easily recognizable features that do not move

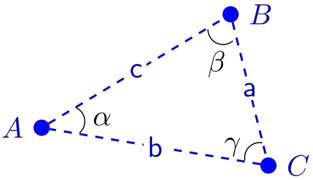
Examples:

Algorithm 1: *Carnot's algorithm*

DATA:

- distance between lidar and landmarks
- angle from which lidar sees the landmarks

IDEA: exploit Carnot theorem:



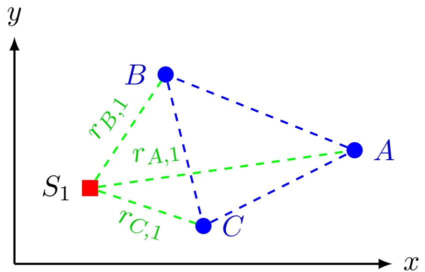
$$a^2 = b^2 + c^2 - 2bc\cos\alpha$$

Algorithm 1: *Carnot's algorithm*

DATA:

- distance between lidar and landmarks
- angle from which lidar sees the landmarks

$$\widehat{AB}_k^2 = r_{A,k}^2 + r_{B,k}^2 - 2r_{A,k}r_{B,k}\cos\phi_{AB,k}$$
$$\widehat{BC}_k^2 = r_{B,k}^2 + r_{C,k}^2 - 2r_{B,k}r_{C,k}\cos\phi_{BC,k}$$
$$\widehat{CA}_k^2 = r_{C,k}^2 + r_{A,k}^2 - 2r_{C,k}r_{A,k}\cos\phi_{CA,k}$$



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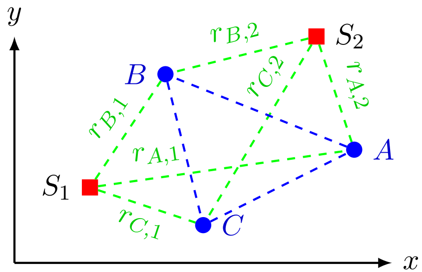

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DATA:

- distance between lidar and landmarks
- angle from which lidar sees the landmarks

PROBLEMS:

- expensive computation due to non linear minimization
- biased estimator $\implies$ not consistent!

Algorithm 2: Sine theorem algorithm

ASSUMPTIONS:

- the robot moves along a straight line
- the sensor takes measurements with a fixed step

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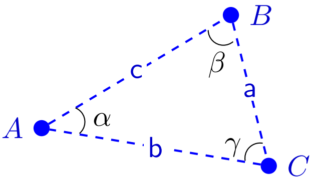
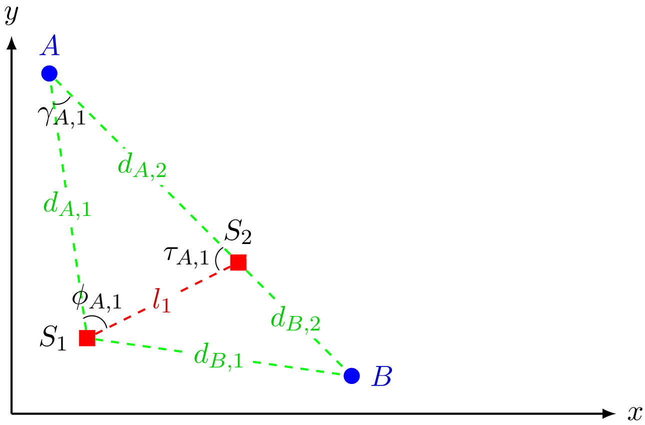
$\Longrightarrow$ use the *Sine Theorem*:

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}$$



we can estimate all the distances $d_{L,i}$:

$$d_{L,i} = \frac{l_i \cdot \sin \tau_{L,i}}{\sin \gamma_{L,i}}.$$



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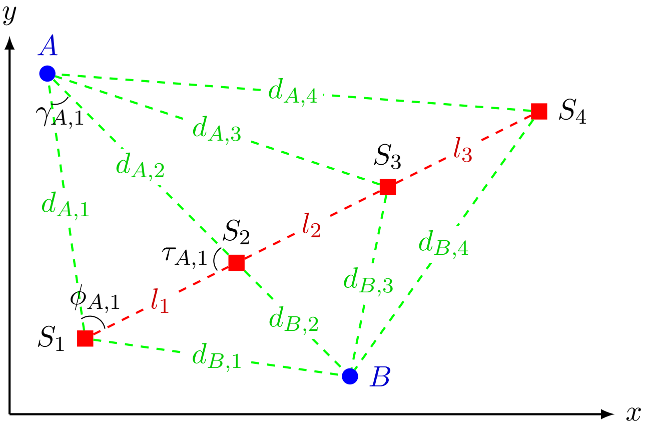

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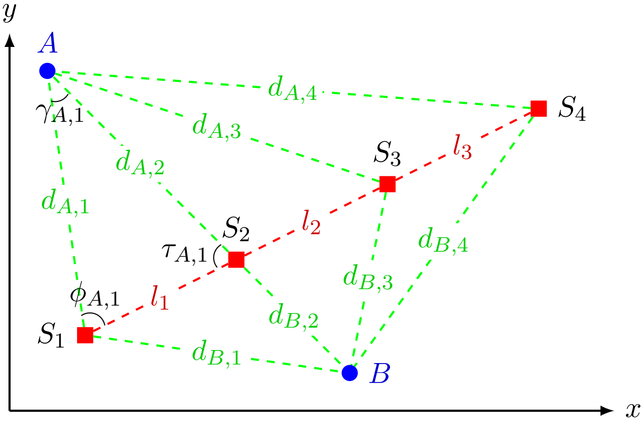


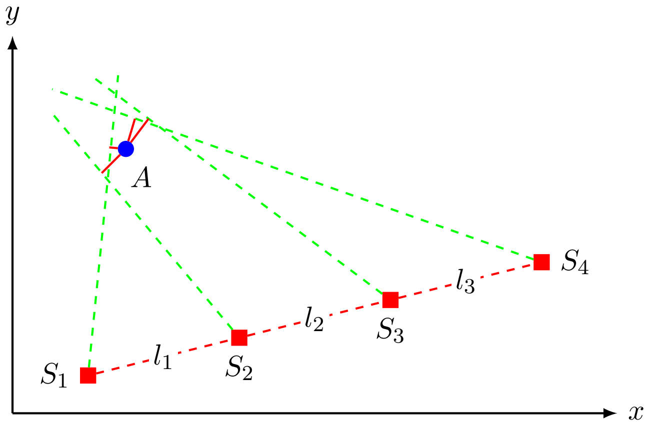
PROBLEMS:

- generally bad estimates for long distances due to small error of angles measurements
- not robust: not perfectly straight trajectories $\Longrightarrow$ big errors

Algorithm 3: Minimization algorithm

ASSUMPTIONS:

- the robot moves along a straight line
- the sensor takes measurements with a fixed step



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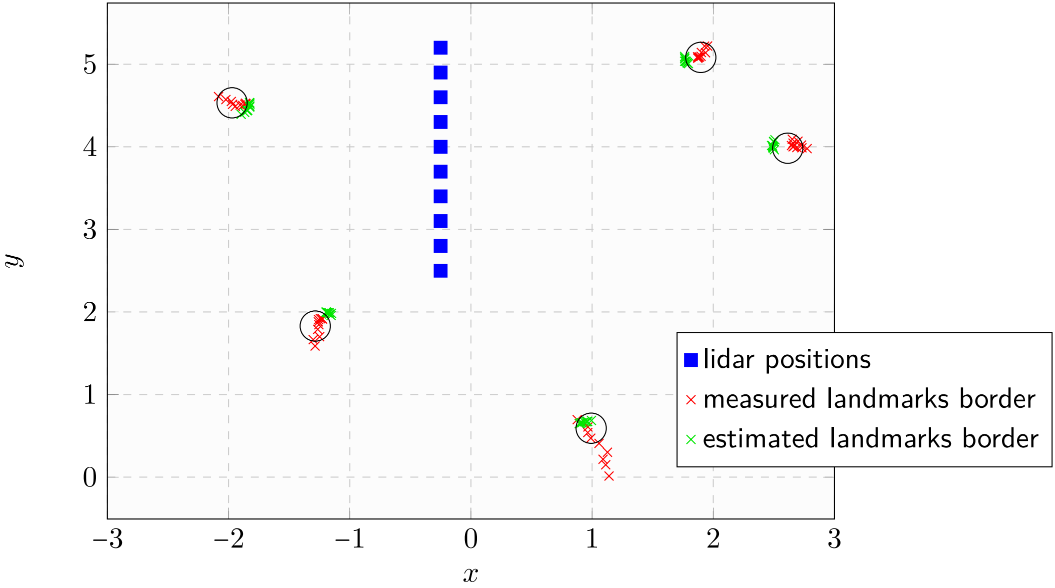
Comparison of results: ratio between Mean Squared Error of raw data and of estimated ones

$$\textbf{MSE} := \frac{\sum_{i=1}^{n}\left(x_i - \widehat{x}_i\right)^2}{n}$$

$$\textbf{MSE ratio} = \frac{\textbf{MSE}(\textit{raw data})}{\textbf{MSE}(\textit{estimated data})}$$

MSE ratio		
Carnot	Sine	Minimization
0.9	0.5	4.2

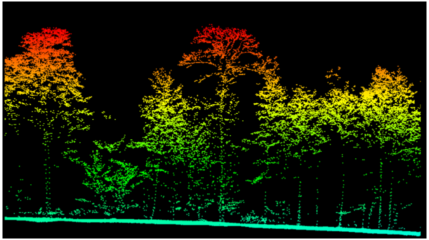


5
4
3
2
1
0
y
−3
−2
−1
0
1
2
3
x
lidar positions
measured landmarks border
estimated landmarks border

Conclusions

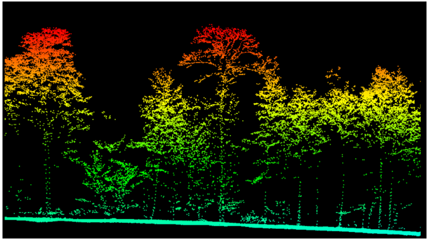
- sensors can be calibrated exploiting the structure of the environment
- this calibration requires assumptions on the trajectory of the sensor in the surrounding environment
- this calibration leads to results comparable to the ones achieving with sophisticated instruments *(but our procedures are easier to perform)*

Future works



Scanning forests

Future works



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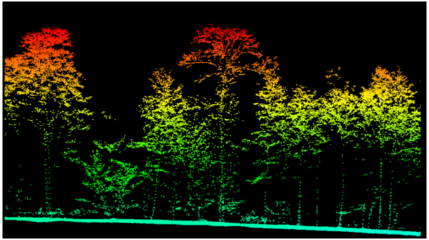

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Wall-based and landmark-based
calibration combined

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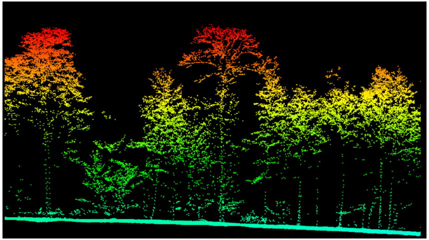

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Continuous calibration

Thanks for the attention