Area Coverage Planning that Accounts for Pose Uncertainty with an AUV Seabed Surveying Application

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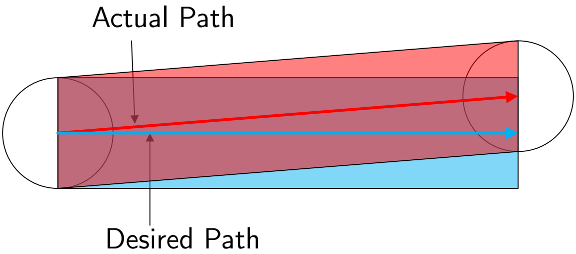
Overview



- (Most) Coverage literature assumes robot state known [1]

[1] Examples that don't include Das et al. IROS 2011, Bosse et al ICRA 2007, and others

Motivation

Outline

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1. Probabilistic Coverage Framework
2. Application to AUV Seabed Surveying
3. Coverage Path Planning with Uncertain Coverage

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1. Probabilistic Coverage Framework
2. Application to AUV Seabed Surveying
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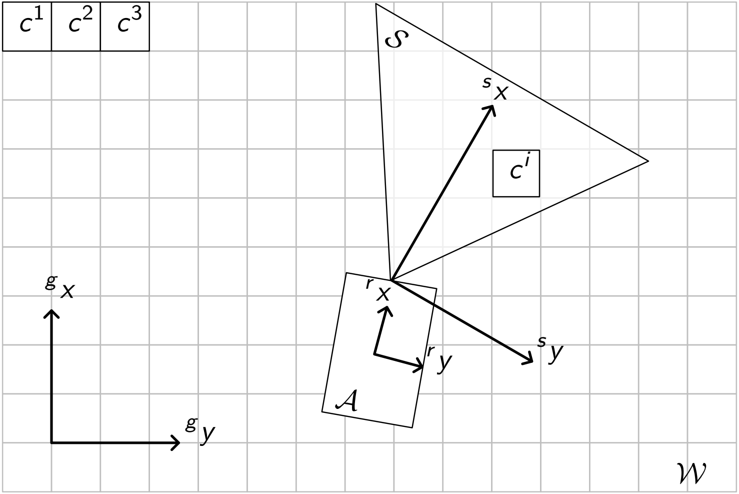
4. Experimental Results

Problem Setup

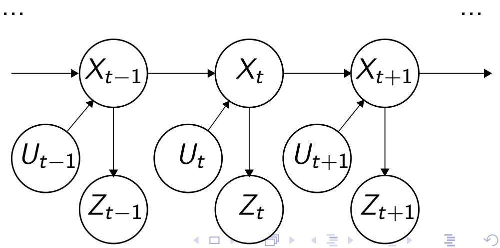


- Filtering

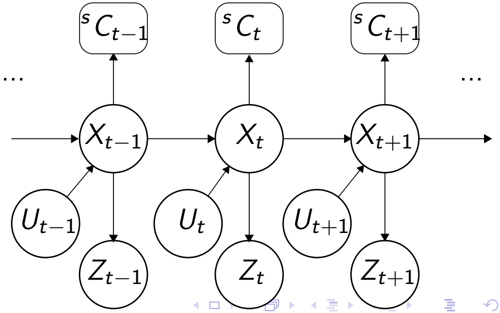
$bel(x_t) \triangleq$
$p(x_t | u_{1:t}, z_{1:t}, x_0)$

- Smoothing

$bel(x_{1:t}) \triangleq$
$p(x_{1:t} | u_{1:t}, z_{1:t}, x_0)$



- ${}^{s}C_t^i$ Location of cell i at time t in the *coverage sensor* frame



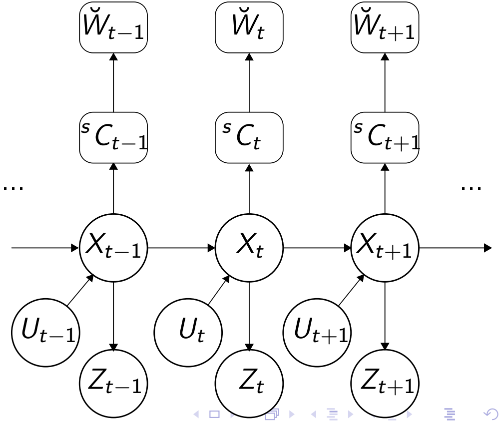
Algorithm Overview

Step 3: Project Cell Location Through Coverage Sensor Model

$$\breve{W}_t^i = \mathcal{H}({}^s C_t^i)$$

$\mathcal{H}$: Coverage sensor

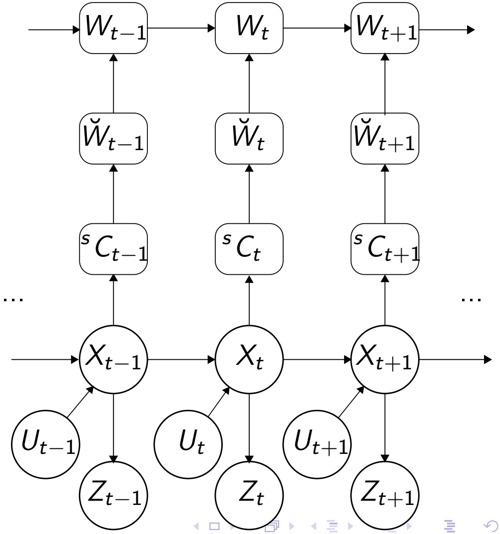
model



Algorithm Overview
Step 4: Recursive Coverage Update

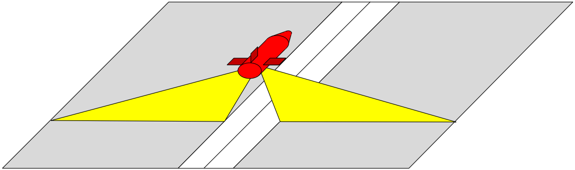
$$W_t^i = \max(\breve{W}_t^i, W_{t-1}^i)$$

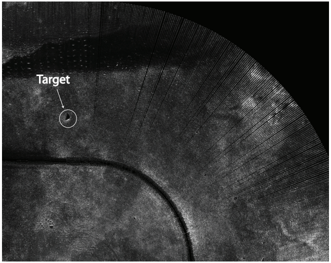
Note: This is an operation on RVs

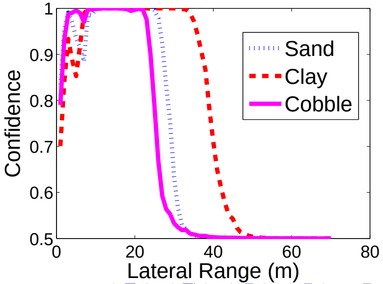


Outline

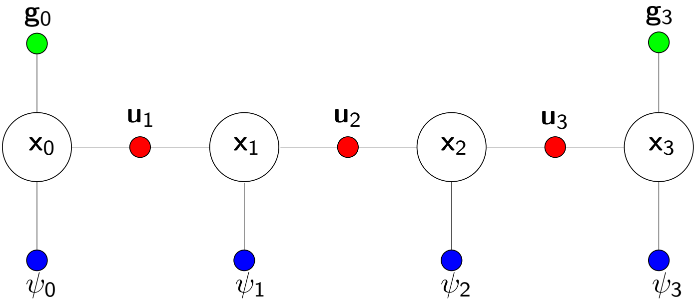
Seabed Surveying with a Sidescan Sonar Sensor





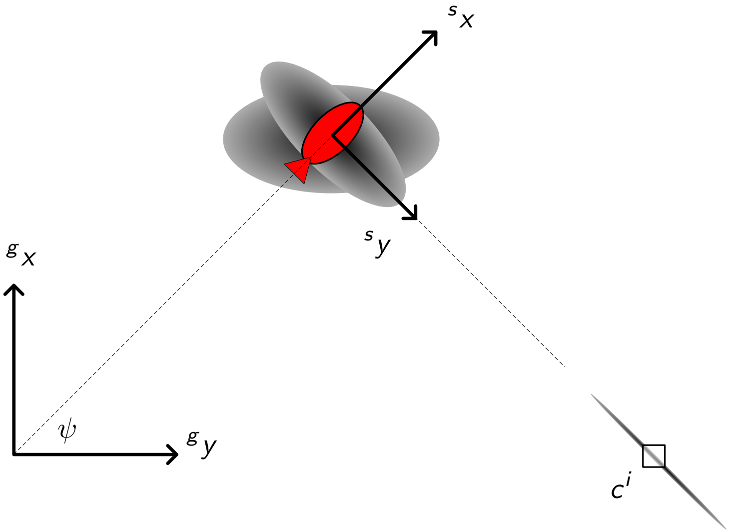


Step 1: Pose Estimation

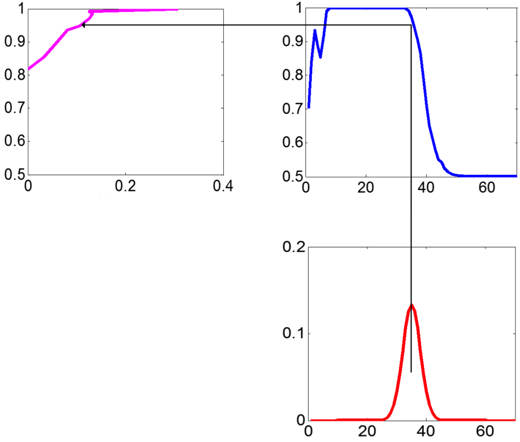


- GPS Measurements
- DVL Measurements
- Compass Measurements

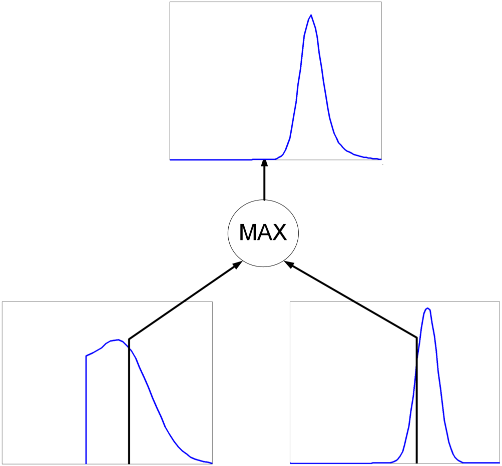
Step 2: Uncertainty Projection



Step 3: Location Uncertainty → Coverage Uncertainty



Step 4: Combining Measurements



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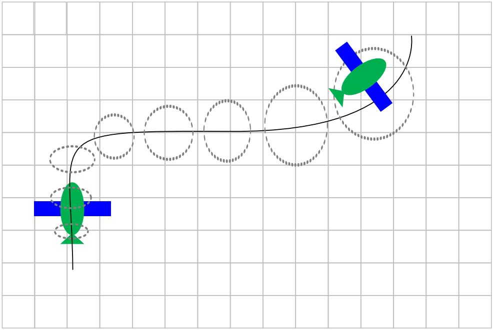
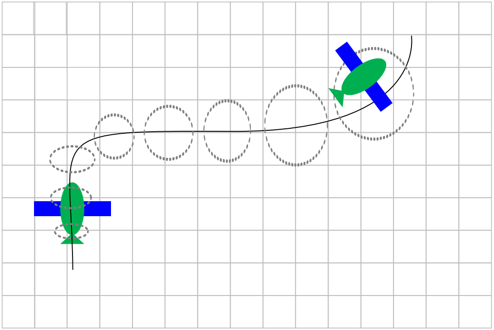
Coverage as Entropy Reduction [2]



$$p(T_t^i = 1) = E[W_t^i]$$

[2] Paull et al. IEEE/ASME Trans. Mechatronics, 2013.

Coverage as Entropy Reduction [2]



$$p(T_t^i = 1) = E[W_t^i]$$

$$\Delta H(T_t^i | X_t) = H(T_t^i) - E_{X_t}[H(T_t^i | X_t)]$$

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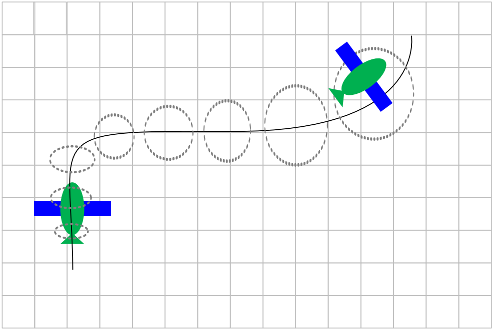

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$$\tau : [0,1] \rightarrow SE(2), s \rightarrow \tau(s)$$

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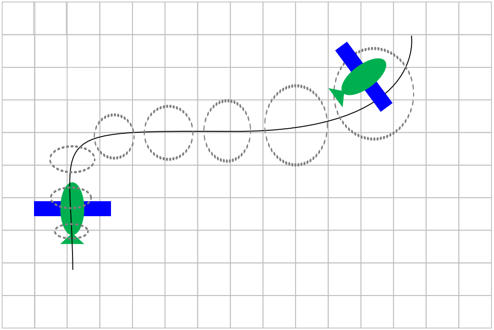

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$$\tau : [0,1] \to SE(2), s \to \tau(s)$$

$$\tau^* = \arg\max_{\tau} B(\tau) \triangleq \int_0^1 \sum_i \Delta H(T_t^i | \tau(s)) ds$$

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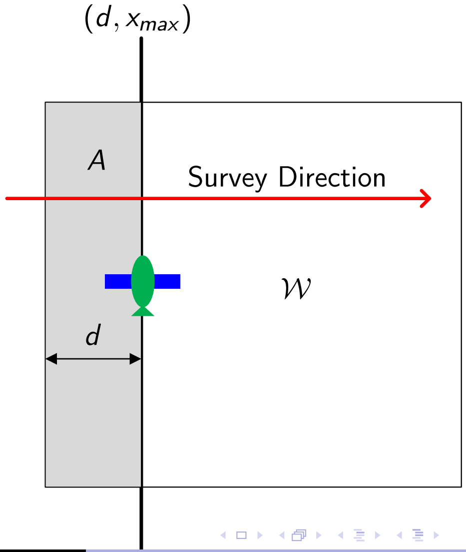
Adaptive Track

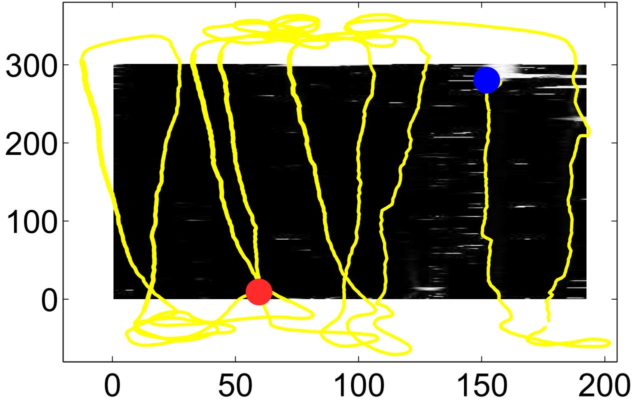
$$\tau_d(0) = (d, x_{min})$$
$$\tau_d(1) = (d, x_{max})$$



Outline

Hardware Field Trials

Final Result



Conclusions and Future Work

Summary

- Probabilistic coverage
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Future Work

- More general path planning
- Presence of obstacles
- Cooperative