Distributed localization and control of a group of underwater robots using contractor programming

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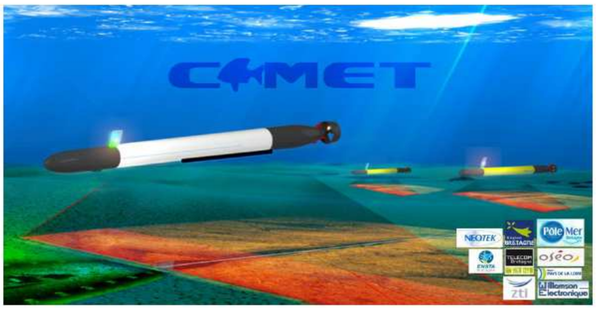
ENSTA Bretagne, OSM, LabSTICC.

Video of the presentation

https://youtu.be/q6F7WDCcf2A

1 Scout project



Goal : (i) coordination of underwater robots ; (ii) collaborative behavior.

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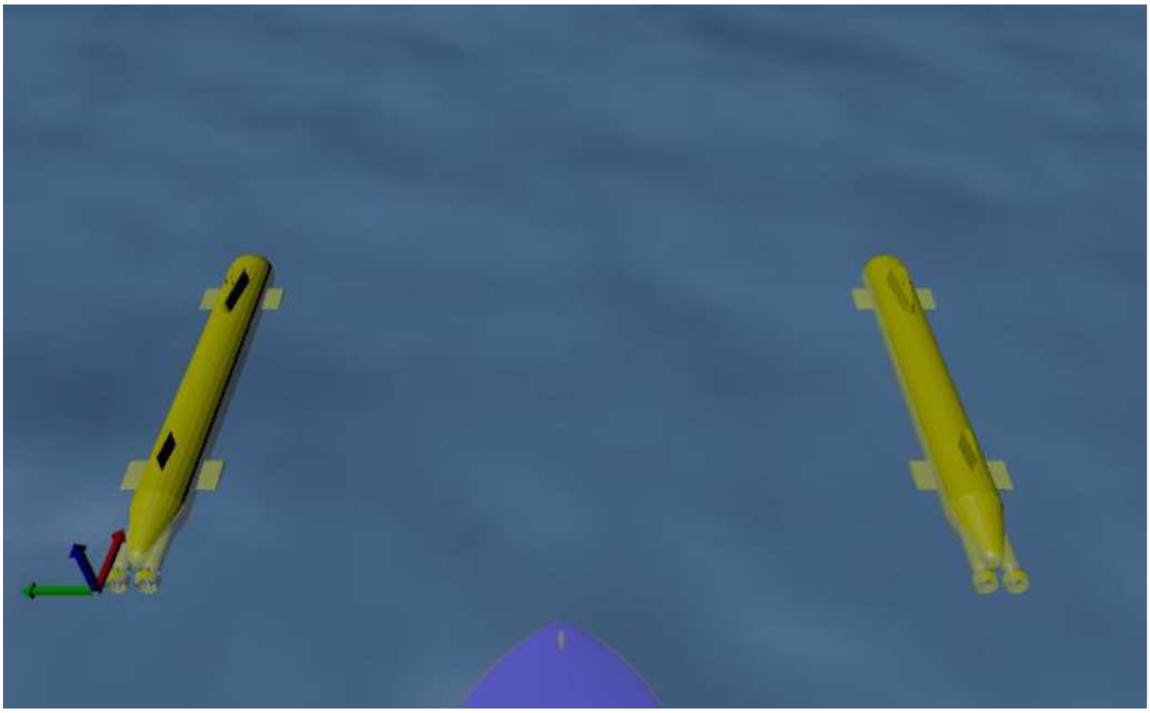
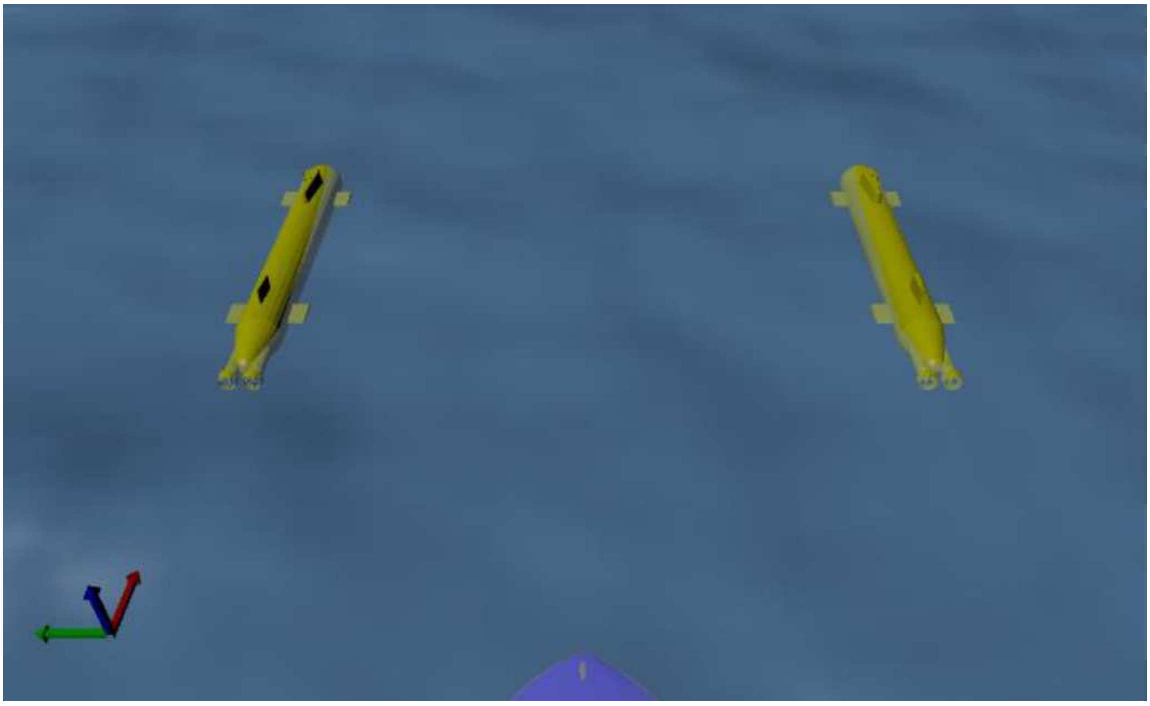
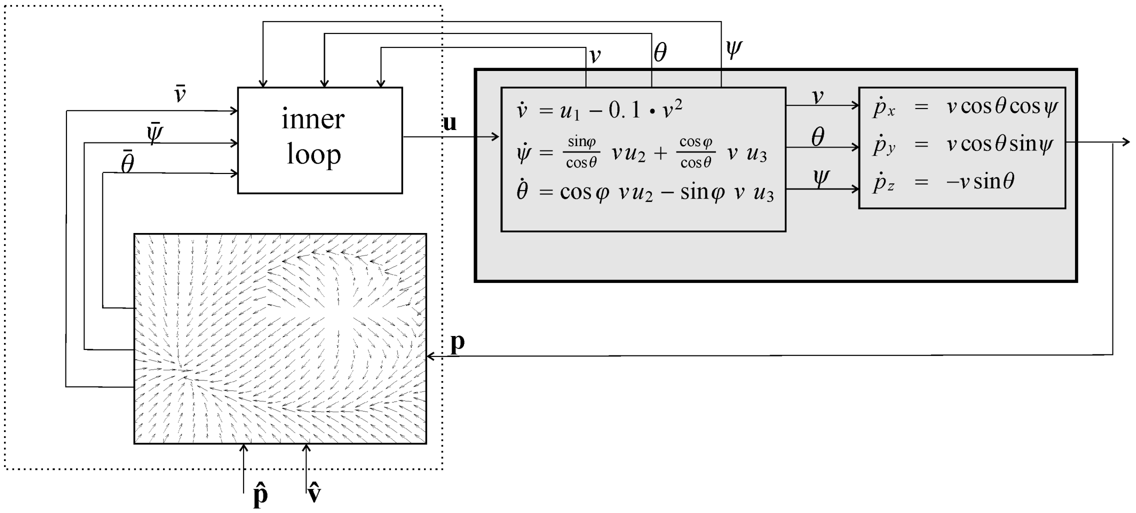
Compagny: RTsys (P. Raude)

Students: G. Ricciardelli, L. Devigne, C. Guillemot, S. Pommier, T. Viravau, T. Le Mezo, B. Sultan, B. Moura, M. Fadlane, A. Bellaiche, T. Blanchard, U. Da rocha, G. Pinto, K. Machado.





2 Controller



inner loop
u
p
p̂
v̂
$\bar{v}$
$\bar{\psi}$
$\bar{\theta}$
v
θ
ψ
$\dot{v} = u_1 - 0.1 \cdot v^2$
$\dot{\psi} = \frac{\sin\varphi}{\cos\theta} v u_2 + \frac{\cos\varphi}{\cos\theta} v u_3$
$\dot{\theta} = \cos\varphi\, v u_2 - \sin\varphi\, v u_3$
$\dot{p}_x = v\cos\theta\cos\psi$
$\dot{p}_y = v\cos\theta\sin\psi$
$\dot{p}_z = -v\sin\theta$

3 Localization problem

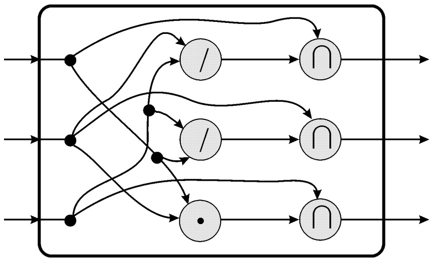
Range only
Based on interval analysis
Robust with respect to outliers
Distributed computation
Low rate communication

We propose here to use a contractor programming approach

4 Matrices and contractors

$$\begin{array}{ccc} \text{linear application} & \longrightarrow & \text{matrices} \\ \mathcal{L}: \left\{ \begin{array}{lcl} \alpha & = & 2a + 3h \\ \gamma & = & h - 5a \end{array} \right. & \longrightarrow & \mathbf{A} = \begin{pmatrix} 2 & 3 \\ 1 & -5 \end{pmatrix} \end{array}$$

We have a matrix algebra and Matlab.
We have: $\text{var}(\mathcal{L}) = \{a, h\}$, $\text{covar}(\mathcal{L}) = \{\alpha, \gamma\}$.
But we cannot write: $\text{var}(\mathbf{A}) = \{a, h\}$, $\text{covar}(\mathbf{A}) = \{\alpha, \gamma\}$.

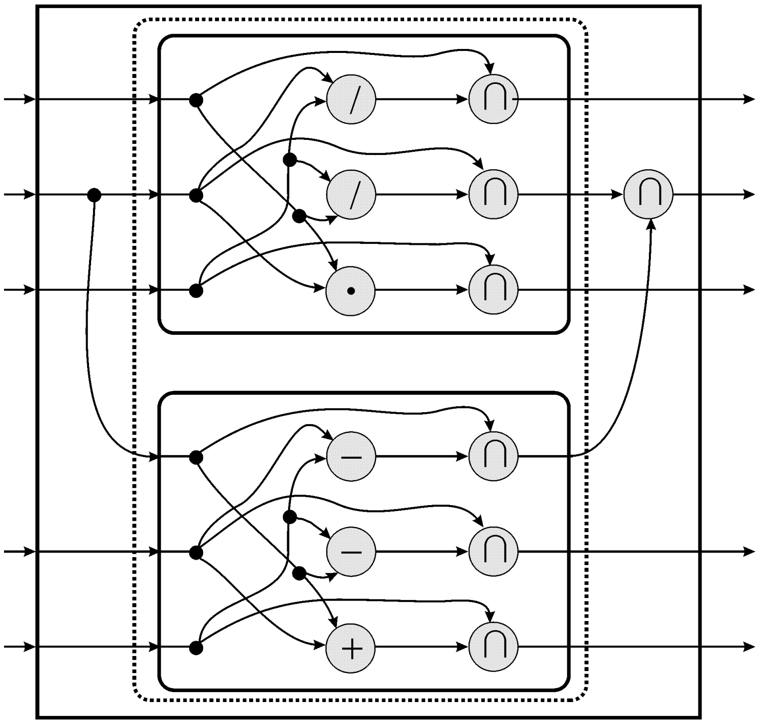
constraint	$\longrightarrow$	contractor
$a \cdot b = z$	$\longrightarrow$	

Contractor fusion

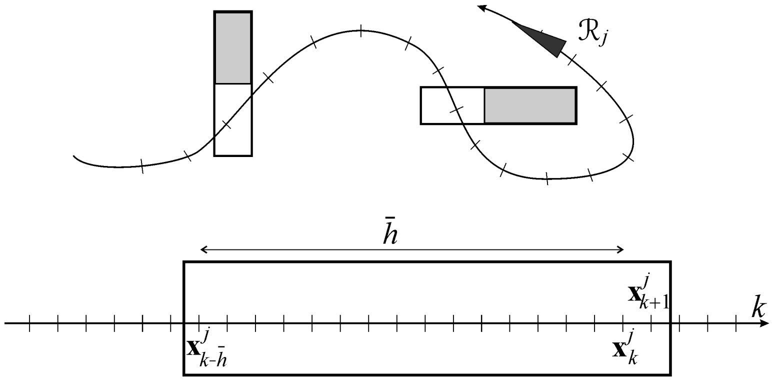
$$\begin{cases} a \cdot b = z & \longrightarrow \quad \mathcal{C}_1 \\ b + c = d & \longrightarrow \quad \mathcal{C}_2 \end{cases}$$

Since b occurs in both constraints, we fuse the two contractors as:

$$\begin{aligned} \mathcal{C} &= \mathcal{C}_1 \times \mathcal{C}_2 \rfloor_{(2,1)} \\ &= \mathcal{C}_1 | \mathcal{C}_2 \text{ (for short)} \end{aligned}$$



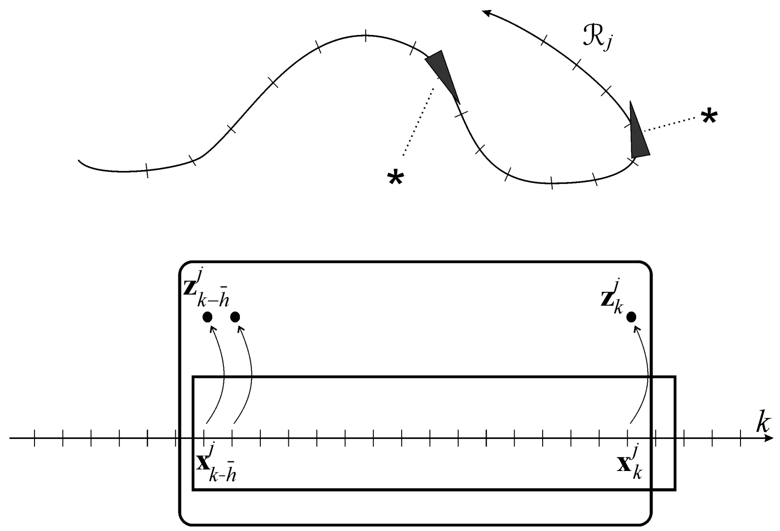
5 Localization with contractors



$$\mathbf{x}^j_{h+1} = \mathbf{f}(\mathbf{x}^j_h, \mathbf{u}^j_h), h \in \{k - \bar{h}, \ldots, k\}$$

The observer: $C^{k,j}_{\mathbf{x}} = \bigcap_{h \in \{k-\bar{h},\ldots,k\}} C^j_{\mathbf{x}(h)}$

var$(\mathcal{C}^{k,j}_{\mathbf{x}})$ =var$(\mathcal{C}^{k,j}_{\mathbf{x}(h)}) = \left\{\mathbf{x}^j_{k-\bar{h}}, \ldots, \mathbf{x}^j_k, \mathbf{x}^j_{k+1}\right\}$.

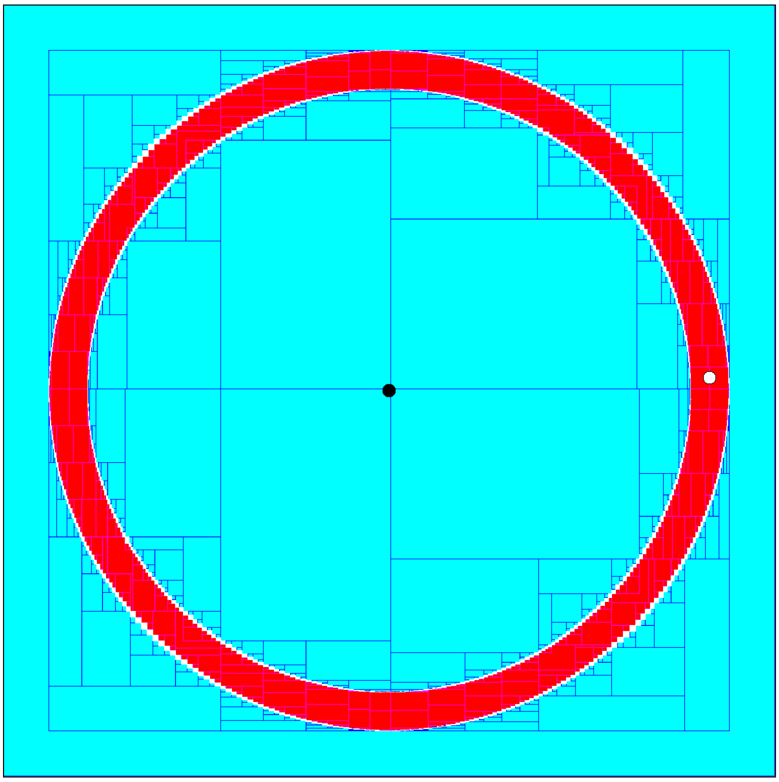


$$\mathbf{z}_h^j = \mathbf{h}(\mathbf{x}_h^j)$$

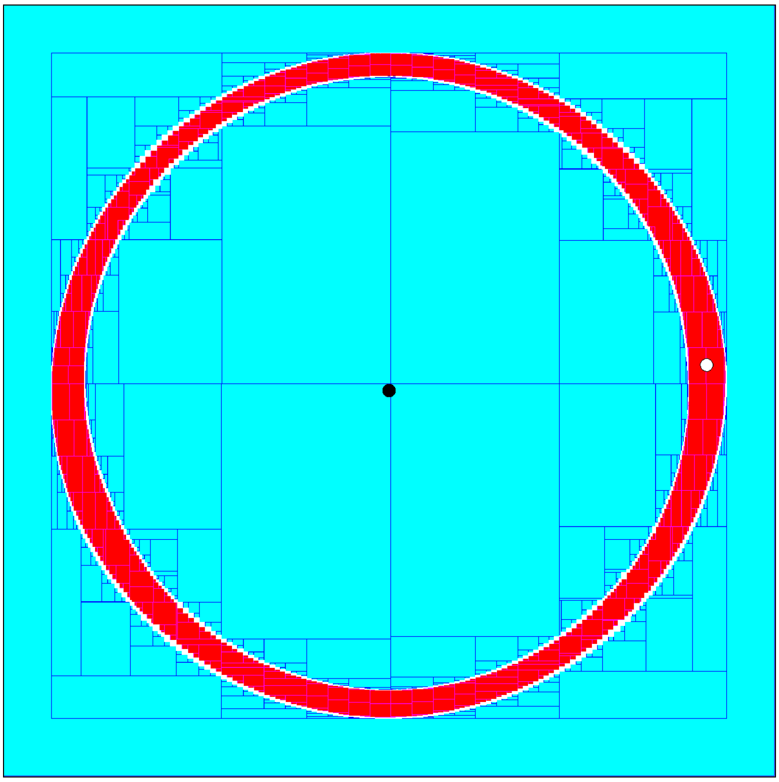
Observer RSO: $C_{\mathbf{x},z}^{k,j} = C_{\mathbf{x}}^{k,j} \cap \bigcap_{h\in\{k-\bar{h},\ldots,k\}}^{\{q_1\}} \left(C_{\mathbf{x}}^{k,j} | C_z^{h,j} \right).$

To get an outer approximation of set$(\mathcal{C}_{\mathbf{x},z}^{k,j})$, we need a paver.

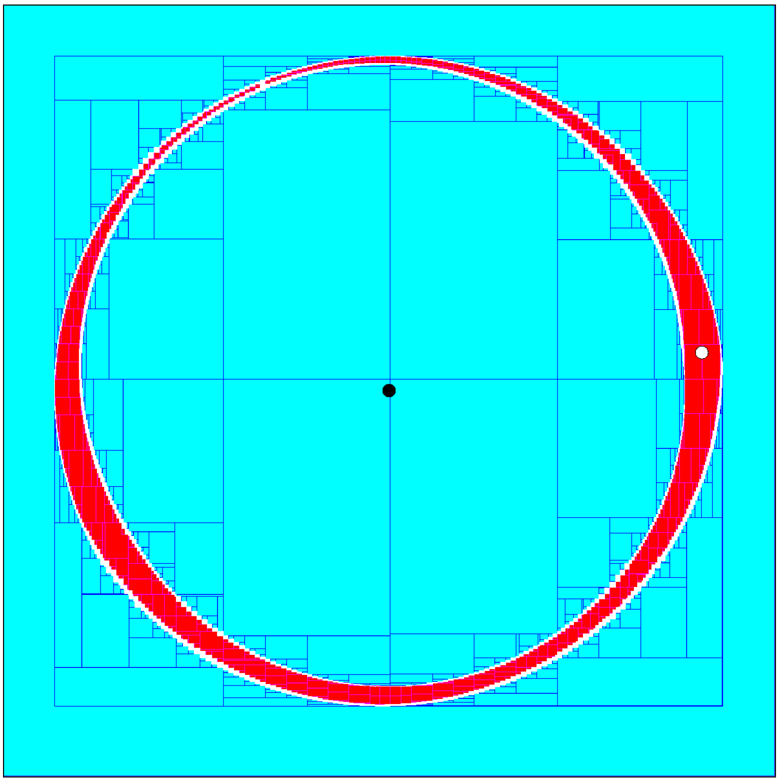
We can also obtain an inner approximation using separators [SMART 2015].



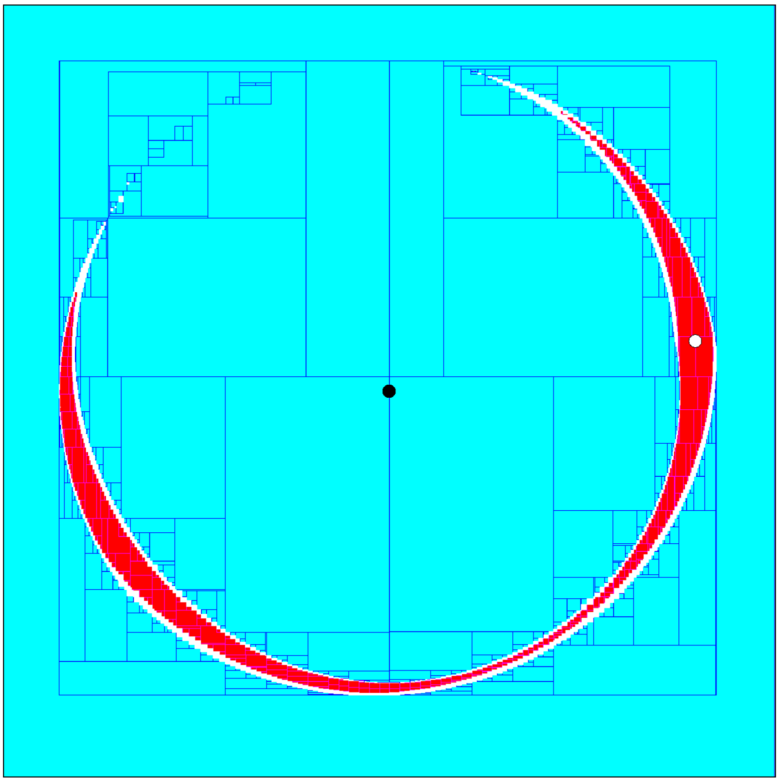
$t = 0$



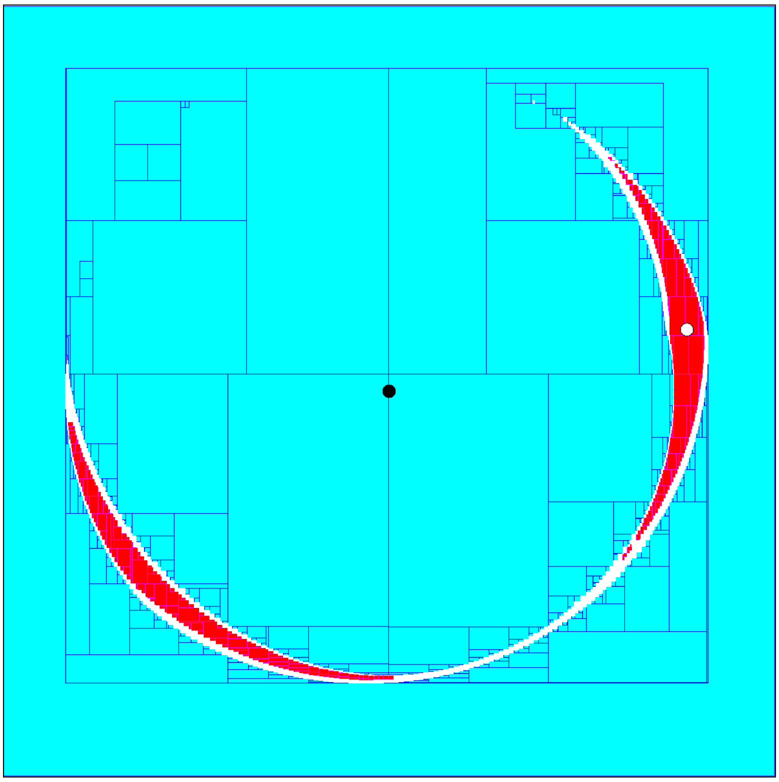
$t = 0.1$



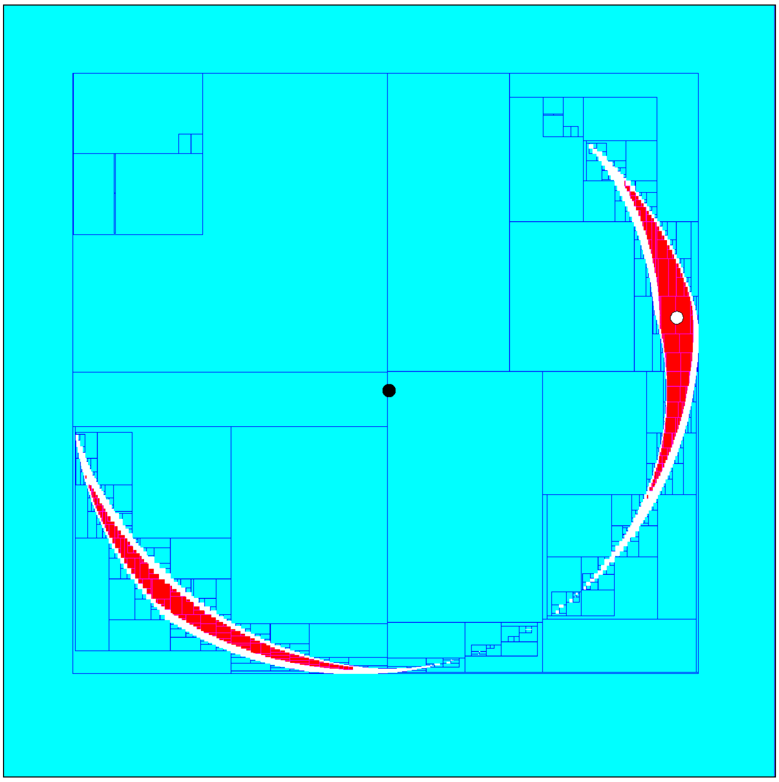
$t = 0.2$



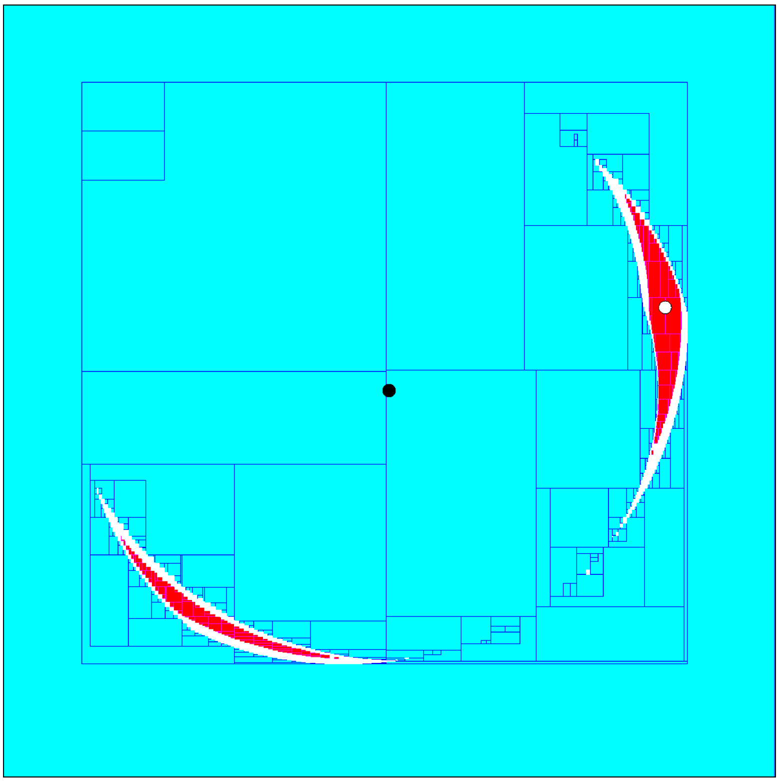
$t = 0.3$



$t = 0.4$



$t = 0.5$

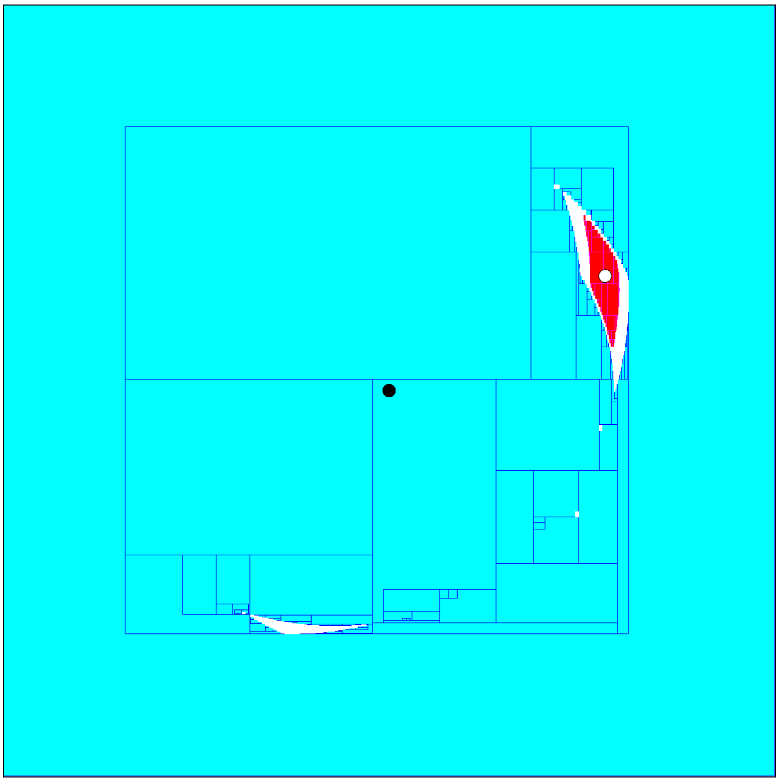


$t = 0.6$

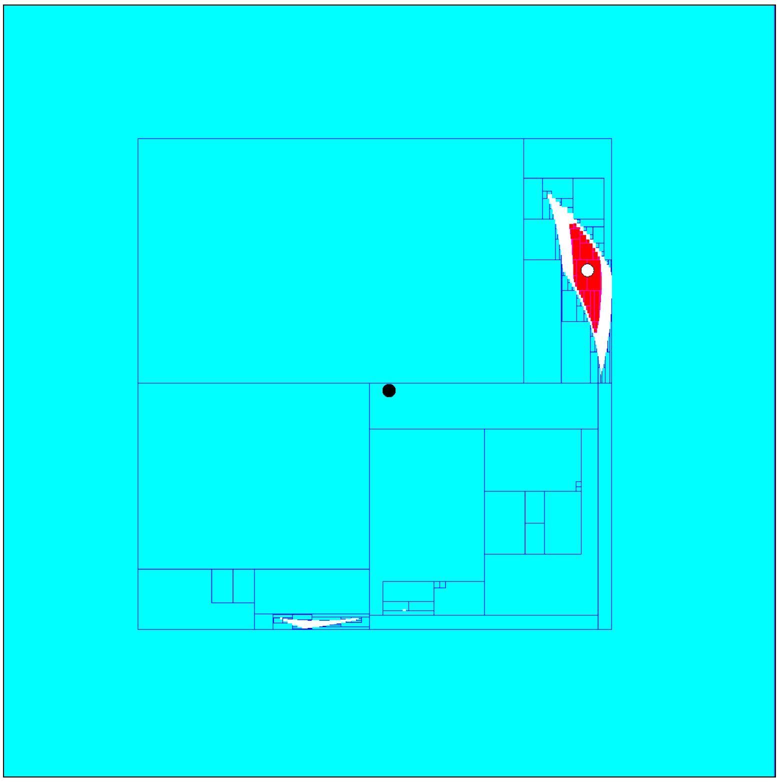
$t = 0.7$

$t = 0.8$

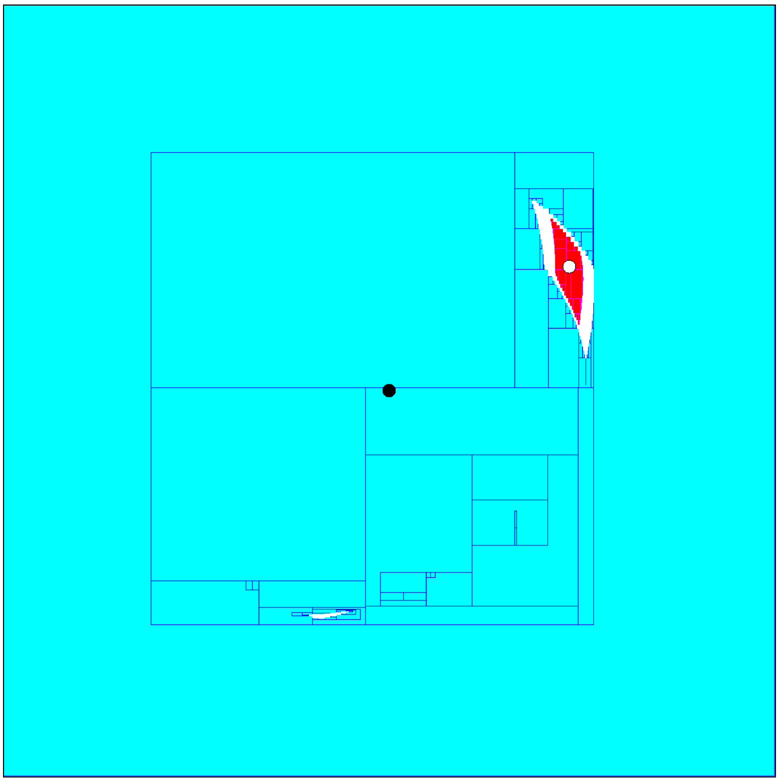
$t = 0.9$



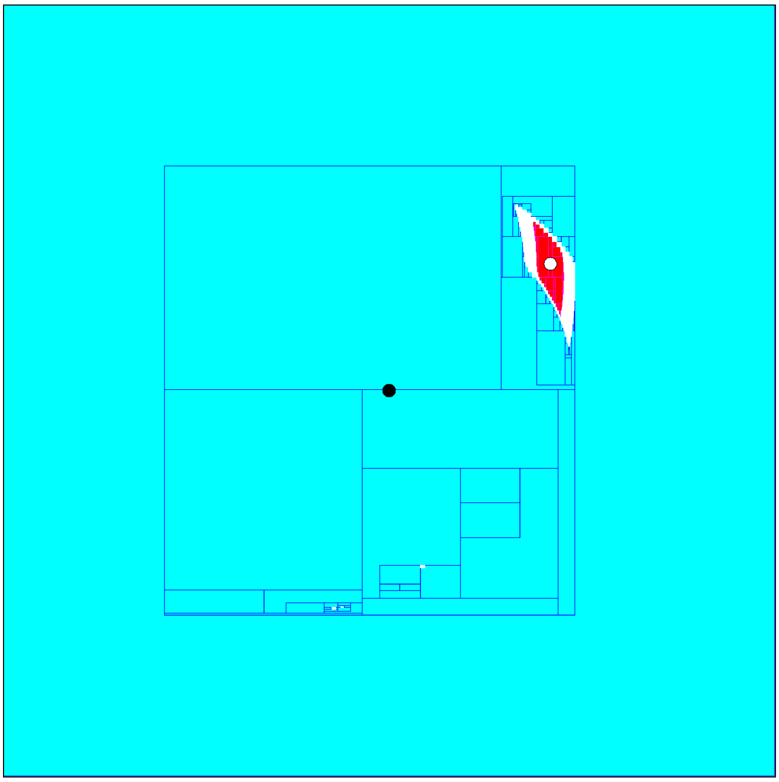
$t = 1.0$



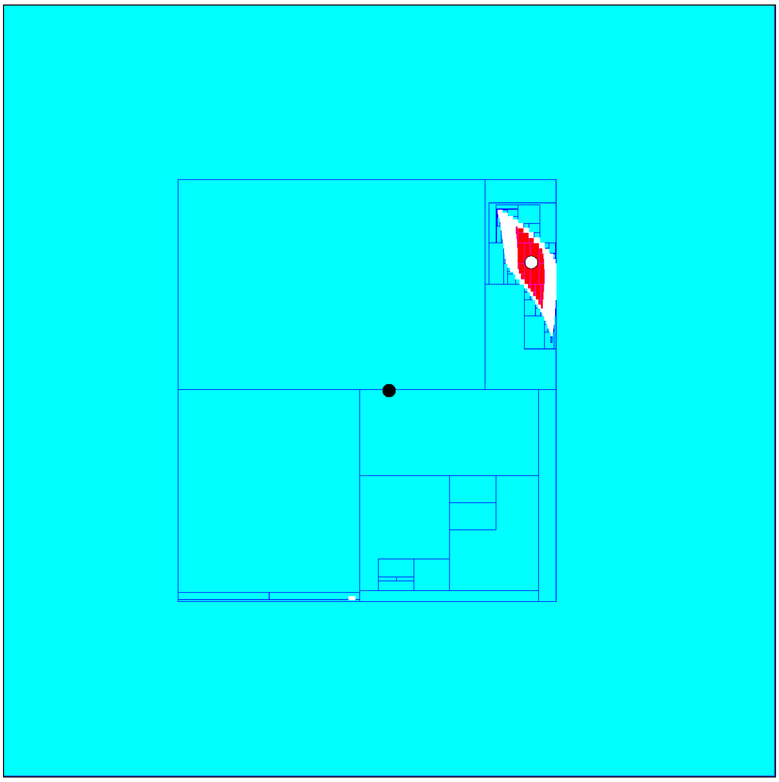
$t = 1.1$



$t = 1.2$

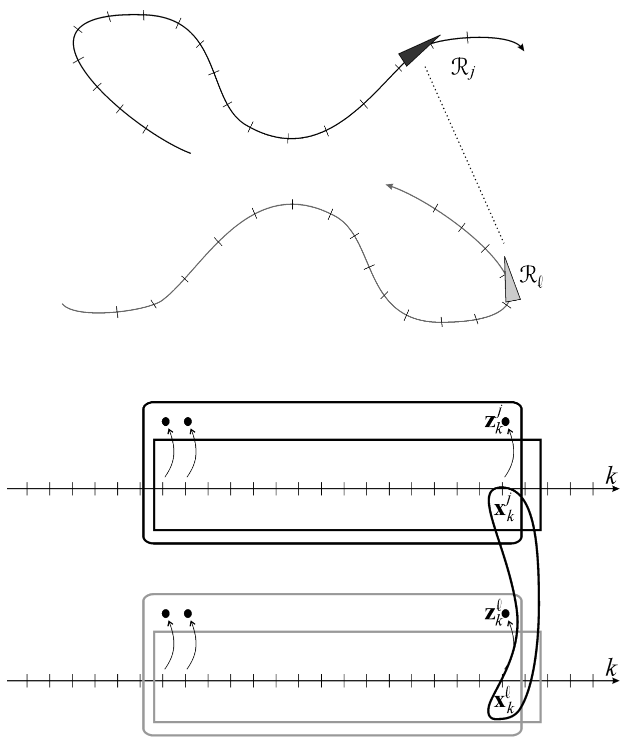


$t = 1.3$



$t = 1.4$

6 Distributed localization

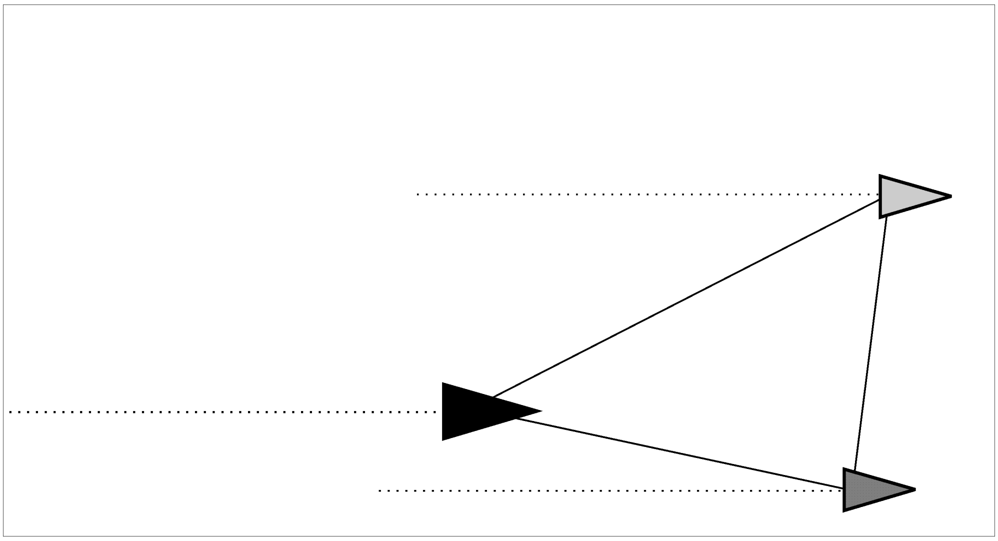


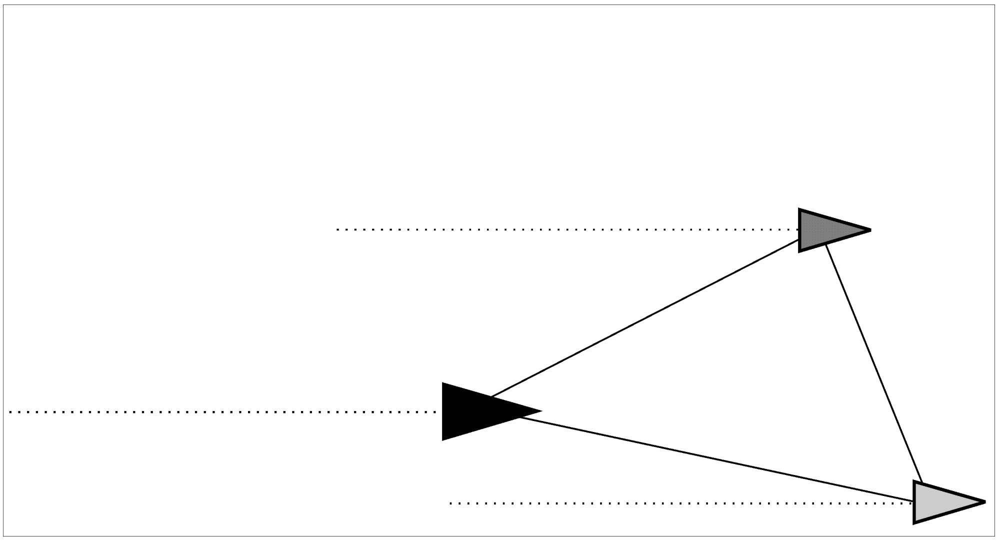
$$\mathbf{y}_h^{j,\ell} = \mathbf{g}(\mathbf{x}_h^j, \mathbf{x}_h^\ell)$$

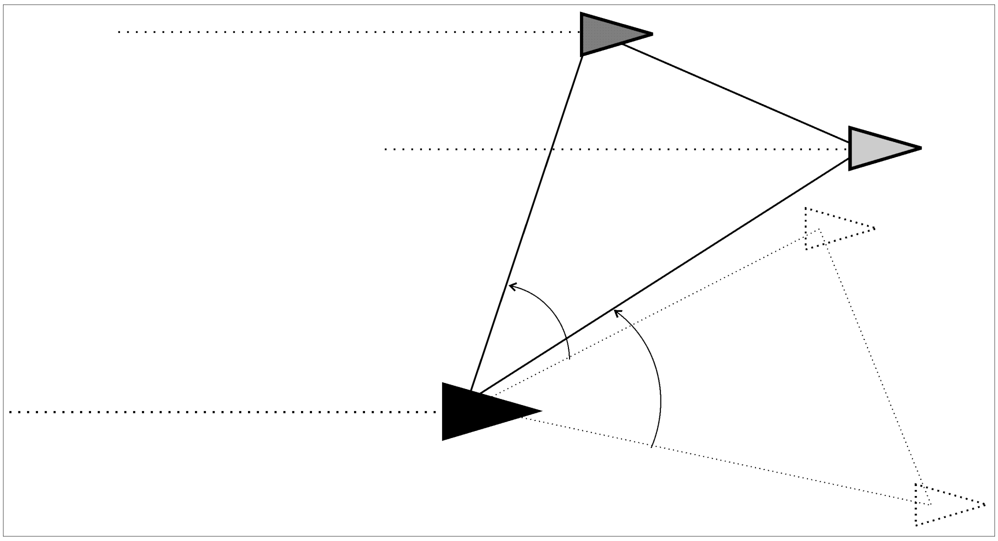
Observer:

$$
\begin{aligned}
C_{\mathbf{x},z}^{k,j} \;&=\; C_{\mathbf{x}}^{k,j} \cap \;\; \bigcap\nolimits_{h\in\{k-\bar{h},\ldots,k\}}^{\{q_1\}} \left(C_{\mathbf{x}}^{k,j} | C_{z}^{h,j} \right) \\
&\cap \;\; \bigcap\nolimits_{h\in\{k-\bar{h},\ldots,k\}}^{\{q_2\}} \left(C_{\mathbf{x}}^{k,j} | C_{y}^{h,j,\ell} \right)
\end{aligned}
$$

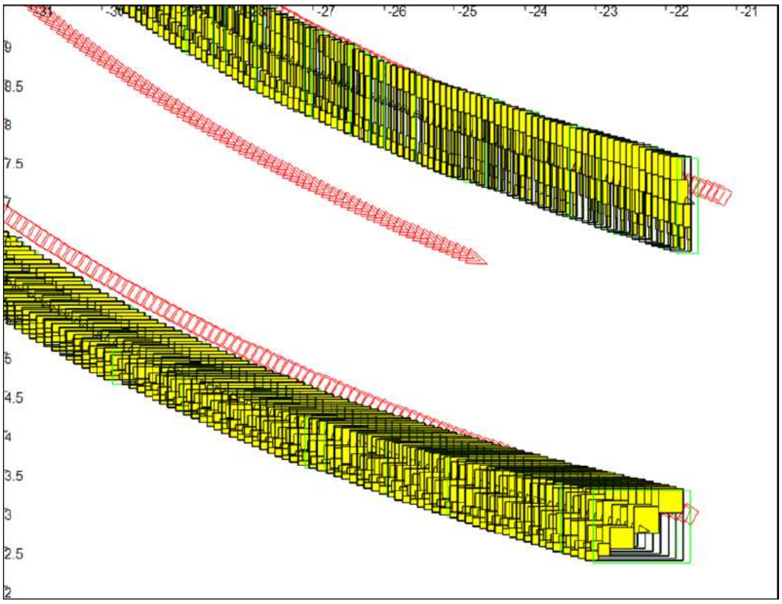
7 Singularity







8 Test case



QT/C++ code available at

http://www.ensta-bretagne.fr/jaulin/easibex.html

9 Tests


ZTI z1050