NavLab IIT

IIT Armour College of Engineering
ILLINOIS INSTITUTE OF TECHNOLOGY

Research Project Presentation

Improving Navigation through code-based landscapes

Objective: Misdetection Error Model

Project Context

- Understanding the relationship between landscape and navigation safety
- Shaping architecture around robotics
- Ensuring localization integrity in regions where GNSS is unavailable
- Lidar Localization for periodic reset on IMU

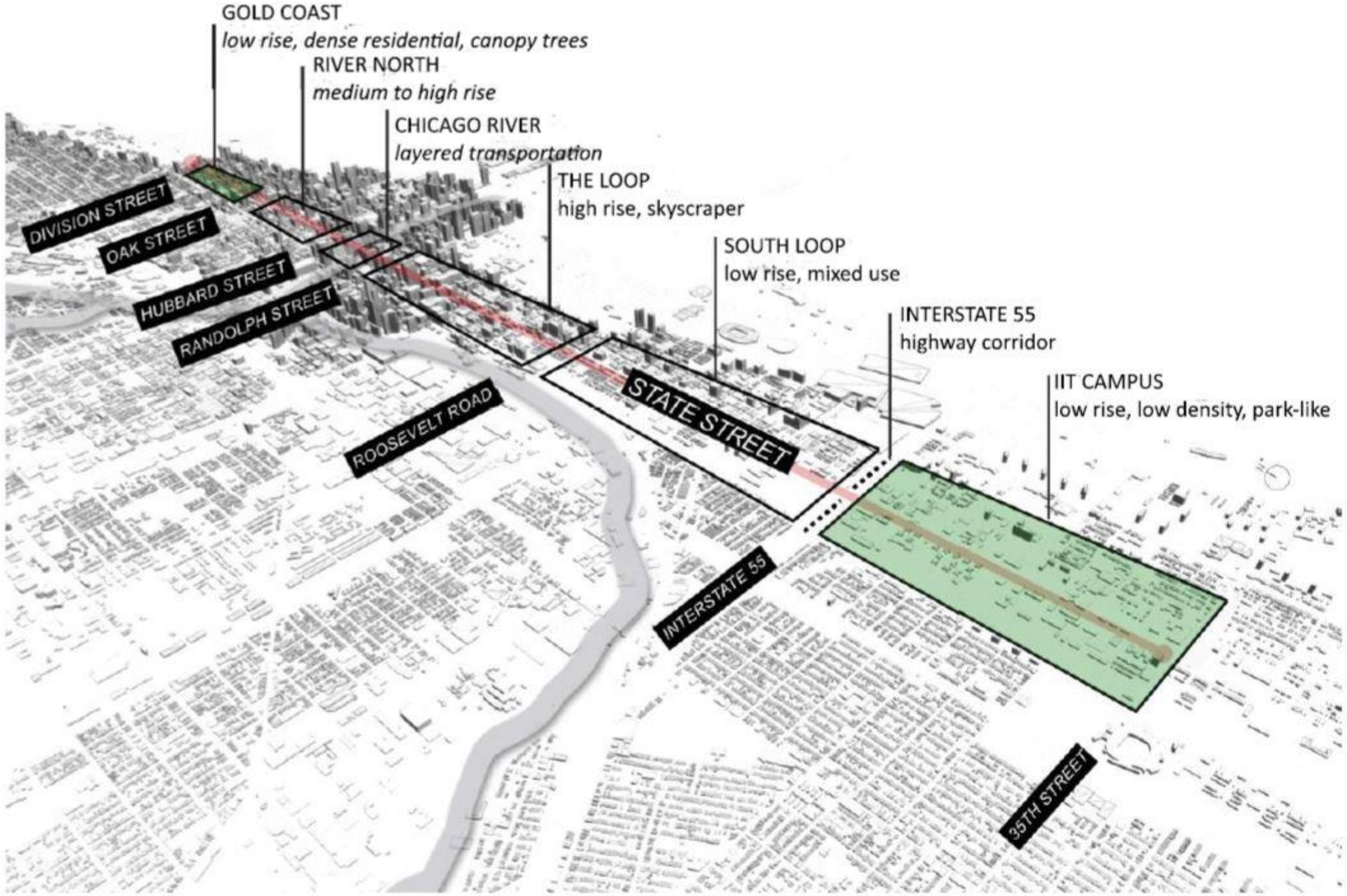

Diagram of State Street Transect

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Code-based landscape

- *Association problem*
  - *The right measurement to the right mapped object*
  - *Maximum likelihood and nearest neighbor process create uncertainty*
- *Providing a landmark signature though code-based landscape*
- *Retrieving the localization of the landmark*

ID 107 → Landmark (42° N, 88° W)

Basis concept of Code based landmark identification

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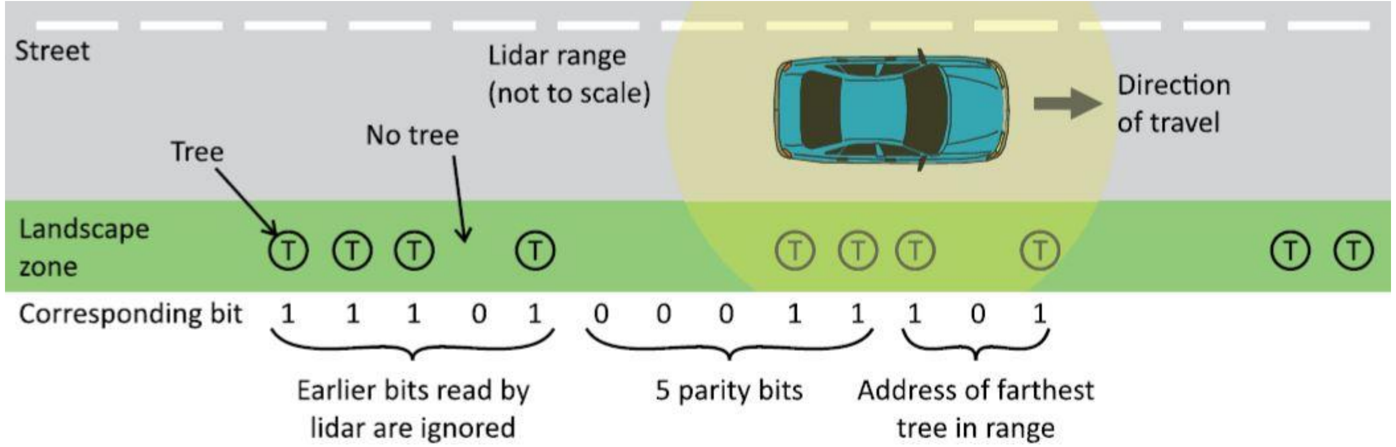
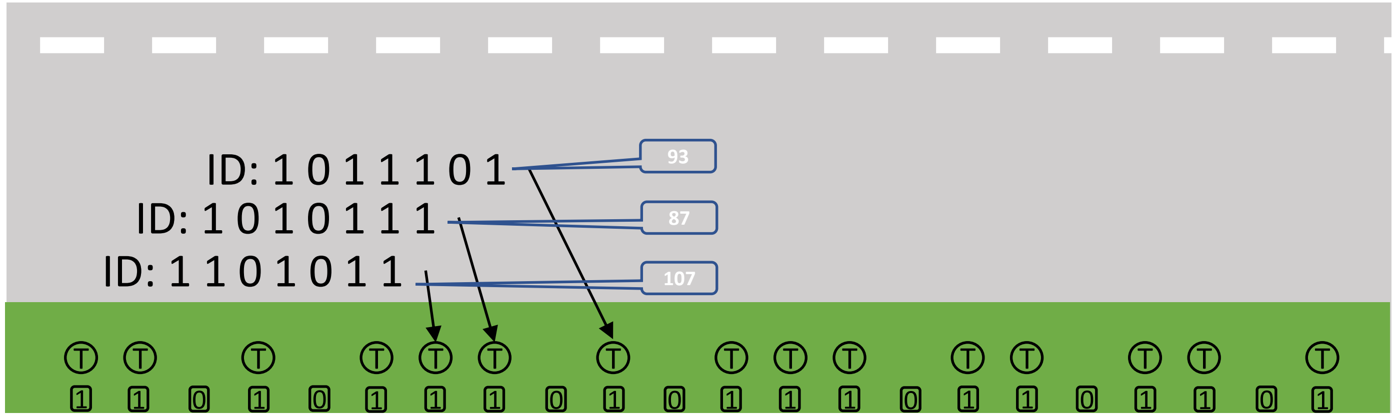
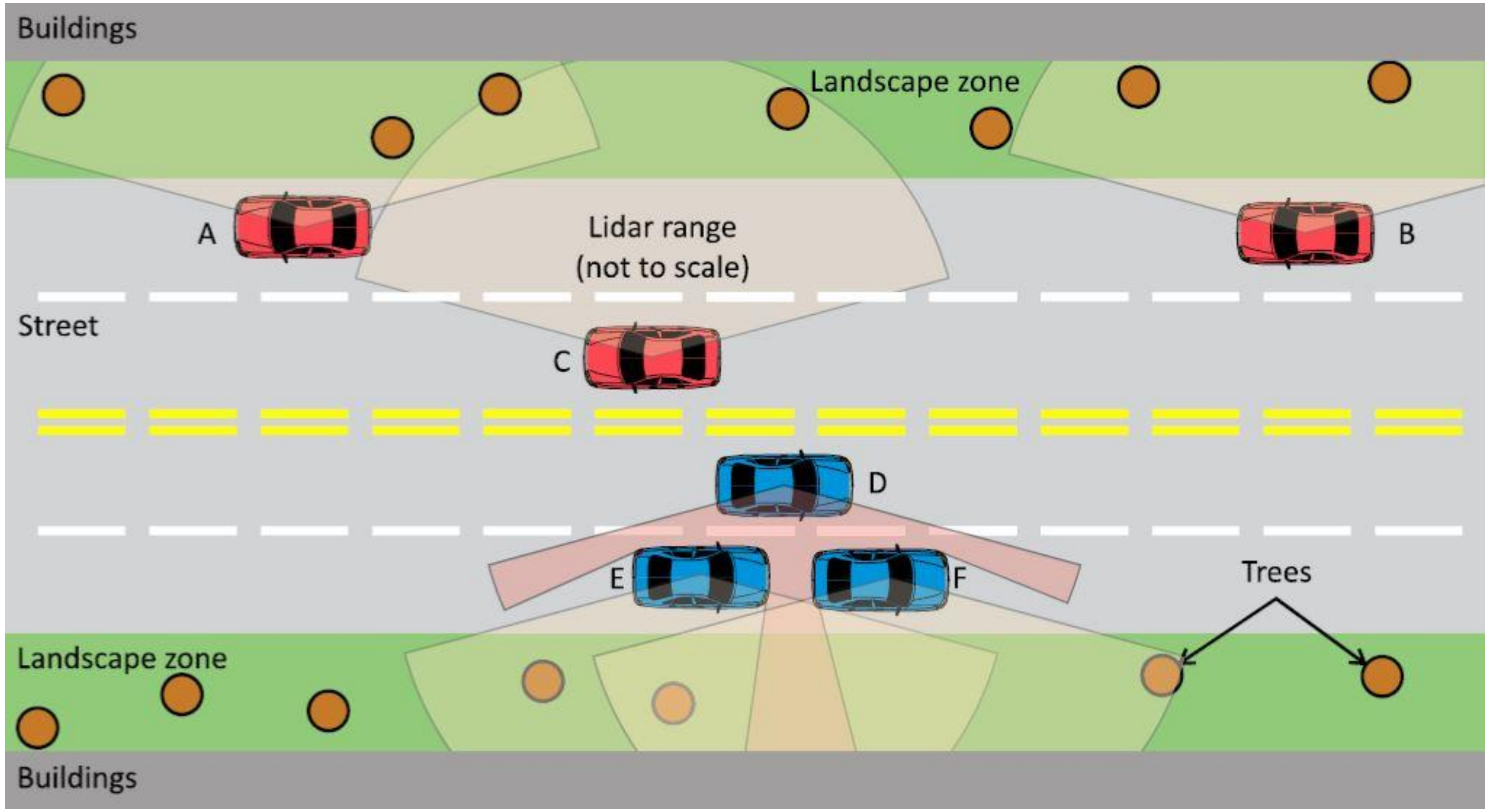




Creating IDs from a set of measurements

This can get complicated

- Numerous sources of Noise
  - GNSS
  - Lidar
  - IMU
- Irregularity of landmark placement – spatial and temporal
- Misdetection possibilities
  - 0 to 1: Measuring an inexistant landmark
  - 1 to 0: Not measuring an existing landmark



A more realistic view of Code based landmark identification

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Error Correcting Codes
A brief Overview

- *Procedures:*
  - *Detect if and how many errors have occurred*
  - *Pinpoint the location of the error(s)*
  - *Correct the error(s)*
  - *Retrieve the initial message*

Hamming (7, 4) Codes:

- Message : a b c d - 1 1 0 1
- Redundancy bits: x y z - 1 0 0
  - $x = a \oplus b \oplus d$
  - $y = a \oplus c \oplus d$
  - $z = b \oplus c \oplus d$
- Codeword = a b c d x y z – 1 1 0 1 1 0 0
- Parity check: Adding a 1 if uneven number of bits, else 0
- Correction of one bit error by checking redundancy bits

Bose-Chaudhuri-Hocquenghem Codes

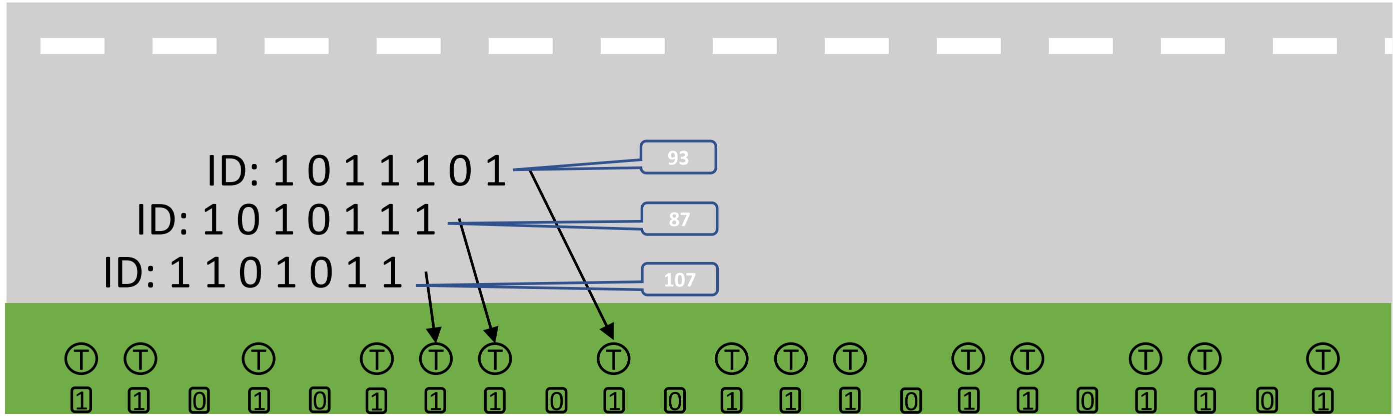
- *BCH [n, k, d] code*
- *Subclass of cyclic code with multiple errors capability*
  - *Cyclic code for handling sequences of landmarks*
  - *At each step, a single bit changes in the sequence*
- *Choosing the number of errors to correct generates the code*

Code vector v:

$$v = (a_{n-1}, a_{n-2}, \ldots, a_0)$$

Polynomial representation of a code vector:

$$f(x) = a_{n-1}x^{n-1} + a_{n-2}x^{n-2} + \ldots + a_0$$



Cyclic nature of the IDs

Error Model Probability of misdetection

- *Focusing on the misdetection*

1 → 0: not detecting an existing landmark

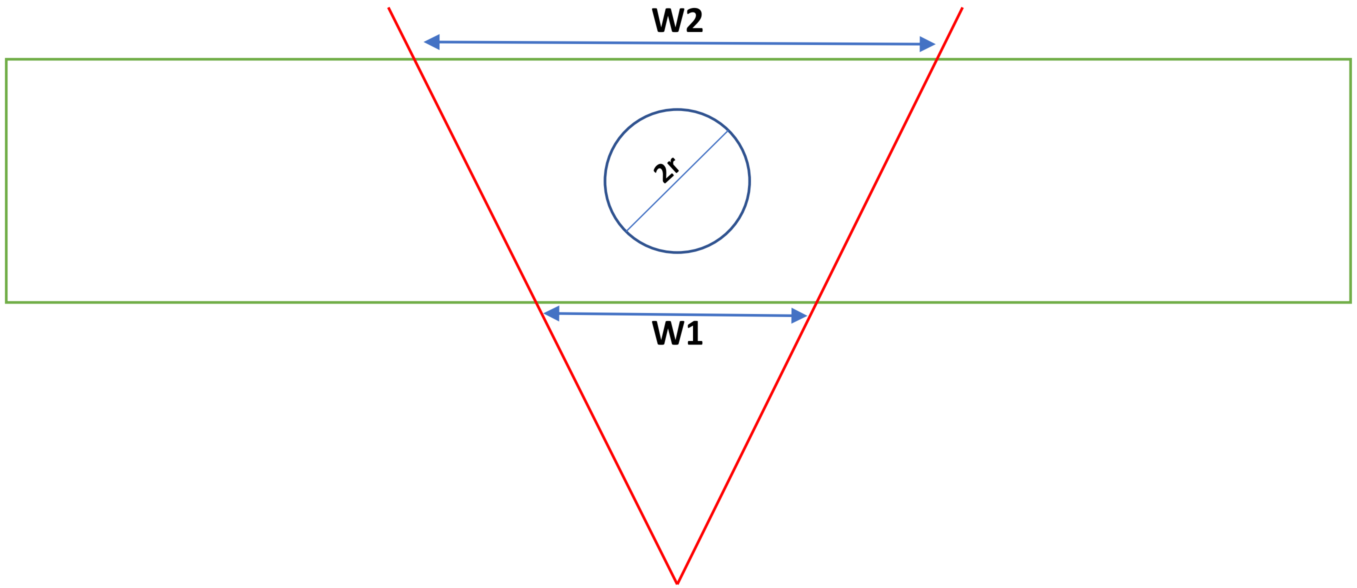
- *Referred as the transitional probability*
- *p(1 → 0): probability of not detecting our landmark from the ratio between dimensions of landmark and section of detection*

Uncertainty bearing: $\sigma_\theta = \Delta\theta + \Delta\sigma + \frac{\Delta\delta}{2}$

- $\Delta\theta$: lidar resolution
- $\Delta\sigma$: vehicle yaw
- $\Delta\delta$: divergence of lidar

Uncertainty position σ_x and σ_y

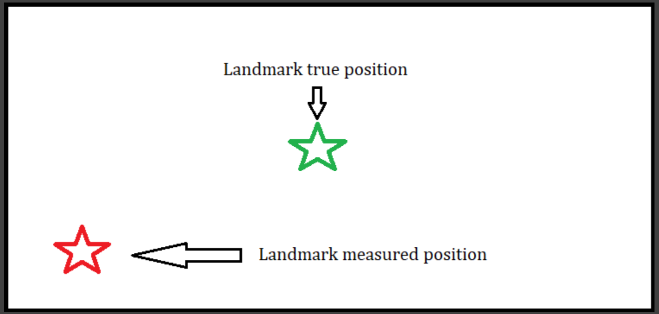
Parameters	Values
σx	1 cm
σy	2 cm
Δθ	0.2 deg
Δσ	6.6 cm
Δδ	0.1 deg
d	6.35 to 10.2 cm



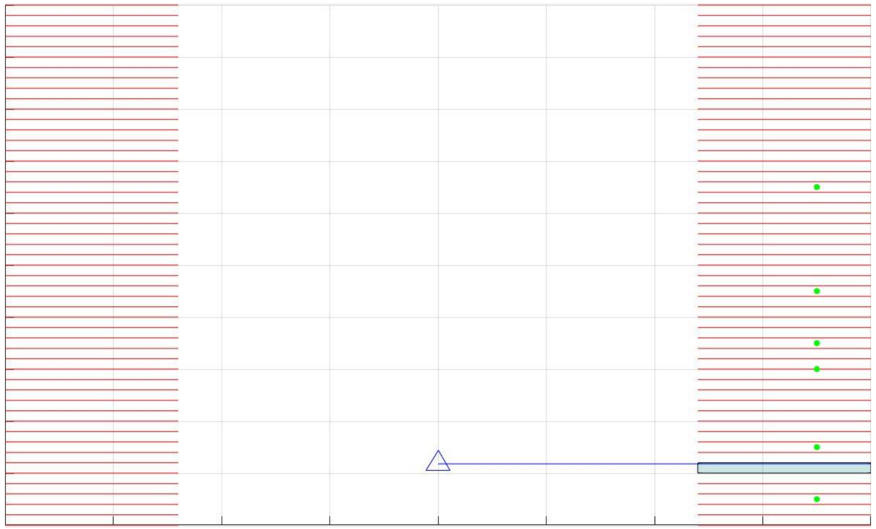
Representation Landmark and Lidar detection

Sections of bit assignments

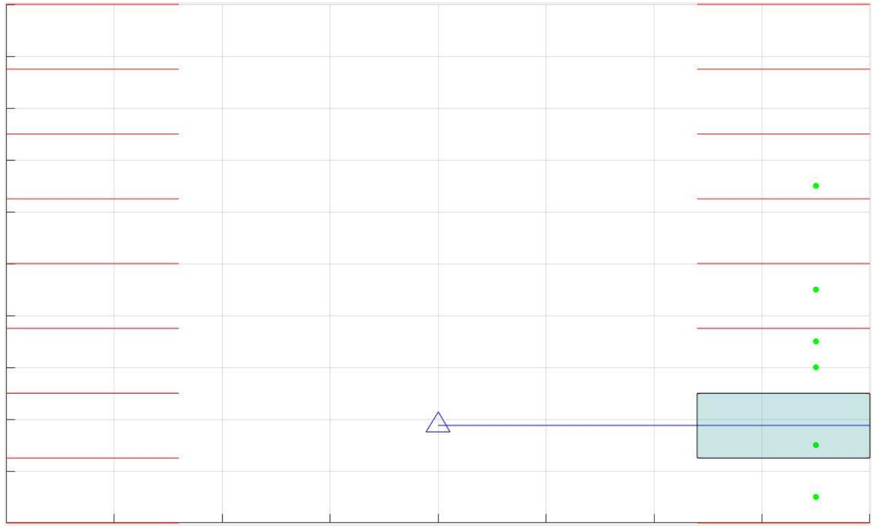
- *Imposing sections of measurements and bit assignement*
- *Unambiguously Identifying and replacing landmarks*



Measurement Ld vs Truth Ld



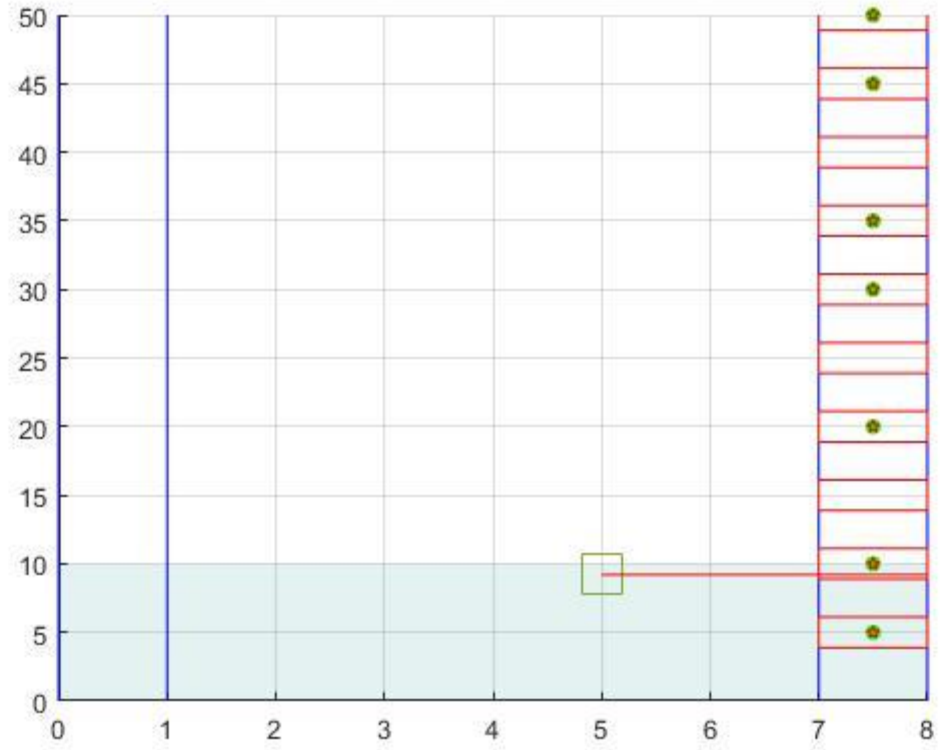
To many sections creates lots of zeros



Not enough sections potentially looses information

Selected Sections of detection

- *Imposing step between or sections of measurements*
- *Practical for constructing a code*
  - *Placing a 1 in the section if a landmark is detected*
  - *Placing a 0 if not*



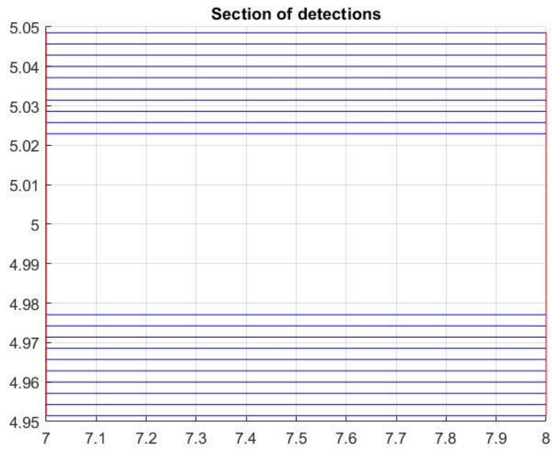
Selected sections with a nominal range

Shape of sections of detections

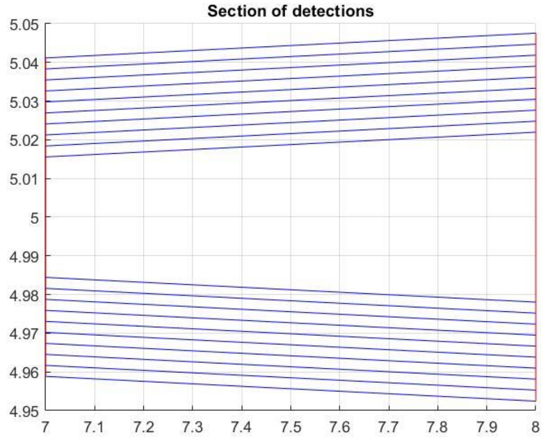
- *Proposed Shape:*
  - *Rectangular*
  - *Trapezoid*

- *Construction by edge cases of*
  - *Incertitude of position*
    - *GNSS sigmas*
    - *IMU drift*
  - *Incertitude of lidar*

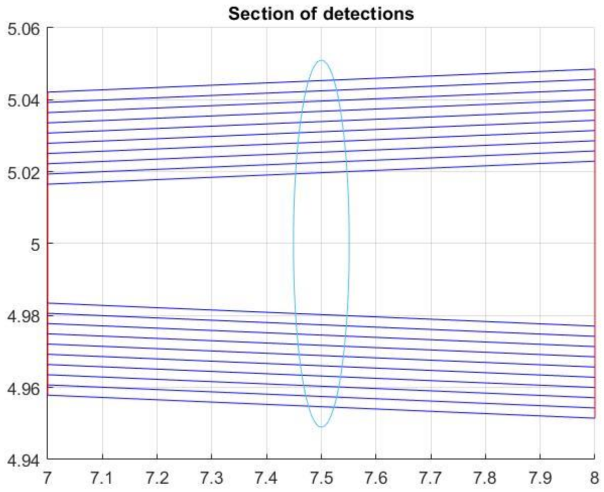
$$\omega_2 = 2[\sigma_x + (L_1 + L_2 + \sigma_y)\sigma_\theta]$$

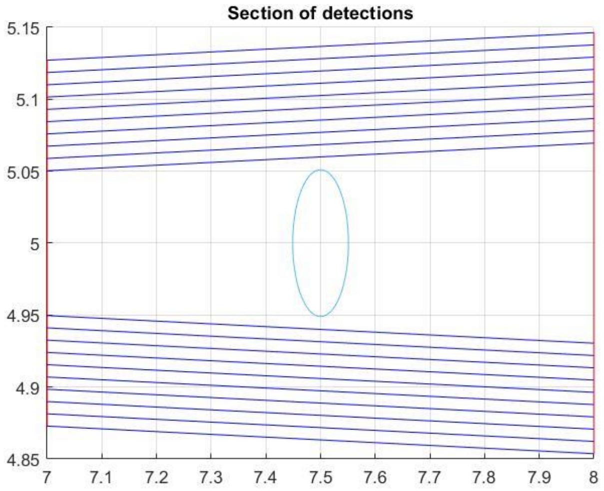


$$\omega_1 = 2[\sigma_x + (L_1 + \sigma_y)\sigma_\theta]$$



Rectangular and Trapezoid: 1 to 5 meters from sidewalk





Trapezoid Section – 10 cm tree – σ and 3σ

Ratio and probabilities

- *σ values for probabilities:*
  - *σ for 67%*
  - *3 σ for 99%*

$\omega_1 = 2[\sigma_x + (L_1 + \sigma_y)\sigma_\theta]$	**σ**	**3 σ**
w1 for L1 = 1m	0.0331 m	0.1007
w1 for L1 = 5m	0.0842 m	0.2543

Widths of sections vs distance from sidewalk

$\frac{2r}{w}$	**σ**	**3 σ**
L1 = 1m, r = 3 cm	1.9184	0.6306
L1 = 5m, r = 3 cm	0.7542	0.2497
L1 = 1m, r = 5 cm	3.0816	1.0129
L1 = 5m, r = 5 cm	1.2114	0.4011

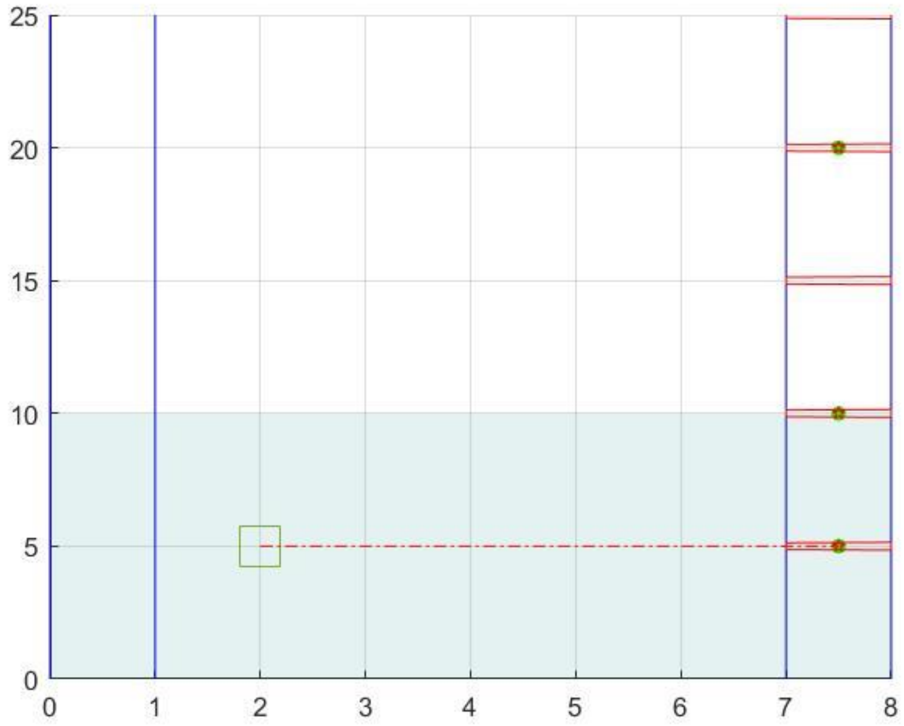
Ratio for projected curve

$\frac{\pi r}{w}$	**σ**	**3 σ**
L1 = 1m, r = 3 cm	3.0135	0.9905
L1 = 5m, r = 3 cm	1.1846	0.3922
L1 = 1m, r = 5 cm	4.8405	1.5911
L1 = 5m, r = 5 cm	1.9029	0.6300

Ratio for circular curve

Conclusion and Perspective

- Defining the error model to take incertitude of IMU drift into account
- Adding noisy landmark and test the process with BCH encoding – decoding



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