Guaranteed Assessment of the Area Explored by an AUV

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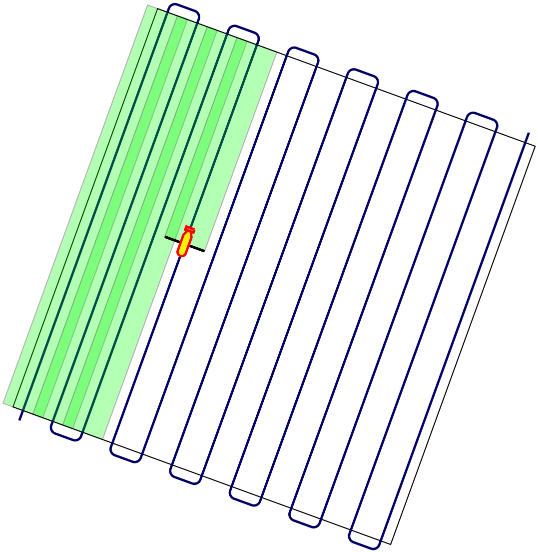
Outlines

Problem Statement

Scenario with SSS

- long mission
- position drift
- unknown environment
- mission re-planning
- no communication



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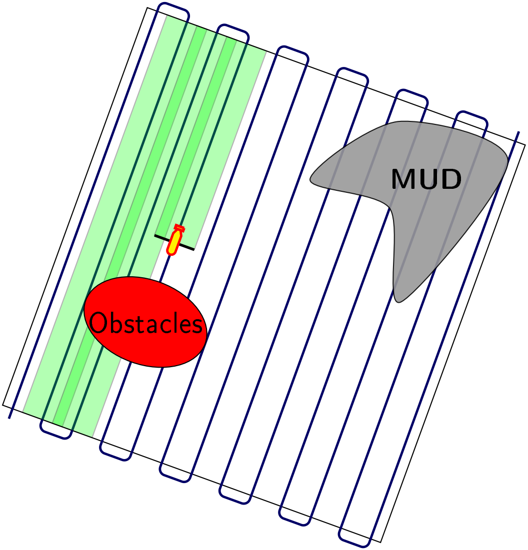

Problem Statement

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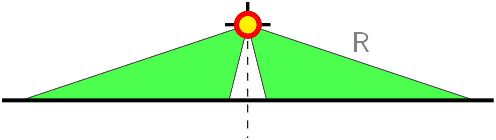
Issues

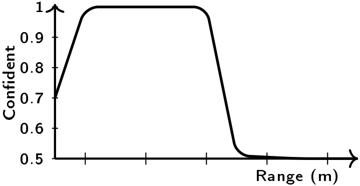
- area explored ?
- data quality ?
- number of view ?

Side scan sonar

Hypothesis

- side scan sonar with gapfiller





Sonar performance

Side scan sonar

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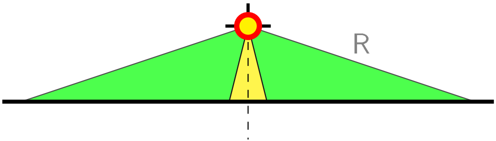
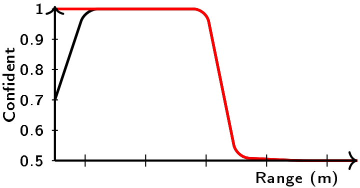


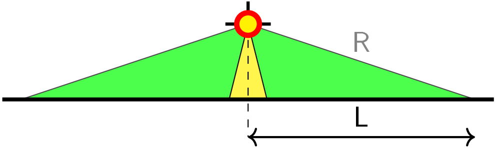


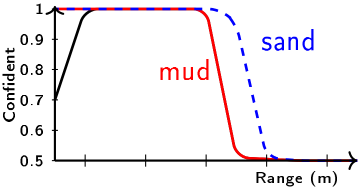
Sonar performance

Side scan sonar

Hypothesis

- side scan sonar with gapfiller
- effective range depends of environmental parameters



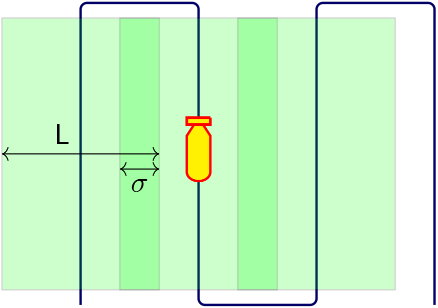


Sonar performance

Outlines

Possible Methods
Geometrical approach

Geometrical footprint of sensors are used to take into account position drift / effective range



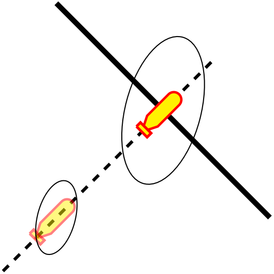
Remarks

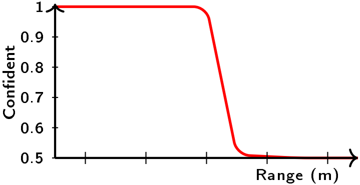
- geometrical assessment
- need a priori knowledge
- easy to use
- not resilient

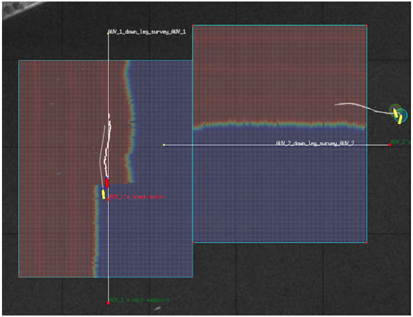
Possible methods

Probabilistic (see Liam Paull [PSL14]

) Use probabilistic framework to build an occupancy grid [PSL14]







Remarks

- Tackles with the "mean" case
- Threshold to make decision ?

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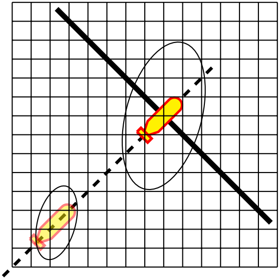

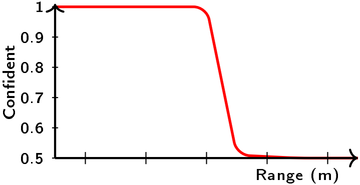

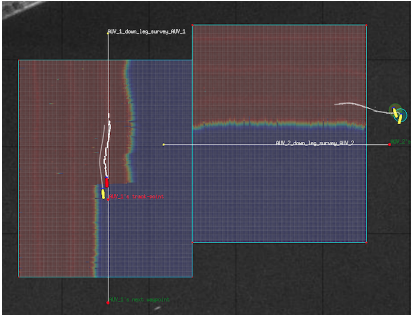

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Possible methods
Sum up

Main issues

- manual parameters need to be set
- difficulties to work with multiple views
- no guaranteed

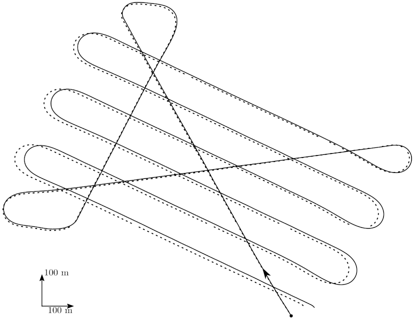
Proposed approach

- guaranteed (based on interval arithmetics)
- simple/relevant parameters
- can be used online
- deals with multiple views

Outlines

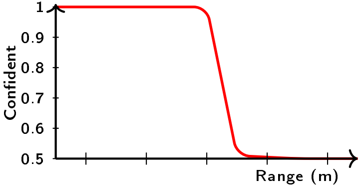
Bounded error context

AUV trajectory



$x(.) \in [x](.)$

Range of the SSS



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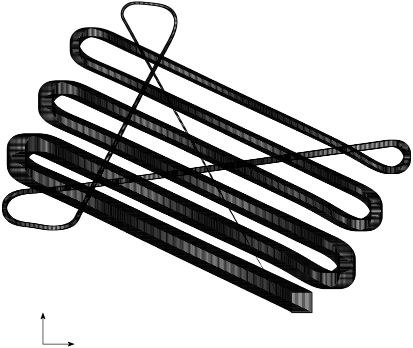

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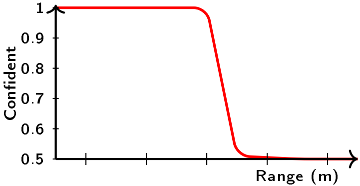

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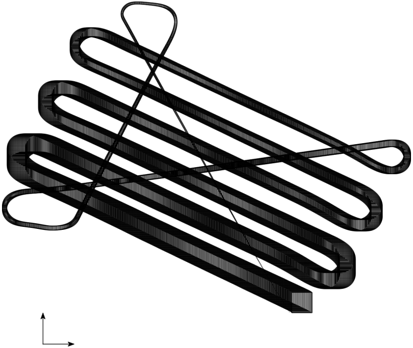

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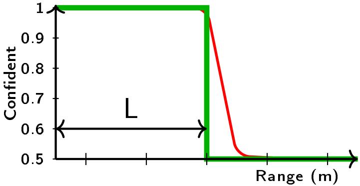


Thick set inversion problem

Consider :

- an uncertain trajectory $\mathbf{x}(.) \in [\mathbf{x}](.)$
- $\varphi : \mathbb{R}^p \times \mathbb{R}^n \longrightarrow \mathbb{R}$ the *visibility function* (continuous)
- $\psi : \mathbb{R}^p \times \mathbb{R}^n \longrightarrow \mathbb{R}$ models the scope of the sensor

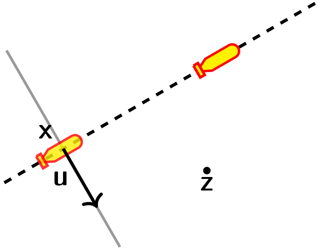
Given $\mathbf{x} \in [\mathbf{x}](.)$, we aim at finding the set:

$$\mathbb{Z}(x) = \{z \in \mathbb{R}^q | \varphi(z, x) = 0 \text{ and } \psi(z, x) \leq 0\}.$$

Thick set inversion problem

Example SSS

$$\varphi(\mathbf{z},\mathbf{x}) \quad = \quad det\left(\mathbf{u},\mathbf{z}-\mathbf{x}\right)$$



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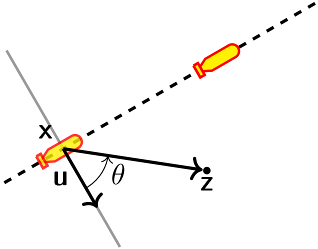

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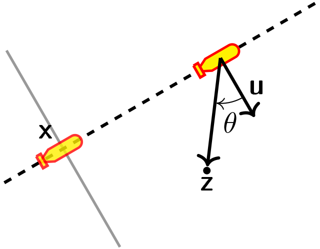

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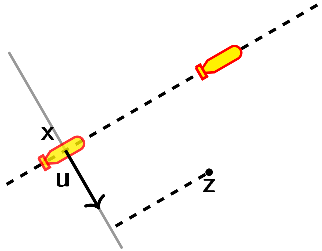
Example SSS

$$\begin{aligned}\varphi(\mathbf{z},\mathbf{x}) &= det\left(\mathbf{u},\mathbf{z}-\mathbf{x}\right)\\ \psi(\mathbf{z},\mathbf{x}) &= \|<\mathbf{u},(\mathbf{z}-\mathbf{x})>\| - L\end{aligned}$$



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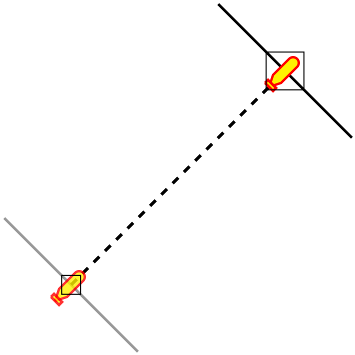
Using interval analysis, can be enclosed by [DJZ13, DJ16]:

$$\mathbb{Z}^- \subset \mathbb{Z} \subset \mathbb{Z}^+.$$

$$\mathbb{Z}^- = \bigcap_{x(.) \in [x](.)} \bigcup_{t \geq 0} \mathbb{Z}(x(t)) \text{ and } \mathbb{Z}^+ = \bigcup_{x(.) \in [x](.)} \bigcup_{t \geq 0} \mathbb{Z}(x(t)).$$

Example



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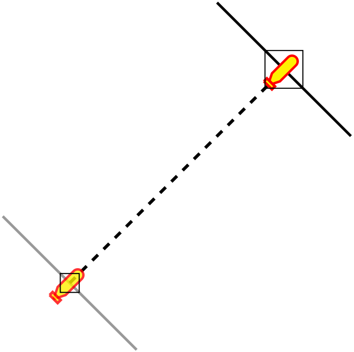

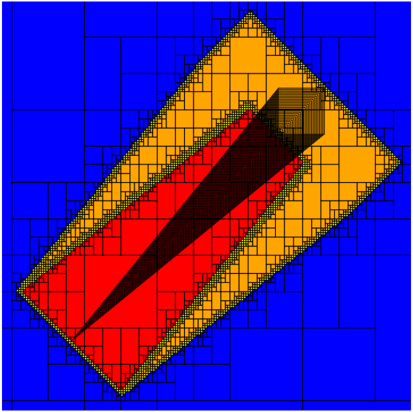

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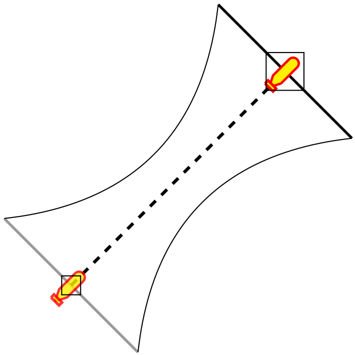
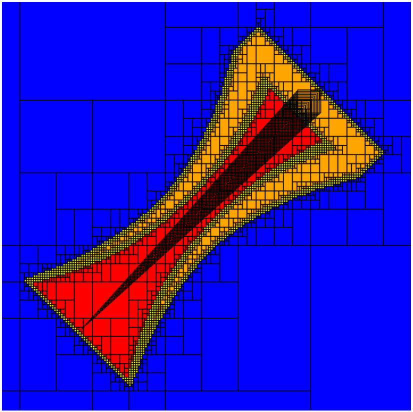
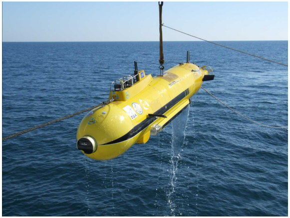




Bigger example

- 5 hours of mission
- error model $\delta_{\mathbf{x}} = 0.2 * \sqrt{t}$
- track to track dist. $=$ 150 m
- effective range 120 m



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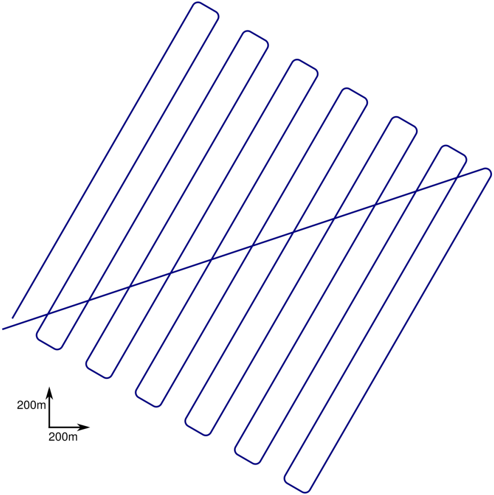
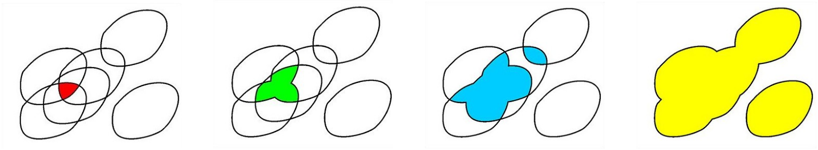


Relaxed Intersection

Definition

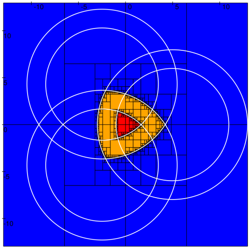
Given m subsets $\mathbb{X}_1, \ldots, \mathbb{X}_m$ of $\mathbb{R}^n$.
The q-relaxed intersection, denoted by $\mathbb{X}^{\{q\}} = \bigcap^{\{q\}} \mathbb{X}_i$, is the set of all $x \in \mathbb{R}^n$ which belong to all $\mathbb{X}_i$'s, except q at most.



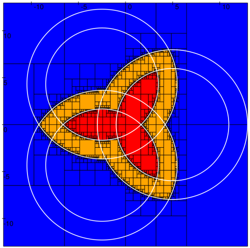
Relaxed Intersection

Examples

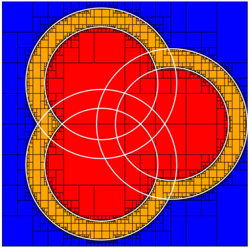
Given 3 disks,



$[\![\mathbb{X}^{\{0\}}]\!]$

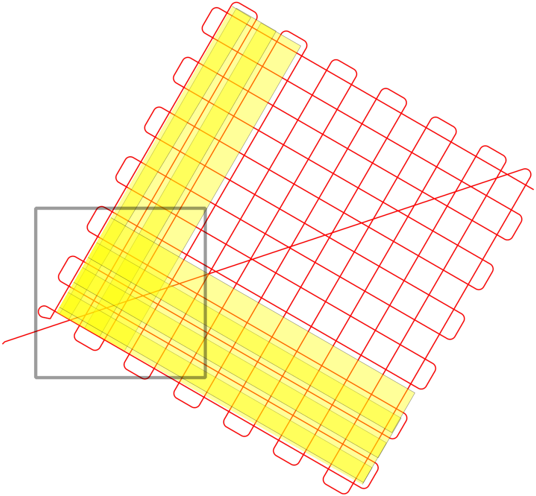


$[\![\mathbb{X}^{\{1\}}]\!]$

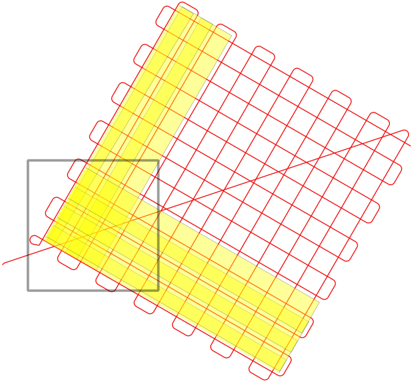


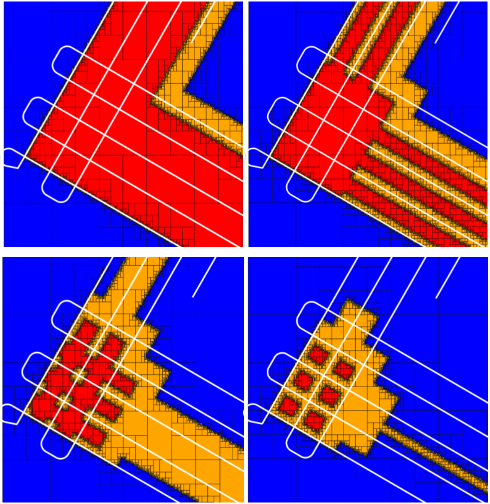
$[\![\mathbb{X}^{\{2\}}]\!]$

Illustration



Illustration





Sum up

Interval methods are powerful to tackle with uncertainty

The proposed interval method

- real time computing
- simple hypothesis
- continuous representation of the space
- useful for small AUV with strong pose uncertainty

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Thank you !

References

B. Desrochers and L. Jaulin.
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