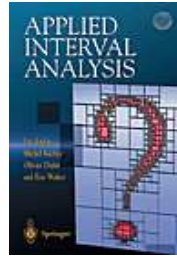


Méthodes ensemblistes pour la robotique



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Vendredi 7 janvier 2011,

1 Approche ensembliste

1.1 Calcul par intervalles

Si $\diamond \in \{+, -, ., /, \max, \min\}$

$$[x] \diamond [y] = [\{x \diamond y \mid x \in [x], y \in [y]\}].$$

Par exemple,

$$\begin{aligned} [-1, 3] + [2, 5] &= [1, 8], \\ [-1, 3] \cdot [2, 5] &= [-5, 15], \\ [-1, 3] / [2, 5] &= [-\tfrac{1}{2}, \tfrac{3}{2}], \end{aligned}$$

Si $f \in \{\cos, \sin, \text{sqr}, \text{sqrt}, \log, \exp, \dots\}$

$$f([x]) = [\{f(x) \mid x \in [x]\}].$$

Par exemple,

$$\begin{aligned}\sin([0, \pi]) &= [0, 1], \\ \text{sqr}([-1, 3]) &= [-1, 3]^2 = [0, 9], \\ \text{sqrt}([-10, 4]) &= \sqrt{[-10, 4]} = [0, 2],\end{aligned}$$

1.2 Fonction d'inclusion

Exemple : Si f est donnée par

Algo $f(\text{in: } \mathbf{x} = (x_1, x_2, x_3), \text{ out: } \mathbf{y} = (y_1, y_2))$
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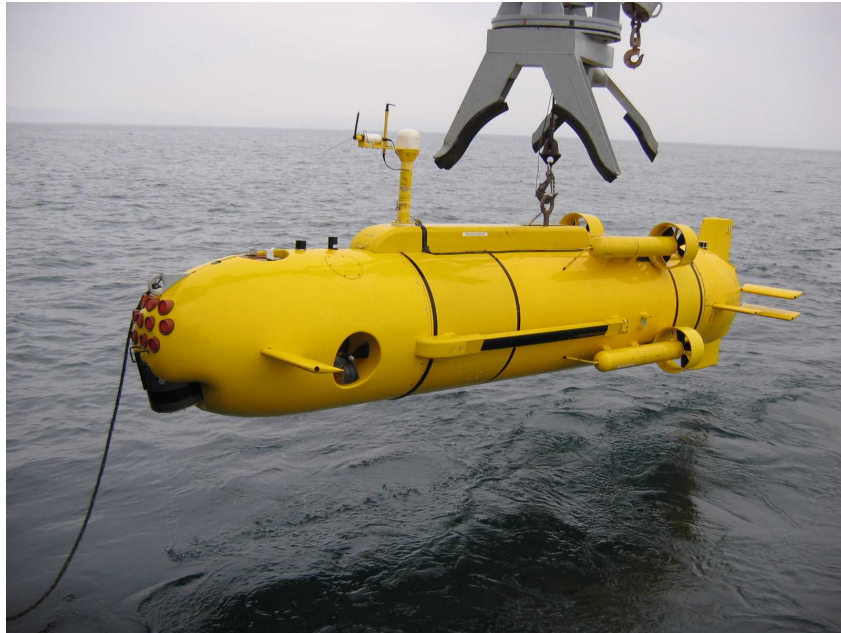
1 $z := x_1;$ 2 for $k := 0$ to 100 3 $z := x_2(z + kx_3);$ 4 next; 5 $y_1 := z;$ 6 $y_2 := \sin(zx_1);$

Sa fonction d'inclusion naturelle est

Algo [f](in: $[x] = ([x_1], [x_2], [x_3])$, out: $[y] = ([y_1], [y_2])$)

```
1   $[z] := [x_1];$   
2  for  $k := 0$  to 100  
3       $[z] := [x_2] * ([z] + k * [x_3]);$   
4  next;  
5   $[y_1] := [z];$   
6   $[y_2] := \sin([z] * [x_1]);$ 
```


2 SLAM



Le *Redermor*, fabriqué par le GESMA
(Groupe d'Etude Sous-Marine de l'Atlantique)

Pourquoi une approche par intervalles ?

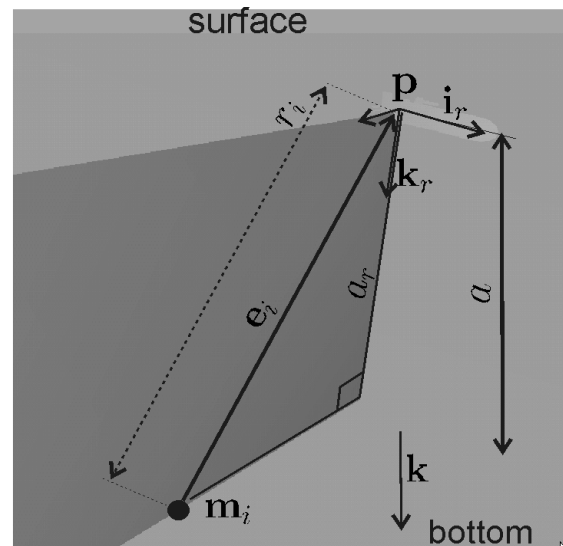
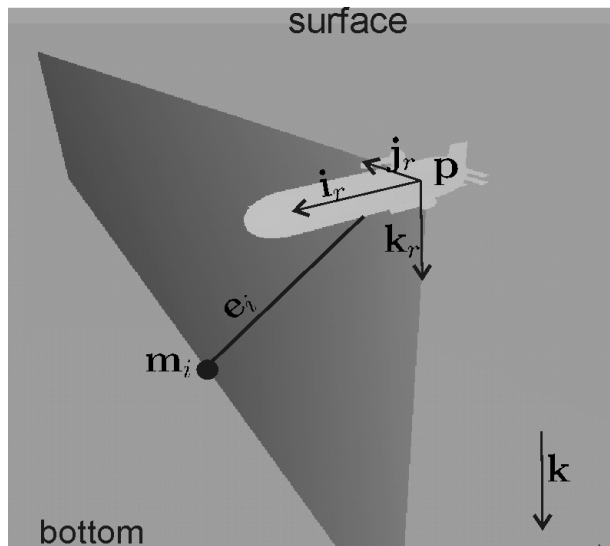
- 1) Besoin d'une approche fiable.
- 2) Les équations du robot sont non linéaires.
- 3) Les bruits de mesure sont non gaussiens.
- 4) Des bornes sur les erreurs sont fournies par les constructeurs des capteurs.
- 5) Beaucoup de mesures redondantes sont disponibles.

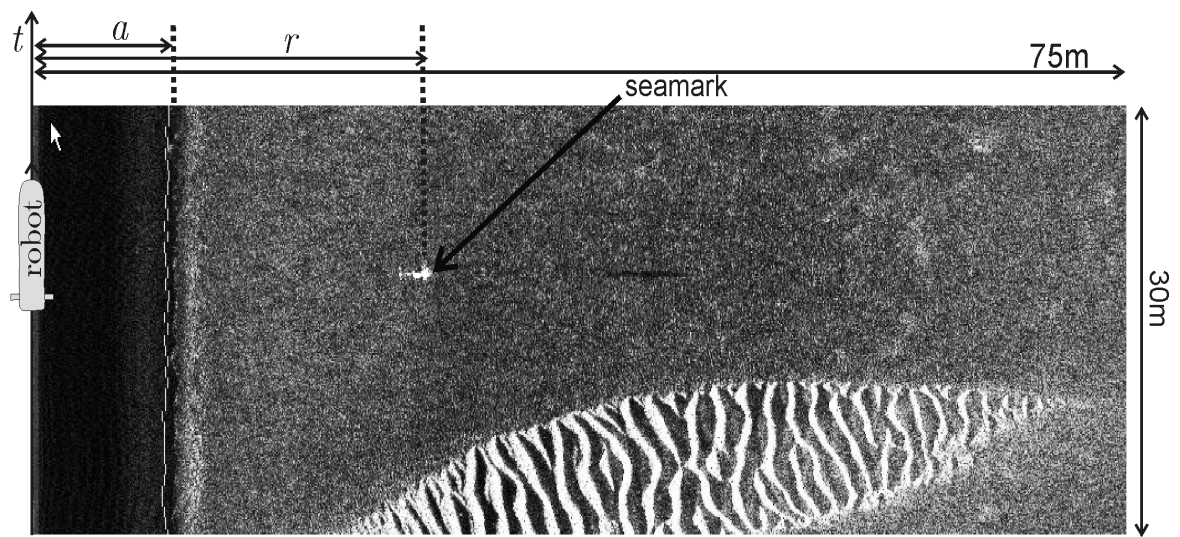
2.1 Capteurs

Un GPS (Global positioning system), disponible à la surface.

$$\begin{aligned} t_0 &= 6000 \text{ s}, & \ell^0 &= (-4.4582279^\circ, 48.2129206^\circ) \pm 2.5m \\ t_f &= 12000 \text{ s}, & \ell^f &= (-4.4546607^\circ, 48.2191297^\circ) \pm 2.5m \end{aligned}$$

Un sonar (KLEIN 5400 side scan sonar). Donne la distance r entre le robot et la mine





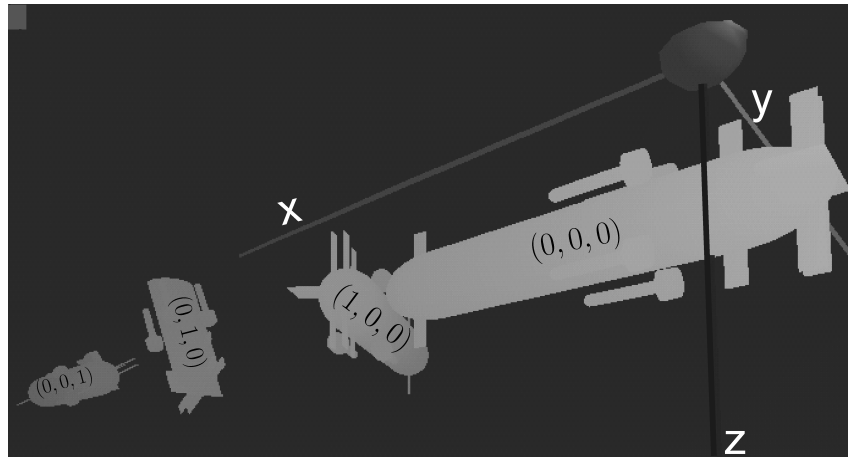
Détection d'une mine à l'aide de SonarPro

Le Loch-Doppler renvoie la vitesse du robot $\mathbf{v}_r$ et son altitude a .

$$\mathbf{v}_r \in \tilde{\mathbf{v}}_r + 0.004 * [-1, 1] . \tilde{\mathbf{v}}_r + 0.004 * [-1, 1]$$

Une centrale inertielle (Octans III from IXSEA) renvoie le roulis ϕ , le tangage θ et le cap ψ du robot.

$$\begin{pmatrix} \phi \\ \theta \\ \psi \end{pmatrix} \in \begin{pmatrix} \tilde{\phi} \\ \tilde{\theta} \\ \tilde{\psi} \end{pmatrix} + \begin{pmatrix} 1.75 \times 10^{-4} \cdot [-1, 1] \\ 1.75 \times 10^{-4} \cdot [-1, 1] \\ 5.27 \times 10^{-3} \cdot [-1, 1] \end{pmatrix}.$$



2.2 Données

Pour chaque $t \in \{6000.0, 6000.1, 6000.2, \dots, 11999.4\}$, nous avons des intervalles pour

$$\phi(t), \theta(t), \psi(t), v_r^x(t), v_r^y(t), v_r^z(t), a(t).$$

Six mines ont été détectées par un opérateur humain, à l'aide de SonarPro.

i	0	1	2	3	4	5
$\tau(i)$	7054	7092	7374	7748	9038	9688
$\sigma(i)$	1	2	1	0	1	5
$\tilde{r}(i)$	52.42	12.47	54.40	52.68	27.73	26.98

6	7	8	9	10	11
10024	10817	11172	11232	11279	11688
4	3	3	4	5	1
37.90	36.71	37.37	31.03	33.51	15.05

2.3 Contraintes

$$t \in \{6000.0, 6000.1, 6000.2, \dots, 11999.4\},$$

$$i \in \{0, 1, \dots, 11\},$$

$$\begin{pmatrix} p_x(t) \\ p_y(t) \end{pmatrix} = 111120 \begin{pmatrix} 0 & 1 \\ \cos\left(\ell_y(t) * \frac{\pi}{180}\right) & 0 \end{pmatrix} \begin{pmatrix} \ell_x(t) - \ell_x^0 \\ \ell_y(t) - \ell_y^0 \end{pmatrix}$$

$$\mathbf{p}(t) = (p_x(t), p_y(t), p_z(t)),$$

$$\mathbf{R}_\psi(t) = \begin{pmatrix} \cos \psi(t) & -\sin \psi(t) & 0 \\ \sin \psi(t) & \cos \psi(t) & 0 \\ 0 & 0 & 1 \end{pmatrix},$$

$$\mathbf{R}_\theta(t) = \begin{pmatrix} \cos \theta(t) & 0 & \sin \theta(t) \\ 0 & 1 & 0 \\ -\sin \theta(t) & 0 & \cos \theta(t) \end{pmatrix},$$

$$\mathbf{R}_\varphi(t) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \varphi(t) & -\sin \varphi(t) \\ 0 & \sin \varphi(t) & \cos \varphi(t) \end{pmatrix},$$

$$\mathbf{R}(t) = \mathbf{R}_\psi(t)\mathbf{R}_\theta(t)\mathbf{R}_\varphi(t),$$

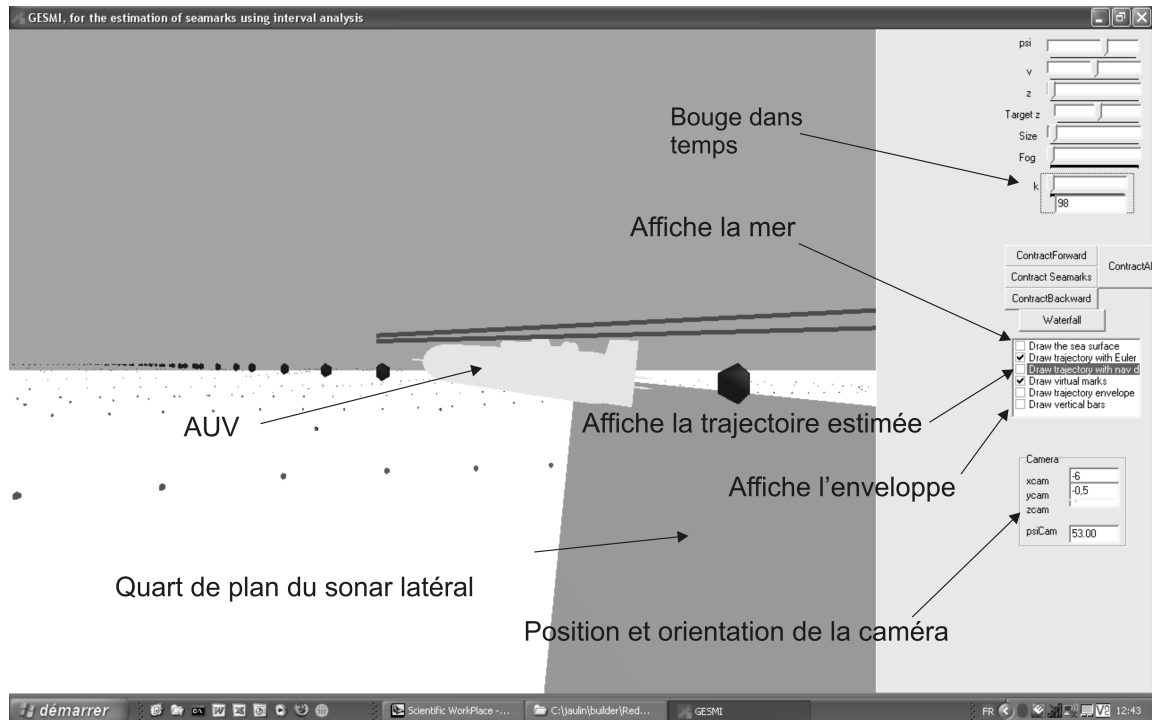
$$\dot{\mathbf{p}}(t) = \mathbf{R}(t).\mathbf{v}_r(t),$$

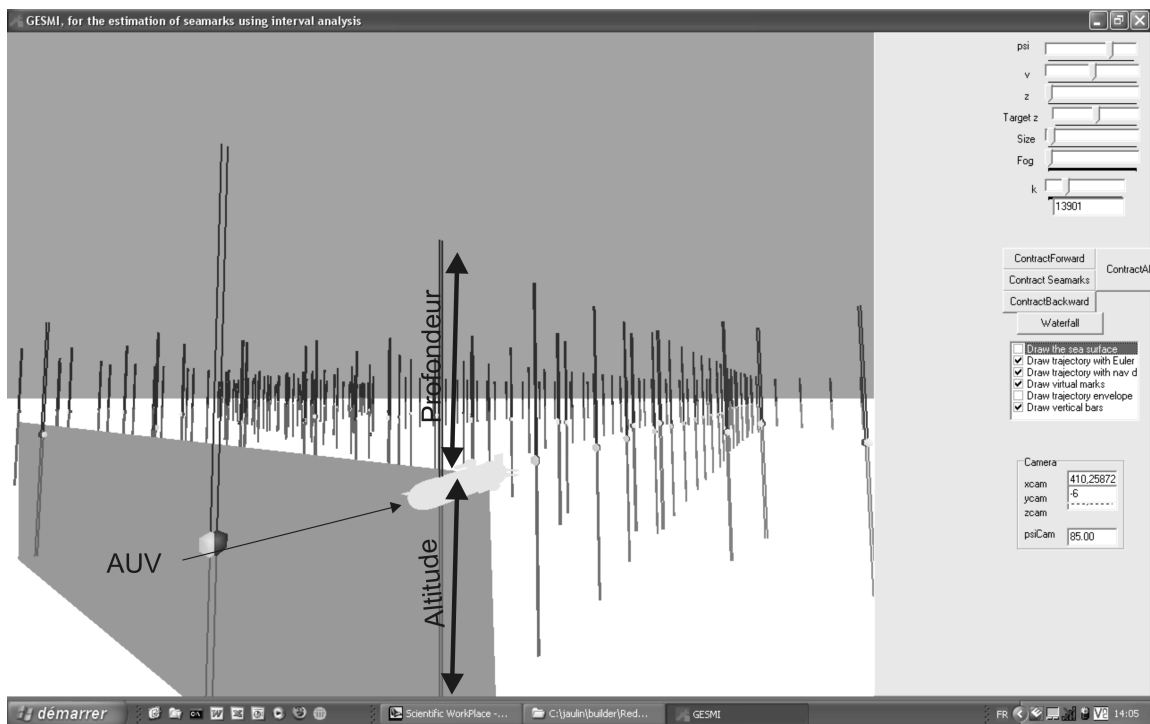
$$||\mathbf{m}(\sigma(i))-\mathbf{p}(\tau(i))||\;=\;r(i),$$

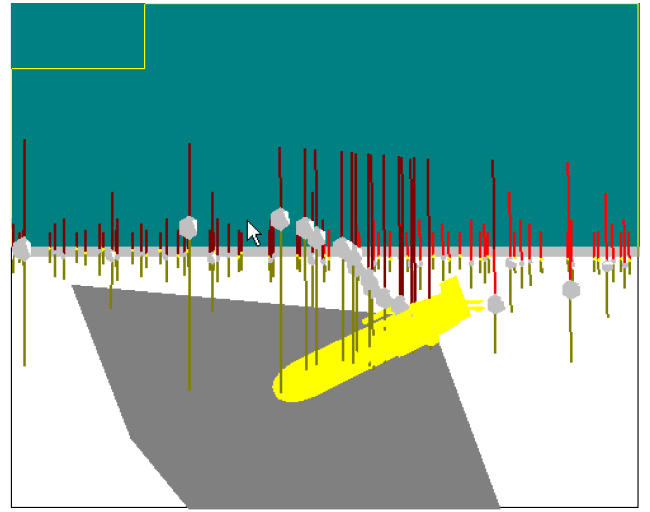
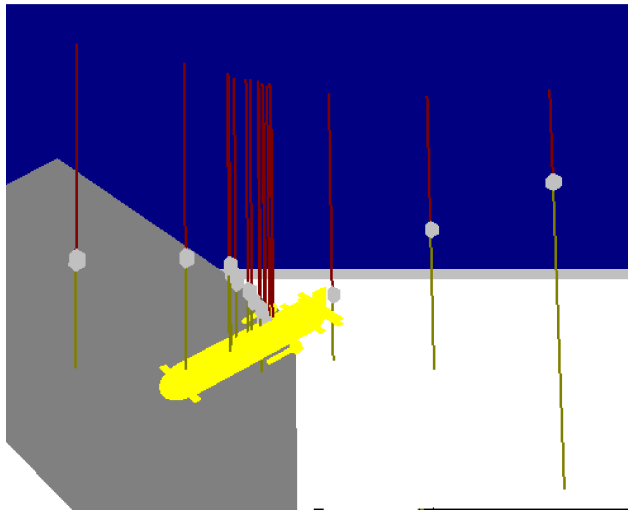
$$\mathbf{R}^\top(\tau(i))\left(\mathbf{m}(\sigma(i))-\mathbf{p}(\tau(i))\right)\in [0]\times [0,\infty]^{\times 2},$$

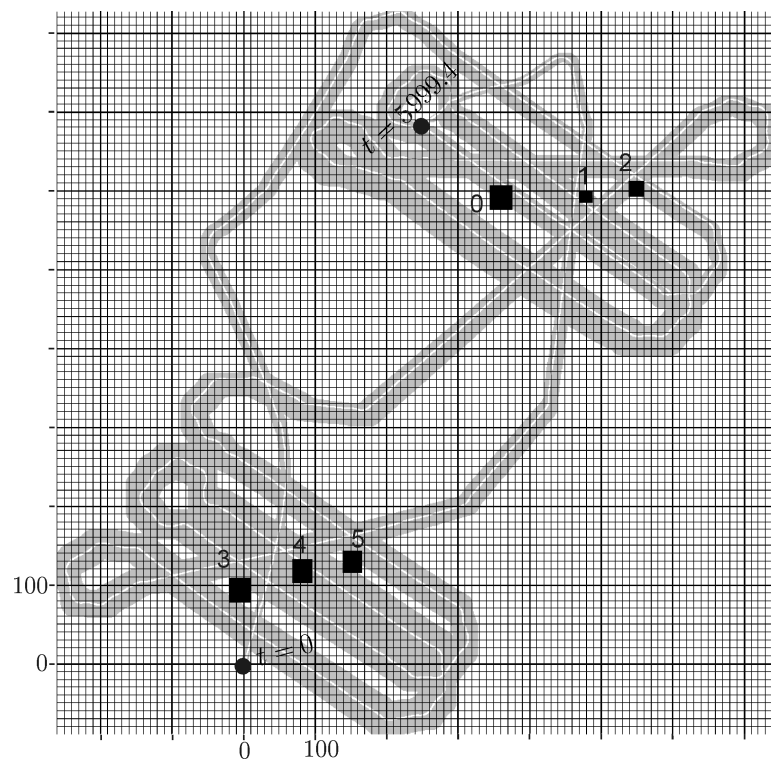
$$m_z(\sigma(i))-p_z(\tau(i))-a(\tau(i))\in [-0.5,0.5]$$

2.4 Logiciel GESMI







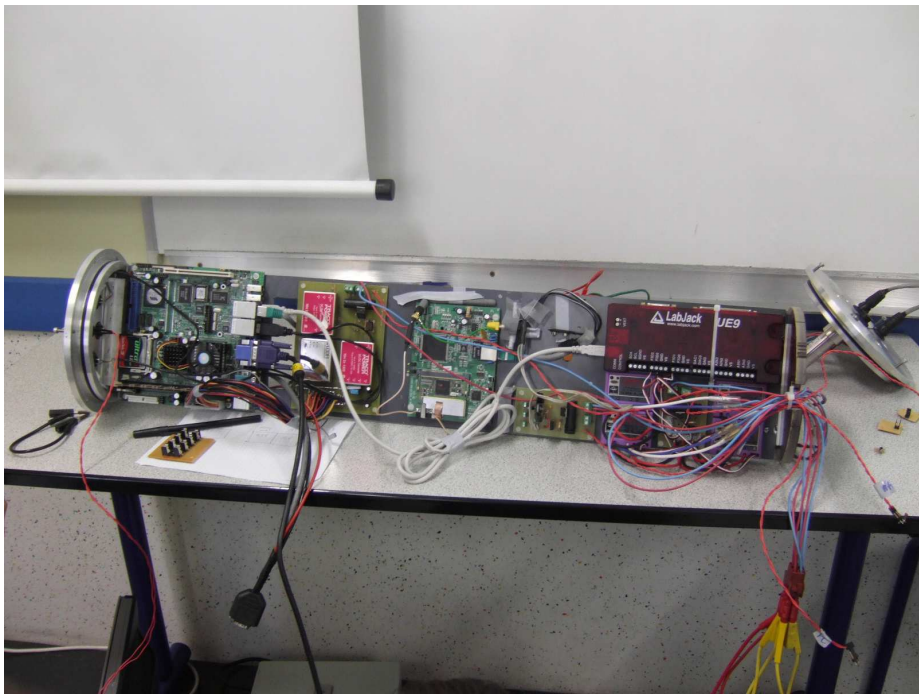


3 SAUCE



Portsmouth, July 12-15, 2007.

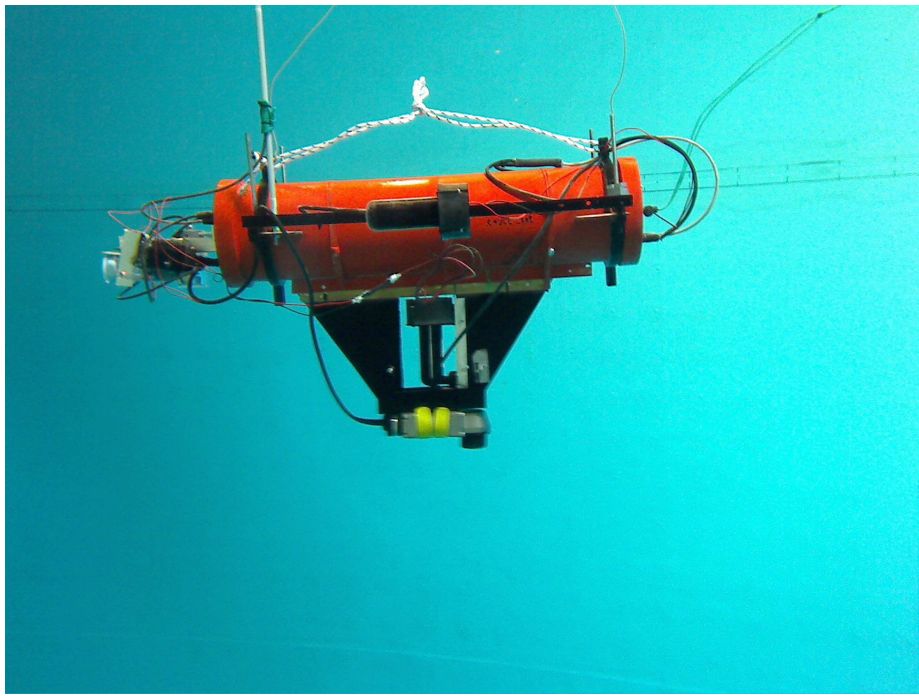




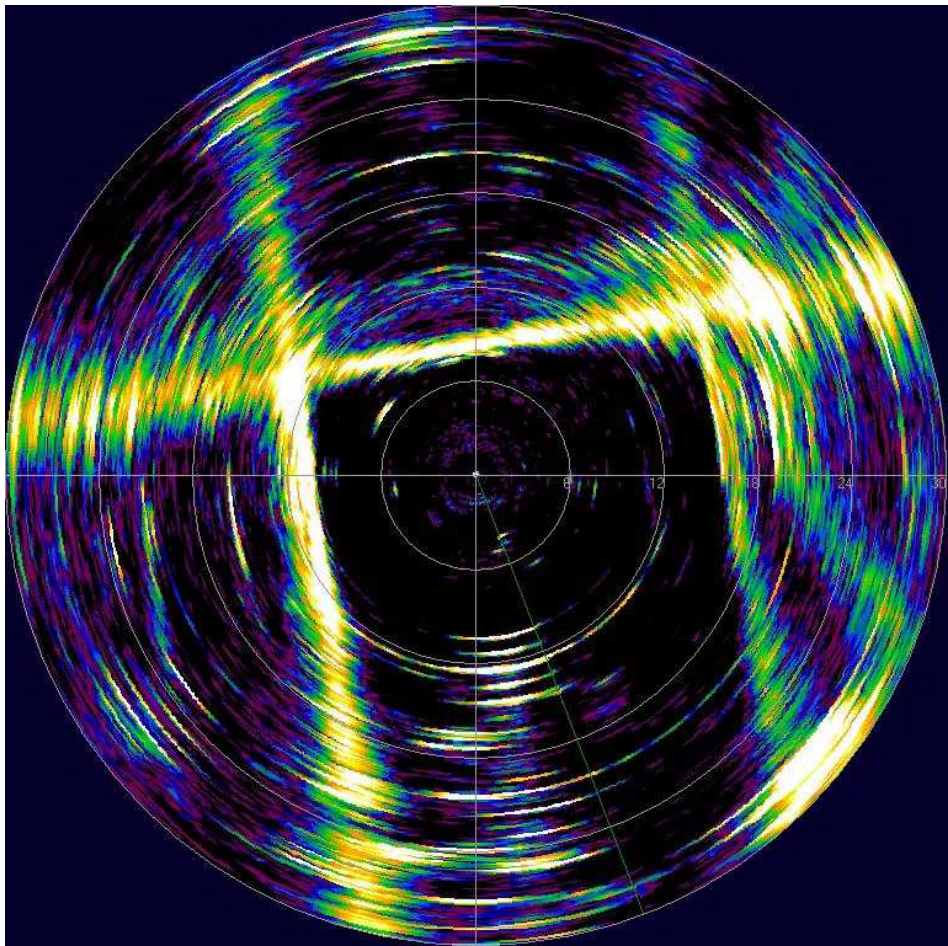


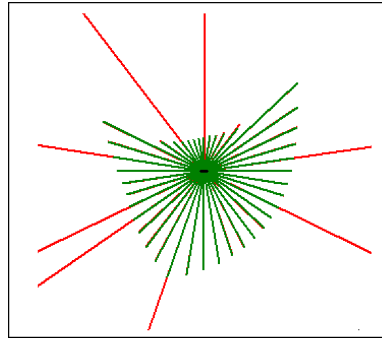
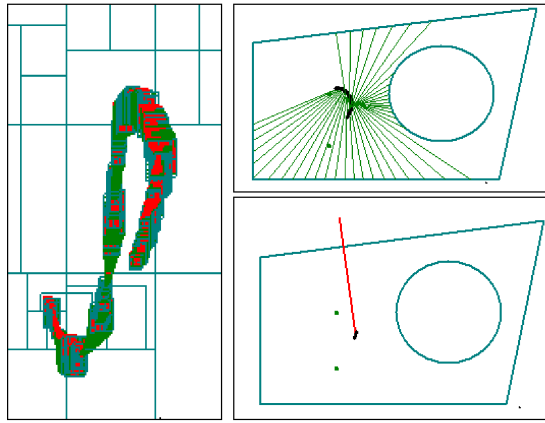






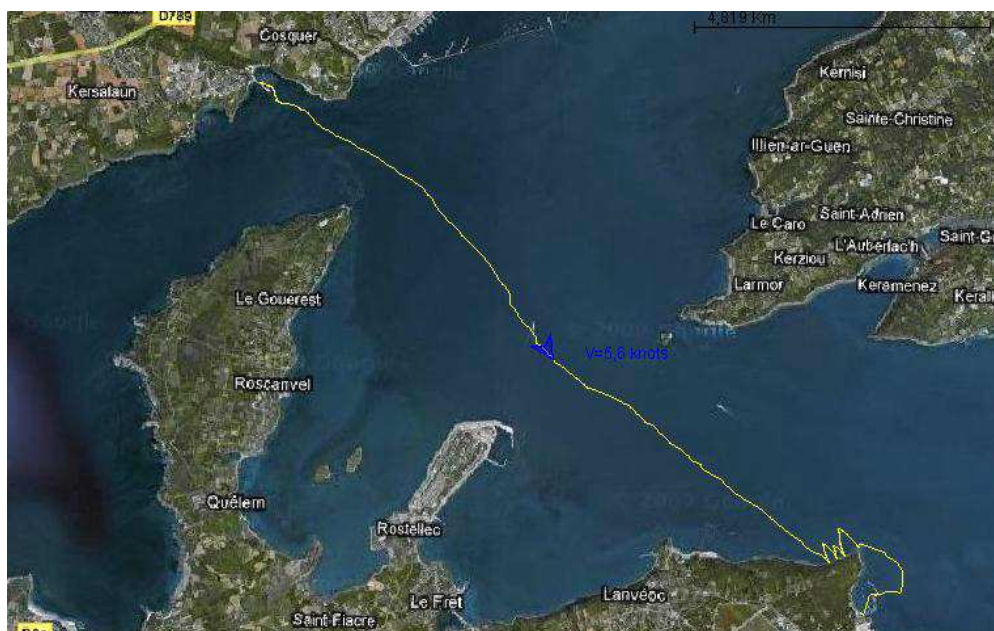
Robot Sauc'isse dans une piscine





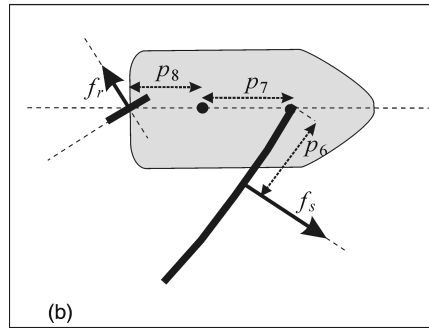
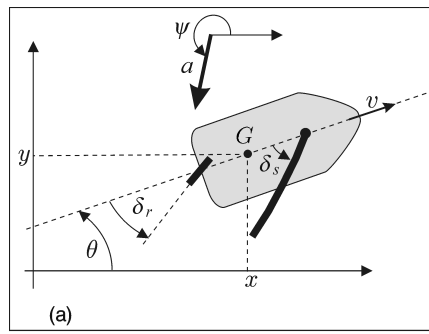
4 Voilier robot

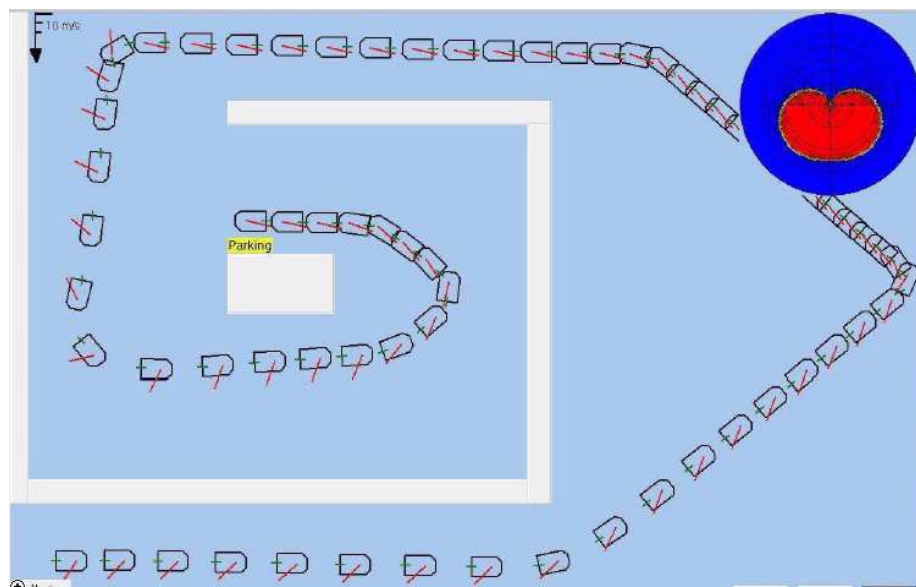




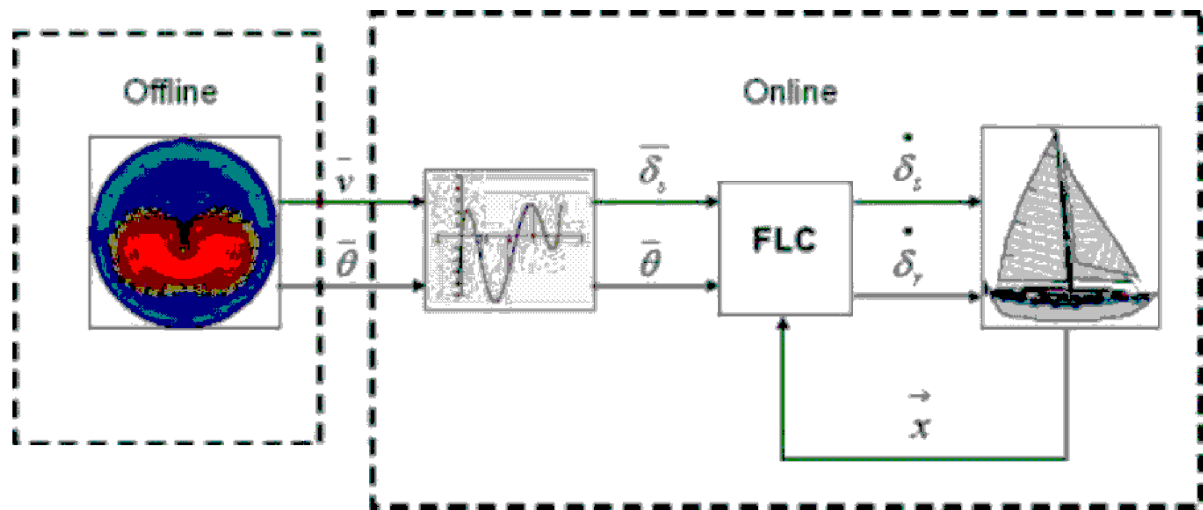
4.1 Equations

$$\left\{ \begin{array}{lcl} \dot{x} & = & v \cos \theta + a \cos \psi \\ \dot{y} & = & v \sin \theta + a \sin \psi \\ \dot{\theta} & = & \omega \\ \dot{v} & = & f_s \cdot \sin \delta_s - f_r \cdot \sin u_1 - v \\ \dot{\omega} & = & f_s \cdot (1 - \cos \delta_s) - f_r \cdot \cos u_1 - \omega \\ f_s & = & a \sin (\theta - \psi + \delta_s) \\ f_r & = & v \sin u_1 \\ \gamma & = & \cos (\theta - \psi) + \cos (u_2) \\ \delta_s & = & \left\{ \begin{array}{ll} \pi - \theta + \psi & \text{if } \gamma \leq 0 \\ \text{sign} (\sin (\theta - \psi)) \cdot u_2 & \text{otherwise.} \end{array} \right. \end{array} \right.$$





4.2 Control



5 CAROTTE



