Chapter 5: Robust observers

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1 State estimation

$$\left\{ \begin{array}{lll} \mathbf{x}(k+1) & = & \mathbf{f}_k(\mathbf{x}(k), \mathbf{n}\,(k)) \\ \mathbf{y}(k) & = & \mathbf{g}_k(\mathbf{x}(k)), \end{array} \right.$$

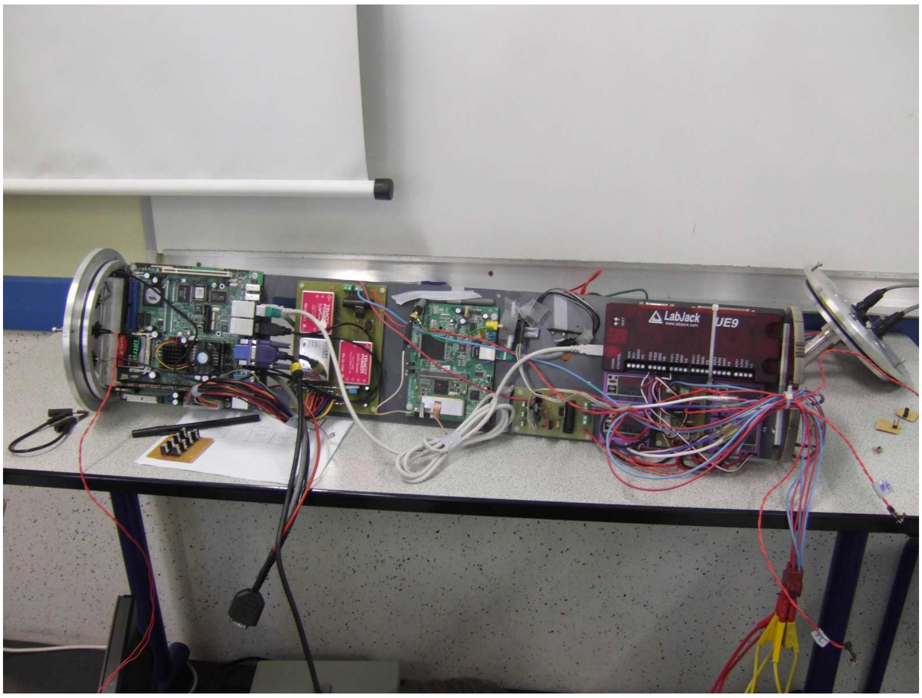
with $\mathbf{n}\,(k) \in \mathbb{N}\,(k)$ and $\mathbf{y}\,(k) \in \mathbb{Y}\,(k)$.

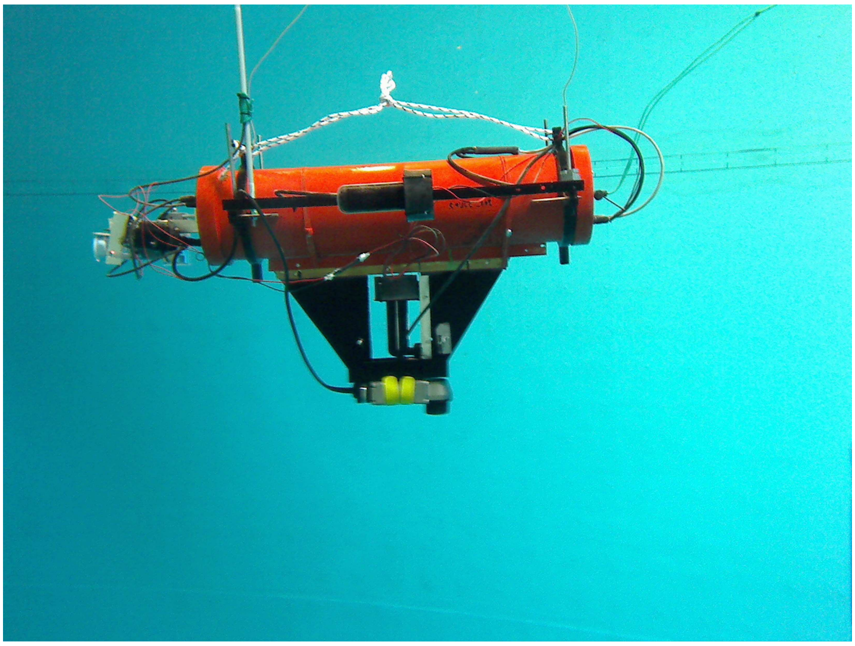
Without outliers

$$\mathbb{X}(k+1) = \mathbf{f}_k\left(\mathbb{X}(k), \mathbb{N}\left(k\right)\right) \quad \cap \quad \mathbf{g}_{k+1}^{-1}\left(\mathbb{Y}(k+1)\right).$$

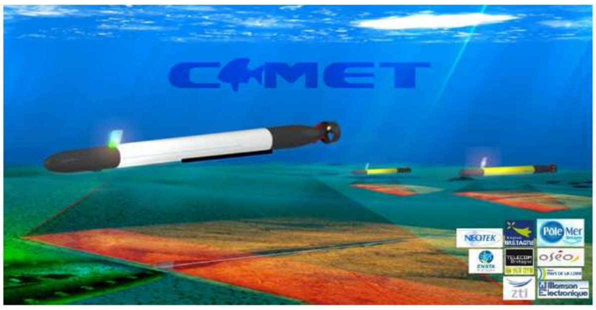
2 SAUC’E

Portsmouth, July 12-15, 2007.


LabJack
UE9



3 Scout project

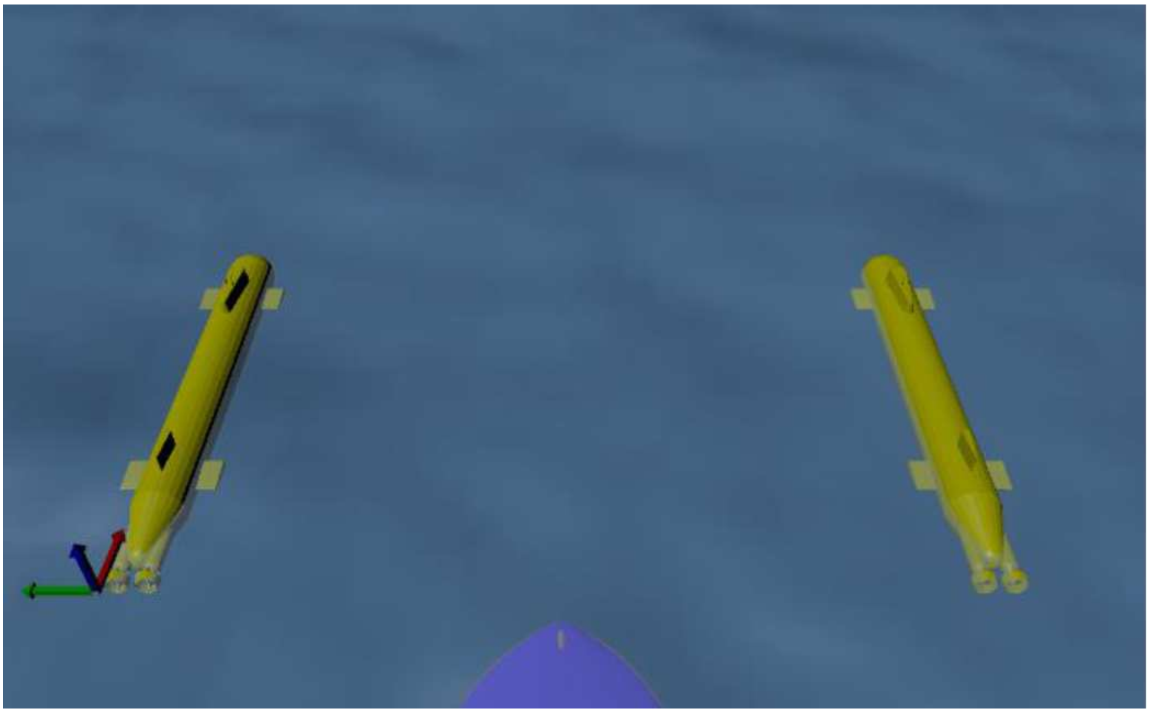


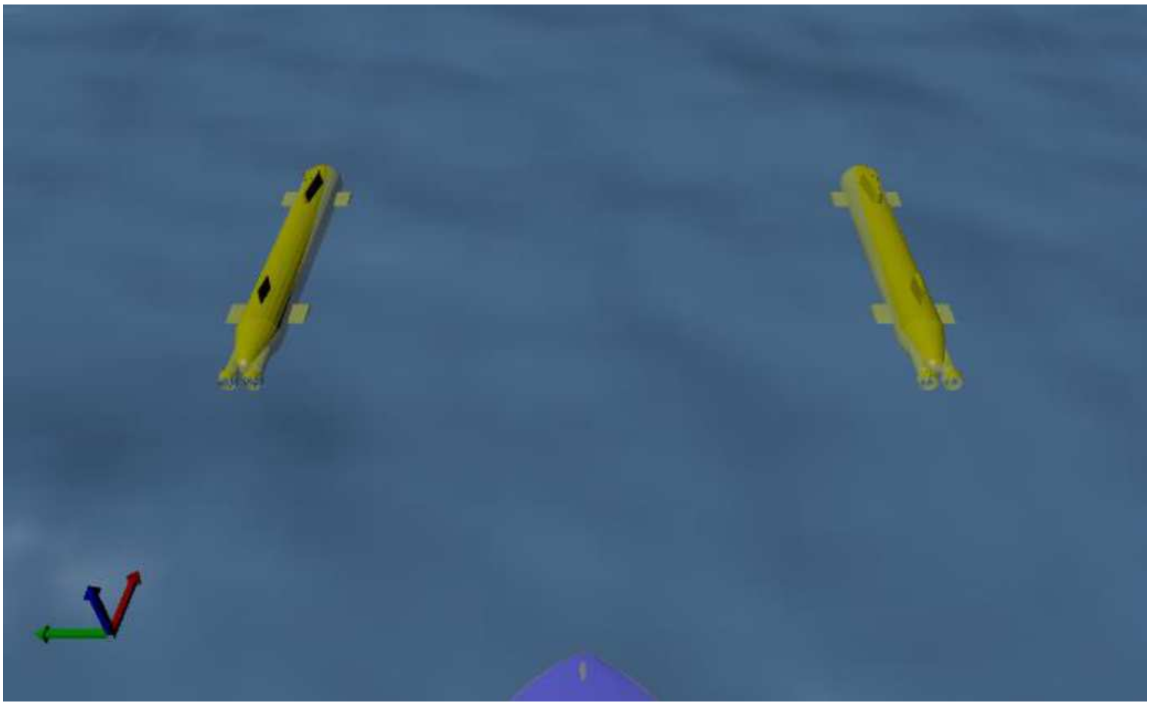
Goal : (i) coordination of underwater robots ; (ii) collaborative behavior.

Supervisors: L. Jaulin, C. Aubry, S. Rohou, B. Zerr, J. Nicola, F. Le bars

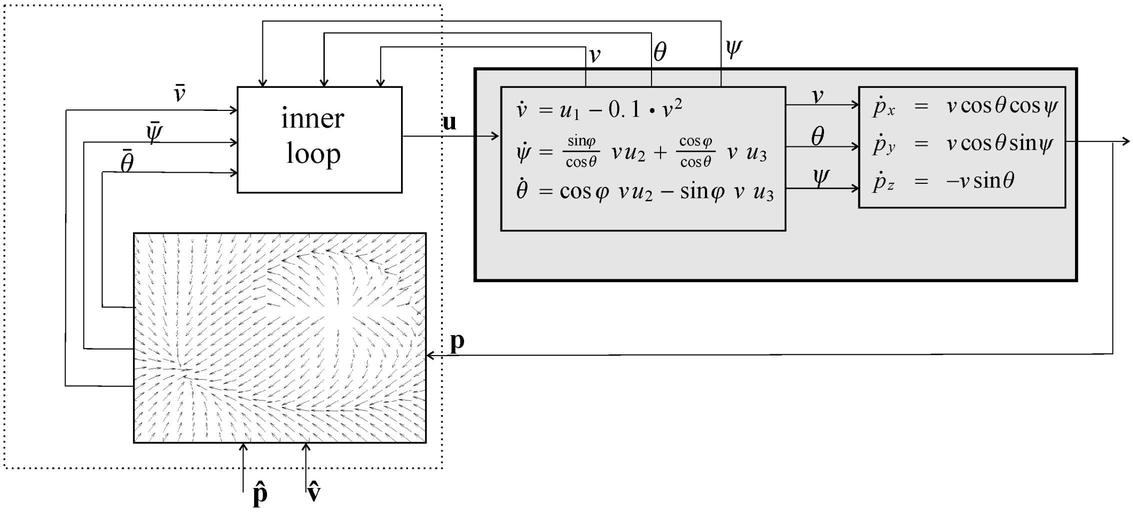
Compagny: RTsys (P. Raude)

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.





4 Controller

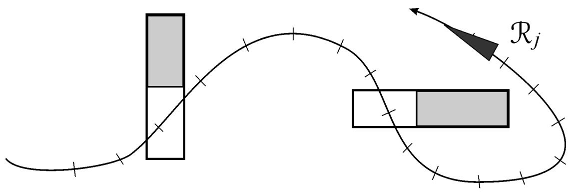

inner loop
$\bar{v}$
$\bar{\psi}$
$\bar{\theta}$
$\mathbf{u}$
v
θ
ψ
$\dot{v} = u_1 - 0.1 \cdot v^2$
$\dot{\psi} = \frac{\sin\varphi}{\cos\theta}\, v u_2 + \frac{\cos\varphi}{\cos\theta}\, v\, u_3$
$\dot{\theta} = \cos\varphi\, v u_2 - \sin\varphi\, v\, u_3$
$\dot{p}_x = v\cos\theta\cos\psi$
$\dot{p}_y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

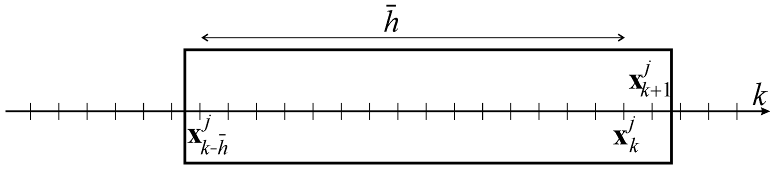
5 Localization problem

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

6 Localization with contractors

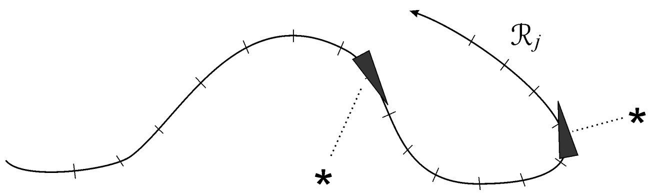


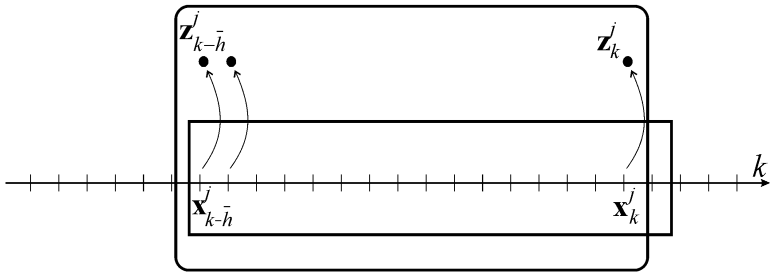


$$\mathbf{x}_{h+1}^{j} = \mathbf{f}(\mathbf{x}_{h}^{j}, \mathbf{u}_{h}^{j}), h \in \{k - \bar{h}, \ldots, k\}$$

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

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

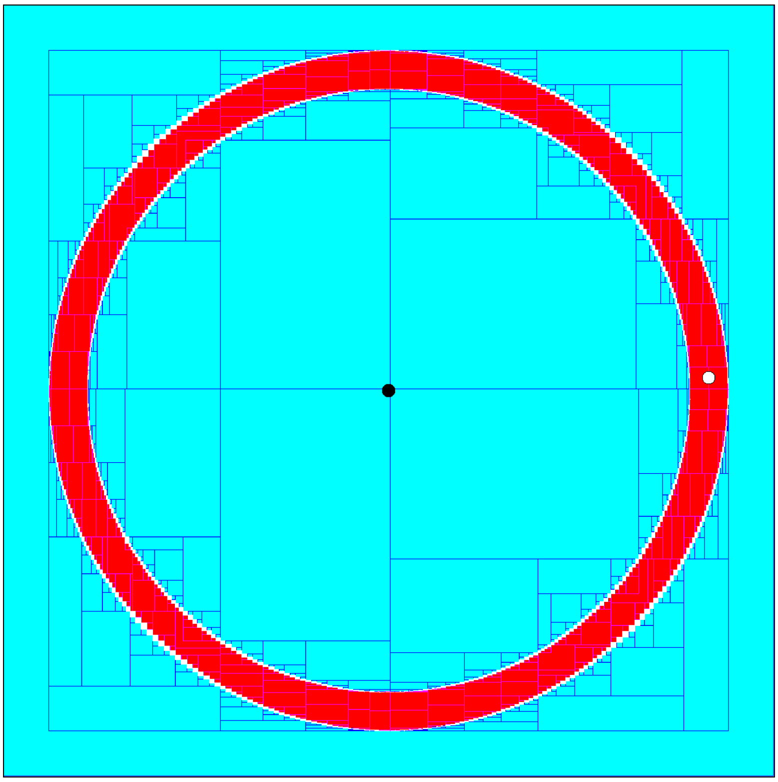




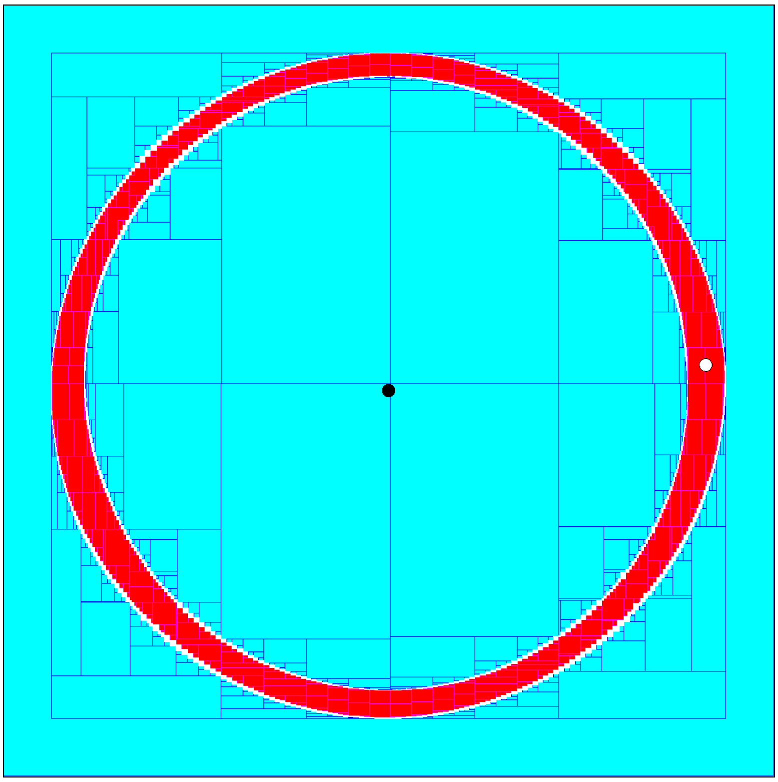
$$\mathbf{z}^j_h = \mathbf{h}(\mathbf{x}^j_h)$$

Observer RSO: $C^{k,j}_{\mathbf{x},z} = C^{k,j}_{\mathbf{x}} \cap \bigcap^{\{q_1\}}_{h\in\{k-\bar{h},\dots,k\}} \left(C^{k,j}_{\mathbf{x}} | C^{h,j}_{z}\right).$

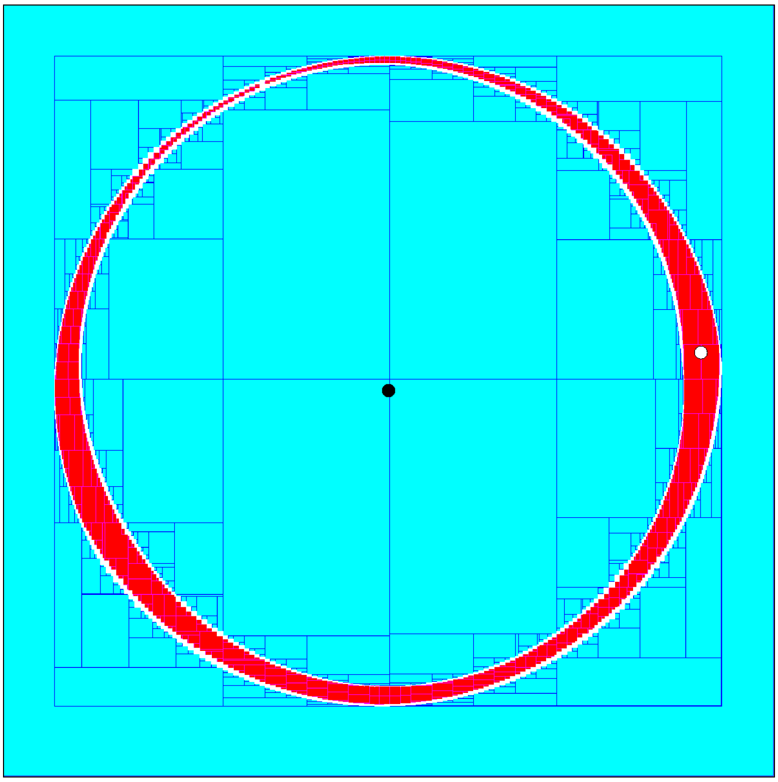
To get an outer approximation of set$(\mathcal{C}_{\mathbf{x},z}^{k,j})$, we need a paver.



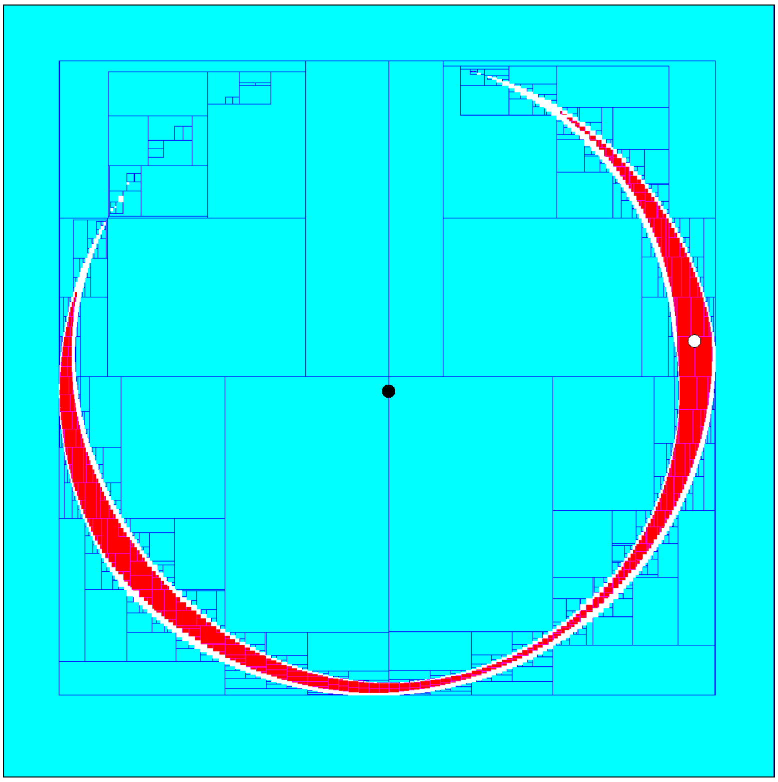
$t = 0$



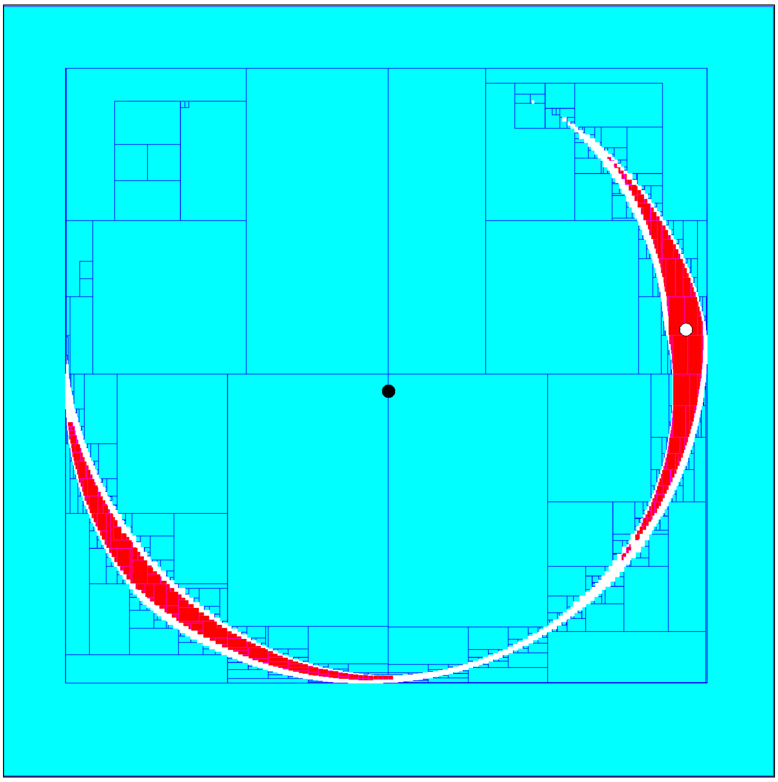
$t = 0.1$



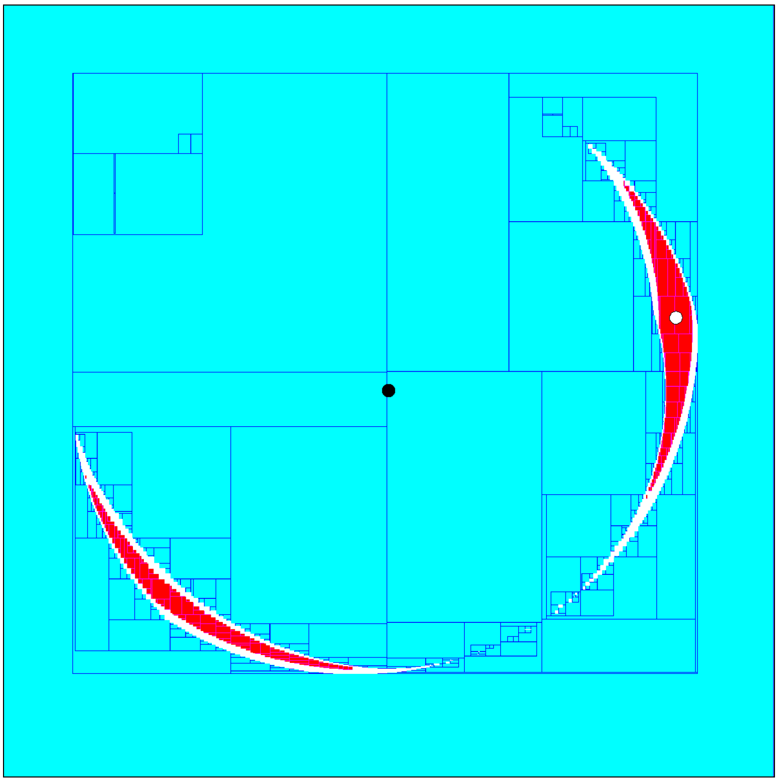
$t = 0.2$



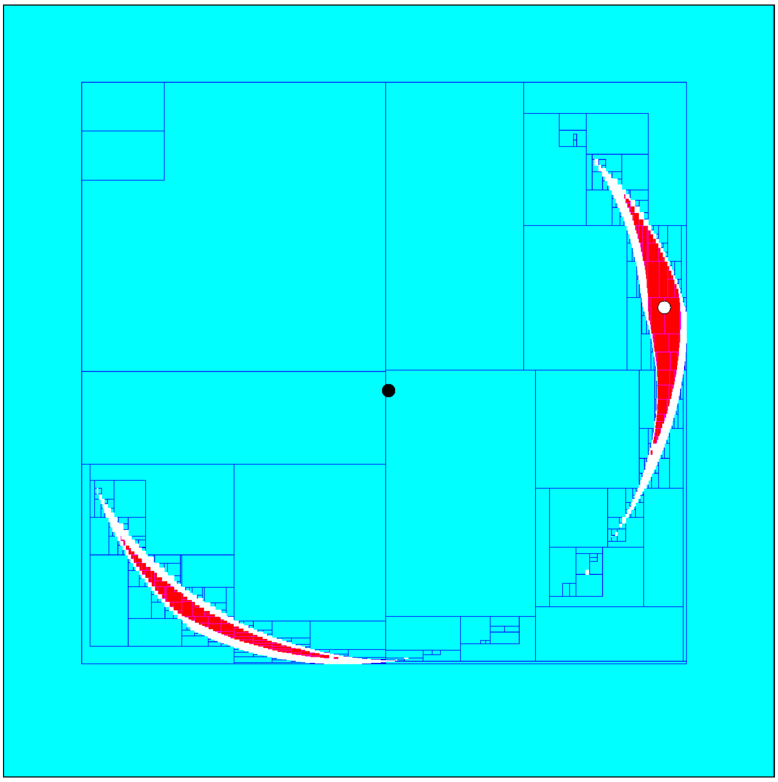
$t = 0.3$



$t = 0.4$



$t = 0.5$

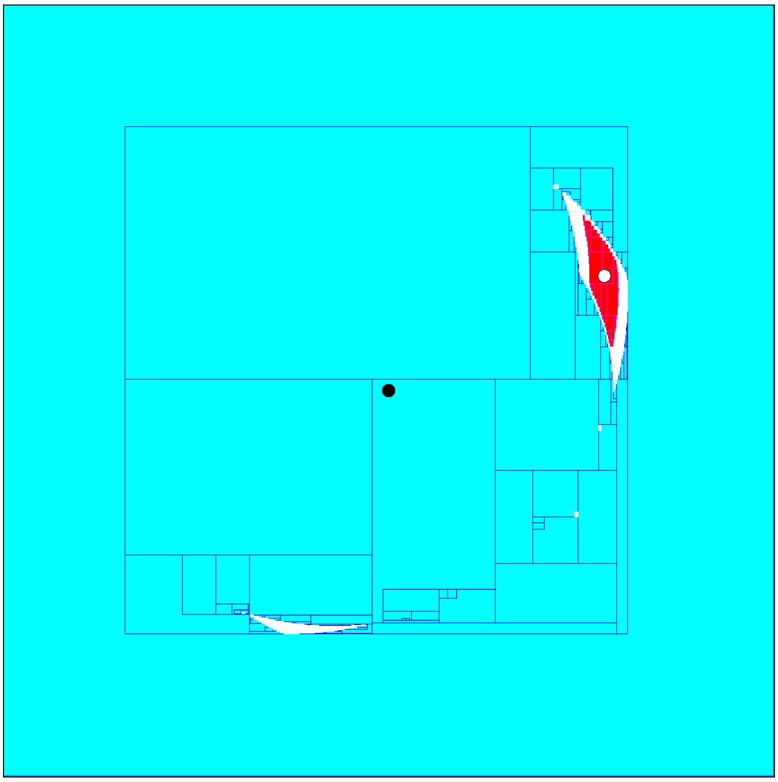


$t = 0.6$

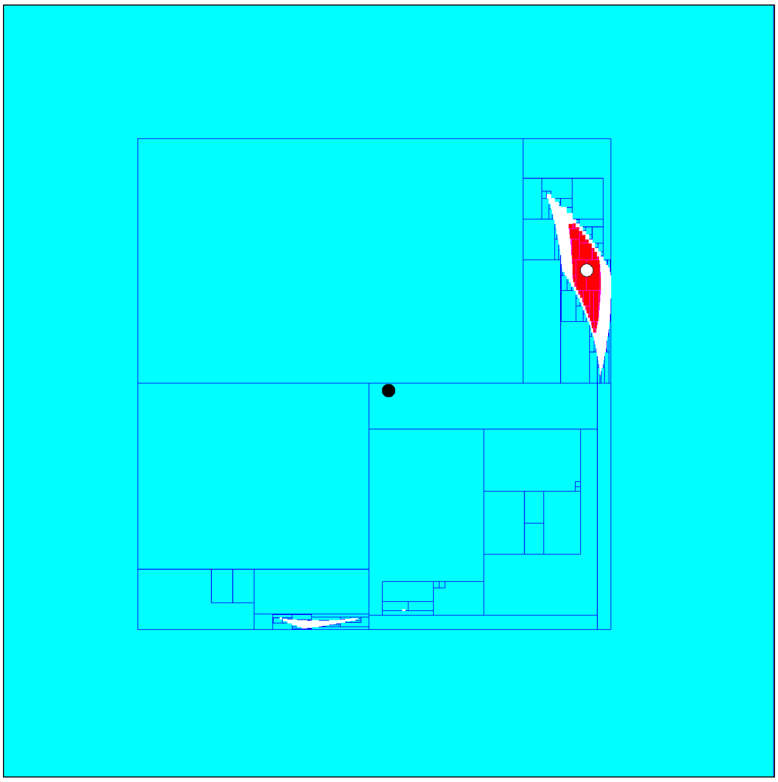
$t = 0.7$

$t = 0.8$

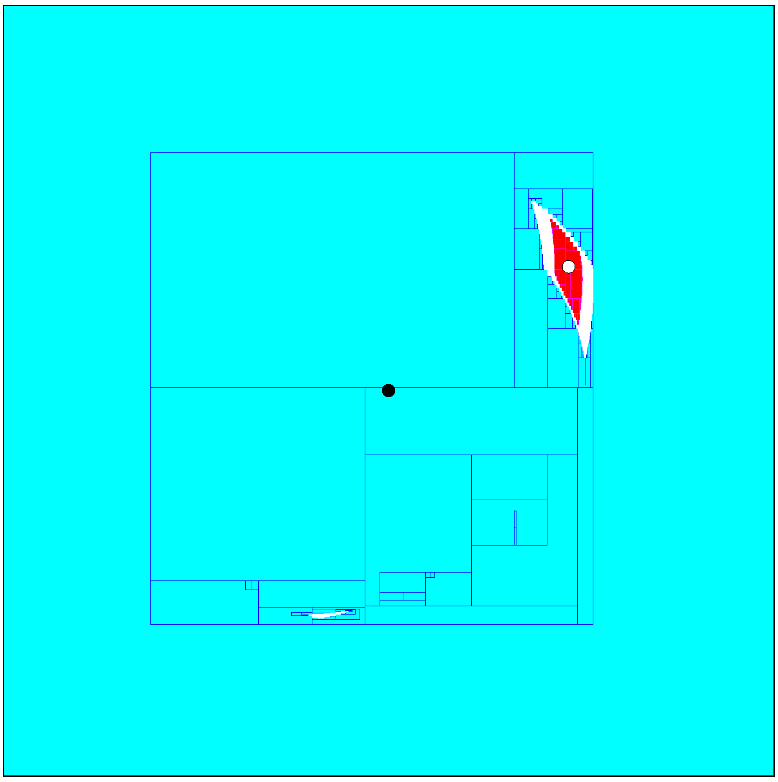
$t = 0.9$



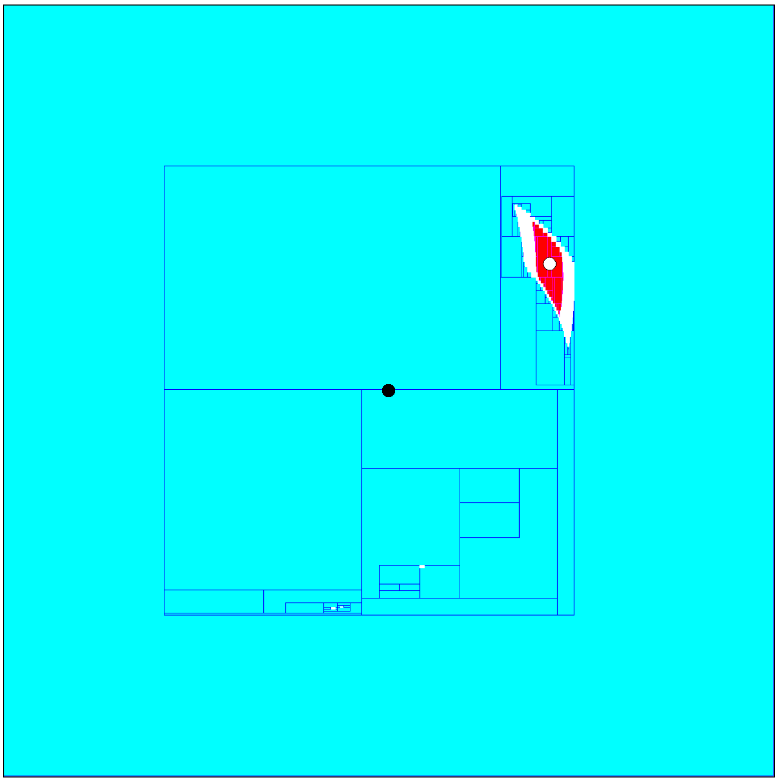
$t = 1.0$



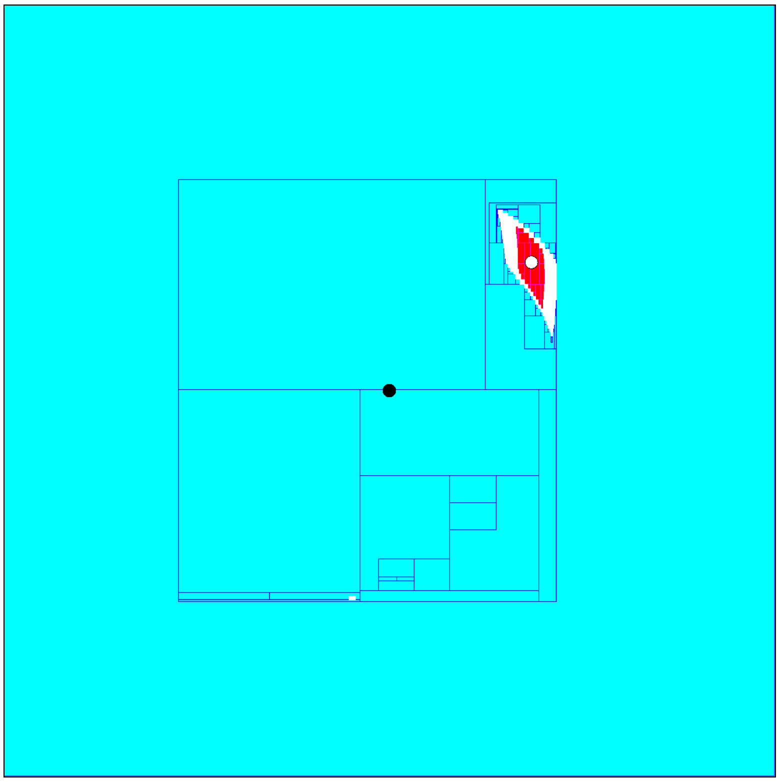
$t = 1.1$



$t = 1.2$

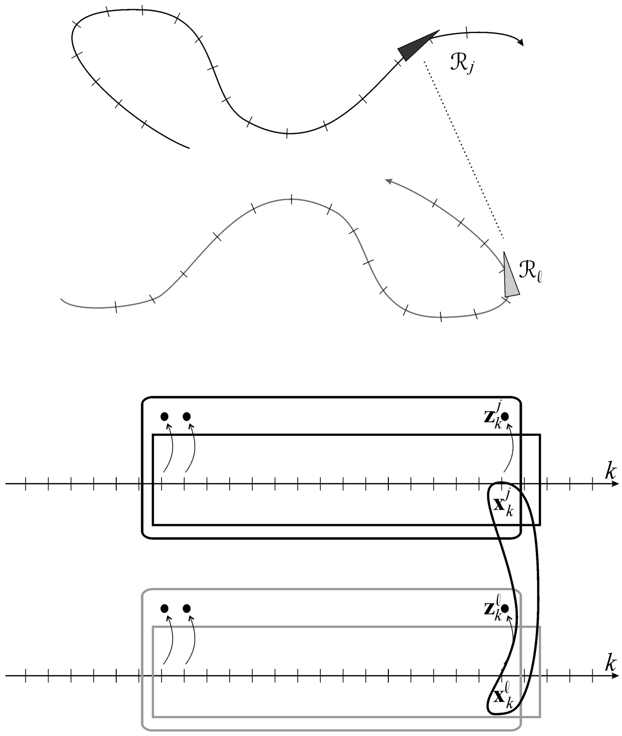


$t = 1.3$



$t = 1.4$

7 Distributed localization

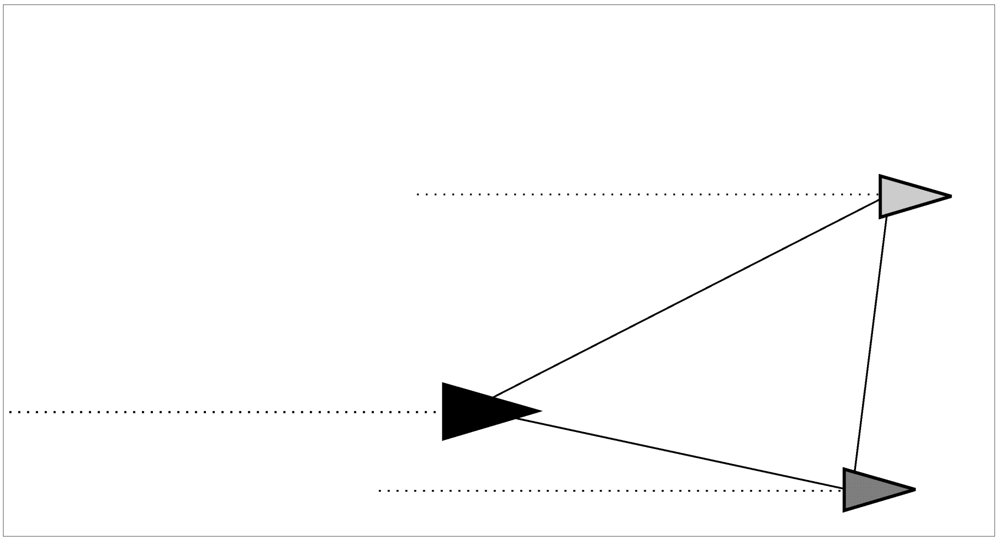


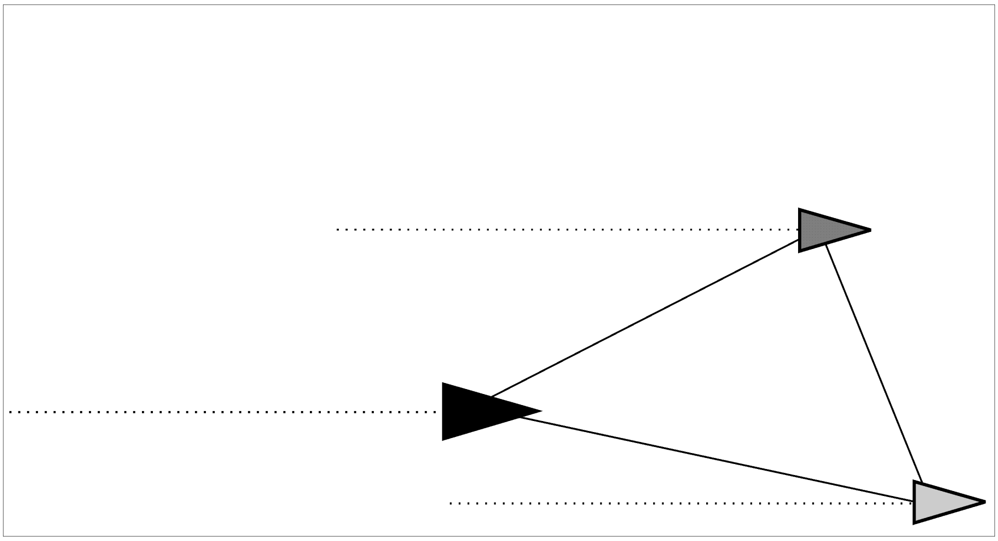
$$\mathbf{y}_h^{j,\ell} = \mathbf{g}(\mathbf{x}_h^j, \mathbf{x}_h^\ell)$$

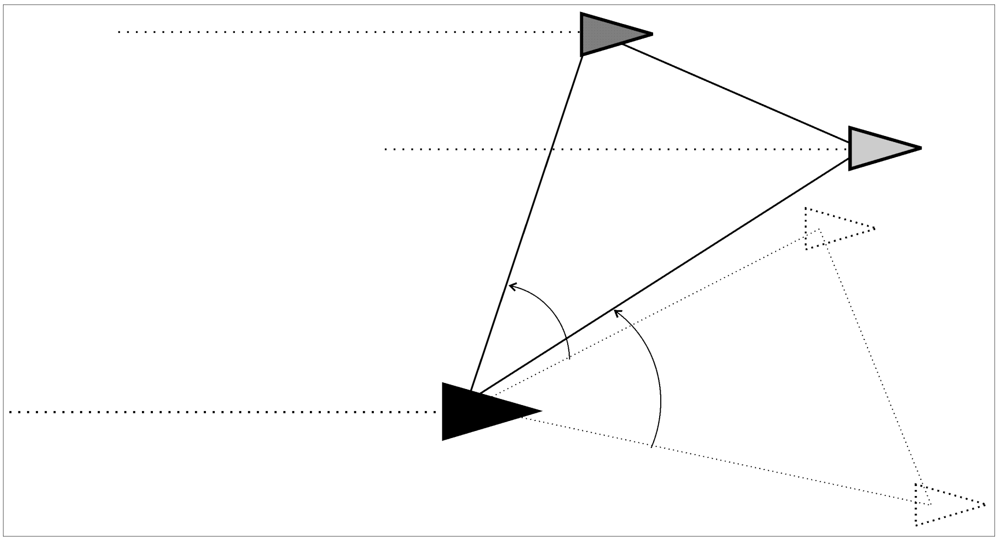
Observer:

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

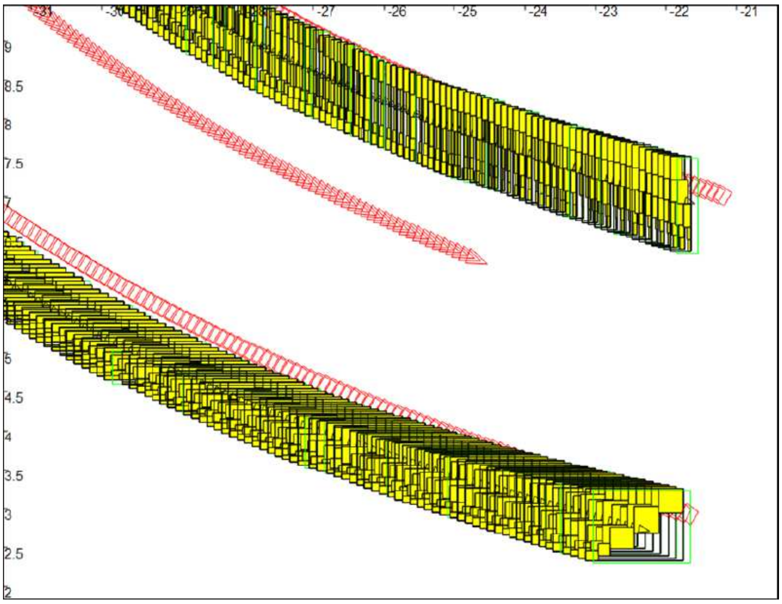
8 Singularity







9 Test case



QT/C++ code available at

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

10 Tests


ZTI z1050