Control of a sailboat and robotics in ENSIETA

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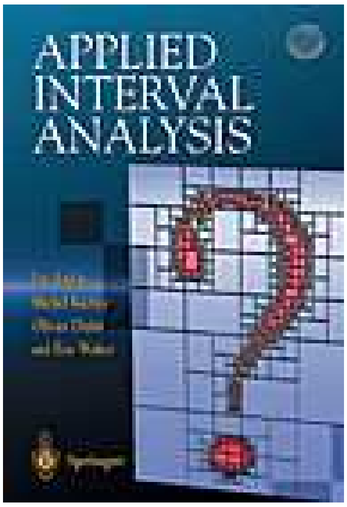
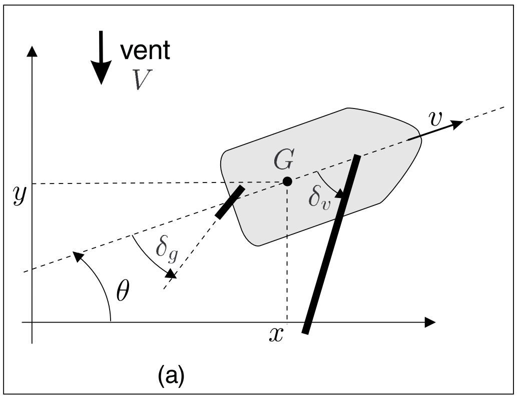
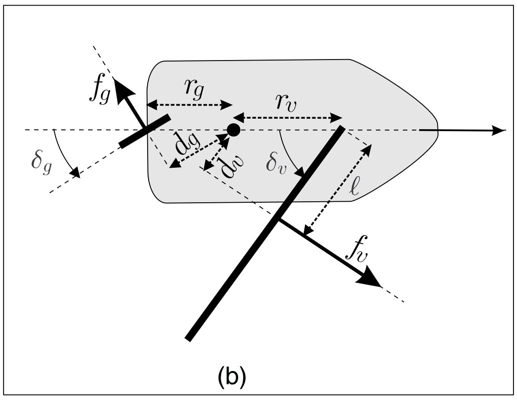
Objective of our team:

Promote interval analysis methods through robotics.


APPLIED
INTERVAL
ANALYSIS

1 Model of a sailboat


vent
V
v
G
y
δ_v
δ_g
θ
x
(a)


f_g
r_g
r_v
d_g
d_v
δ_g
δ_v
ℓ
f_v
(b)

$$
\left\{
\begin{array}{rcc}
\dot{x} & = & v\cos\theta \\
\dot{y} & = & v\sin\theta - \beta V \\
\dot{\theta} & = & \omega \\
\dot{\delta}_s & = & u_1 \\
\dot{\delta}_r & = & u_2 \\
\dot{v} & = & \frac{f_s\sin\delta_s - f_r\sin\delta_r - \alpha_f v}{m} \\
\dot{\omega} & = & \frac{(\ell - r_s\cos\delta_s) f_s - r_r\cos\delta_r f_r - \alpha_\theta \omega}{J} \\
f_s & = & \alpha_s\left(V\cos(\theta + \delta_s) - v\sin\delta_s\right) \\
f_r & = & \alpha_r v\sin\delta_r .
\end{array}
\right.
$$

2 Is it possible to stop the boat ?

Solve the following set of equations

$$\left\{\begin{array}{rcl}
0 & = & v\cos\theta \\
0 & = & v\sin\theta-\beta V \\
0 & = & \omega \\
0 & = & u_1 \\
0 & = & u_2 \\
0 & = & \frac{f_s\sin\delta_s-f_r\sin\delta_r-\alpha_f v}{m} \\
0 & = & \frac{(\ell-r_s\cos\delta_s)f_s-r_r\cos\delta_r f_r-\alpha_\theta\omega}{J} \\
f_s & = & \alpha_s\left(V\cos\left(\theta+\delta_s\right)-v\sin\delta_s\right) \\
f_r & = & \alpha_r v\sin\delta_r.
\end{array}\right.$$

Using interval analysis, we have shown that there exists no solution if $V\neq 0$.

3 Control of the position

Details can be found on the book

Jaulin L. (2005) « Représentation d'état pour la modélisation et la commande des systèmes » (Coll. Automatique de base), Hermes , 198p.

Show the Scilab demo

4 Polar speed diagram

(Collaboration with P. Herrero, J. Vehi and M. Sainz).

The set of feasible (θ, v) is

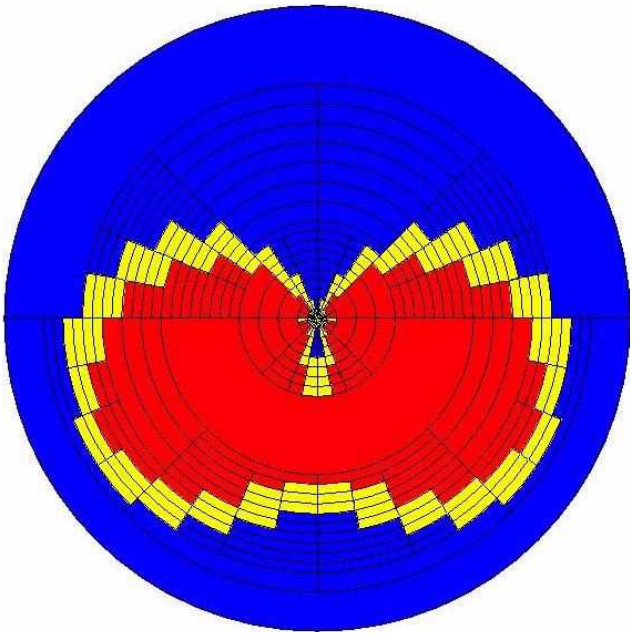
$$\mathbb{W} = \{ \quad (\theta, v) \mid \quad \dot{\theta} = 0, \dot{\delta}_s = 0, \dot{\delta}_r = 0, \dot{v} = 0, \dot{\omega} = 0 \quad \}.$$

i.e.,

$$
\mathbb{W} = \{ \quad (\theta, v) \mid \quad
\begin{array}{l}
\exists(\omega, u_1, u_2, f_s, f_r, \delta_r, \delta_s) \\
\omega = 0, u_1 = 0, u_2 = 0 \\
\frac{f_s \sin \delta_s - f_r \sin \delta_r - \alpha_f v}{m} = 0 \\
\frac{(\ell - r_s \cos \delta_s) f_s - r_r \cos \delta_r f_r}{J} = 0 \\
f_s = \alpha_s \left(V \cos(\theta + \delta_s) - v \sin \delta_s \right) \\
f_r = \alpha_r v \sin \delta_r
\end{array}
\quad \}.
$$

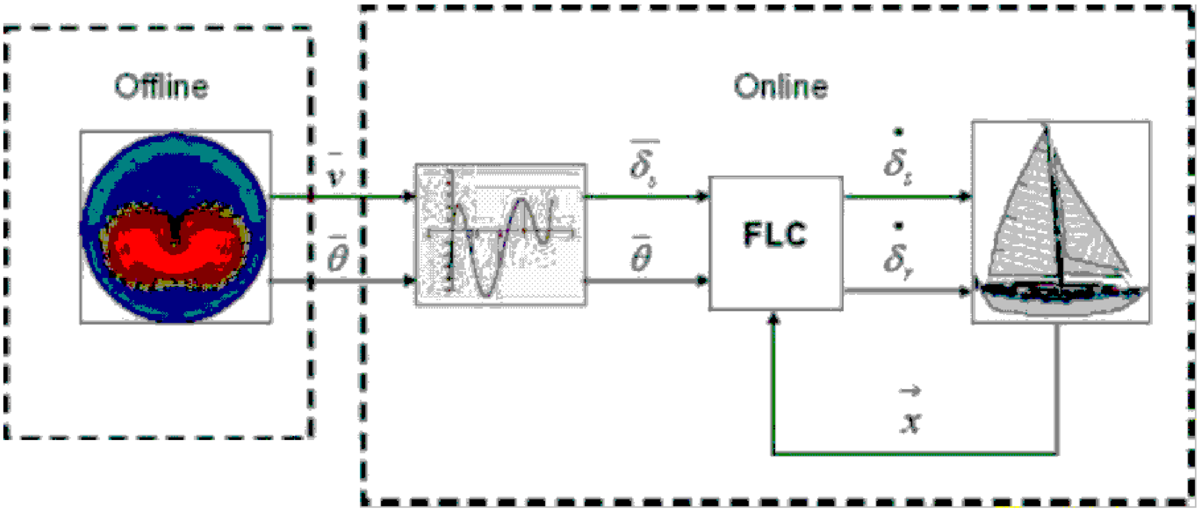
i.e.

$$
\begin{array}{llll}
\mathbb{W} = \{ & (\theta, v) \mid & \exists (f_s, f_r, \delta_r, \delta_s) & \\
& & f_s \sin \delta_s - f_r \sin \delta_r - \alpha_f v = 0 & \\
& & \left(\ell - r_s \cos \delta_s\right) f_s - r_r \cos \delta_r f_r = 0 & \\
& & f_s = \alpha_s \left(V \cos\left(\theta + \delta_s\right) - v \sin \delta_s\right) & \\
& & f_r = \alpha_r v \sin \delta_r & \}.
\end{array}
$$



This picture has been obtained using modal interval techniques

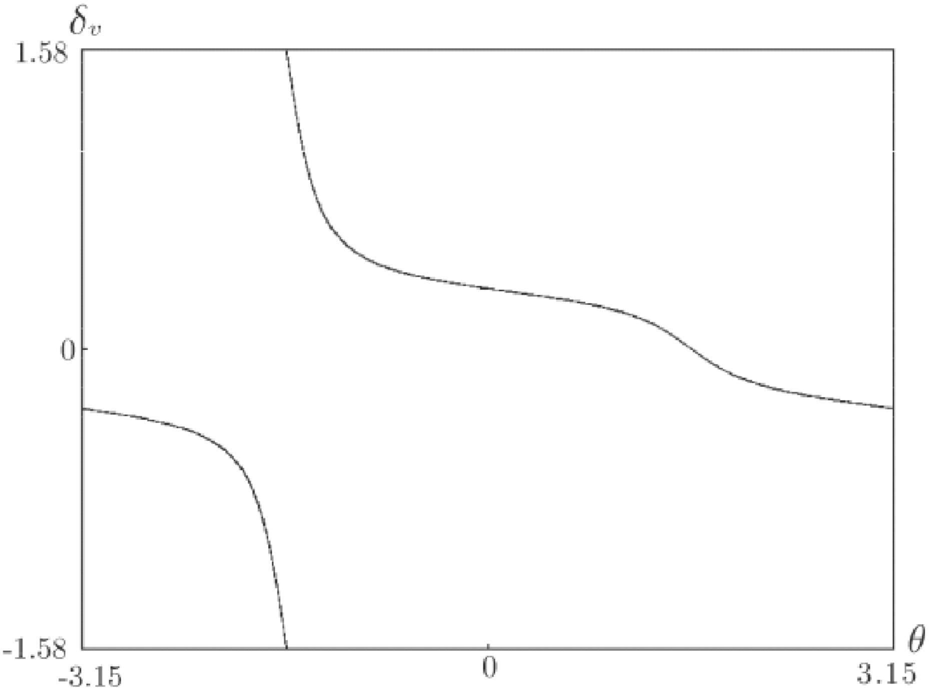
5 Control of the sailboat


Offline
Online
$\bar{v}$
$\bar{\theta}$
$\bar{\delta}_s$
$\bar{\theta}$
FLC
$\dot{\delta}_s$
$\dot{\delta}_r$
$\vec{x}$

6 Optimal sail angle

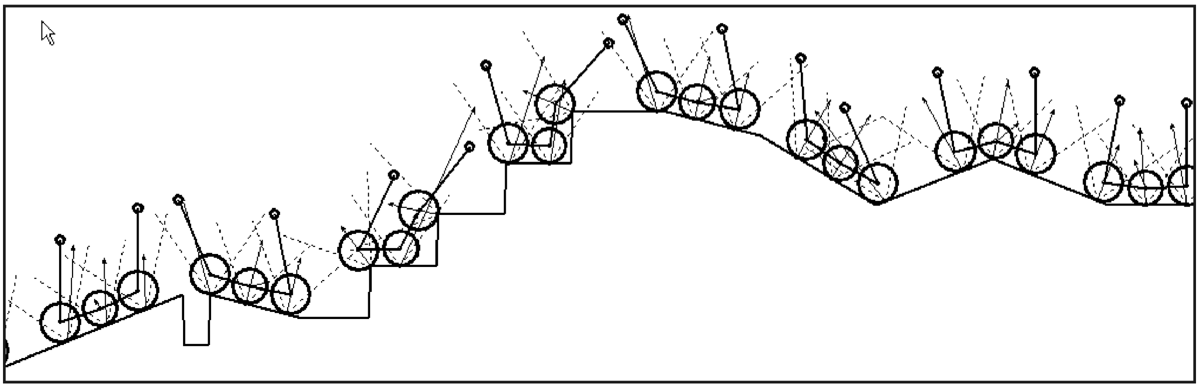
Collaboration with Massa Dao, Xavier Baguenard and M. Lhommeau.

$$\mathbb{O} = \begin{array}{lll} \{(\theta,\delta_s) \ |\exists v, \exists \delta_r & & \\ \alpha_s \left(V \cos\left(\theta+\delta_s\right) - v \sin\delta_s\right) \sin\delta_s & & \\ -\alpha_r v \sin^2\delta_r - \alpha_f v & = 0 & \\ \left(\ell - r_s \cos\delta_s\right)\left(V \cos\left(\theta+\delta_s\right) - v\sin\delta_s\right) & & \\ -\frac{r_r \alpha_r}{\alpha_s} v \sin\delta_r \cos\delta_r & = 0 & \\ \left(\sin(\theta+\delta_s) + \frac{2v\cos\delta_s}{V}\right)\tan\delta_s - \cos(\theta+\delta_s) & = 0 & \} \end{array}$$


δ_v
1.58
0
-1.58
θ
-3.15
0
3.15

7 Control of a climbing robot

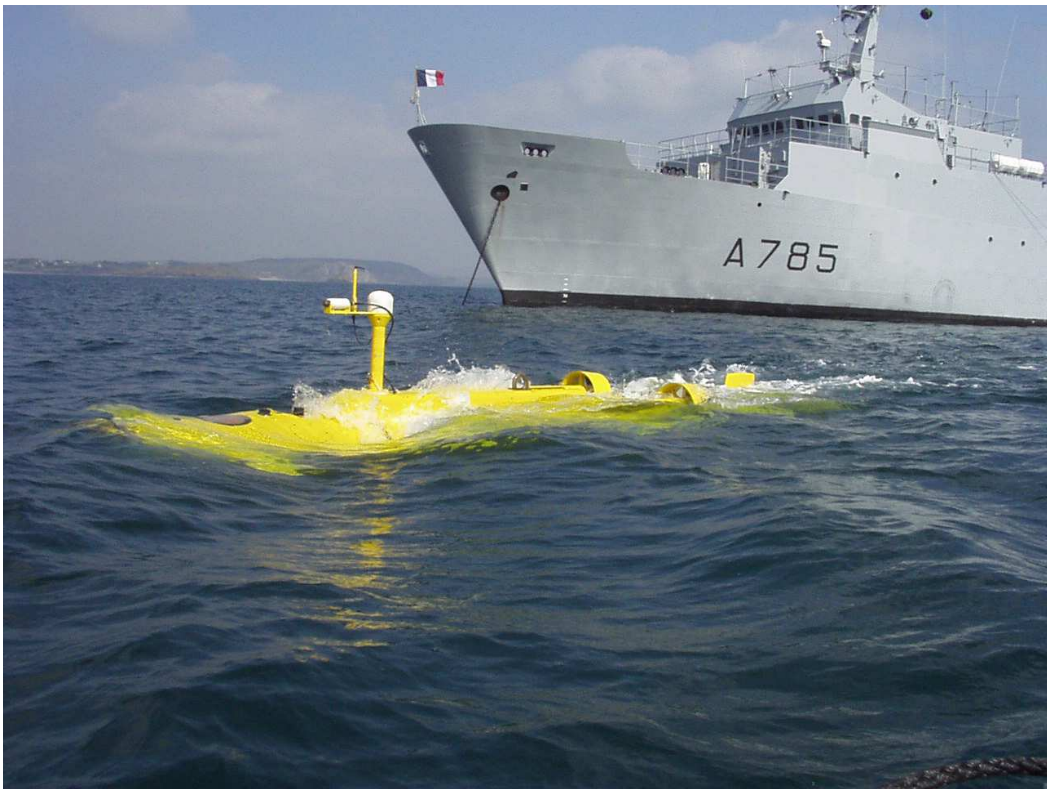
(Collaboration with students and colleagues from ENSIETA)

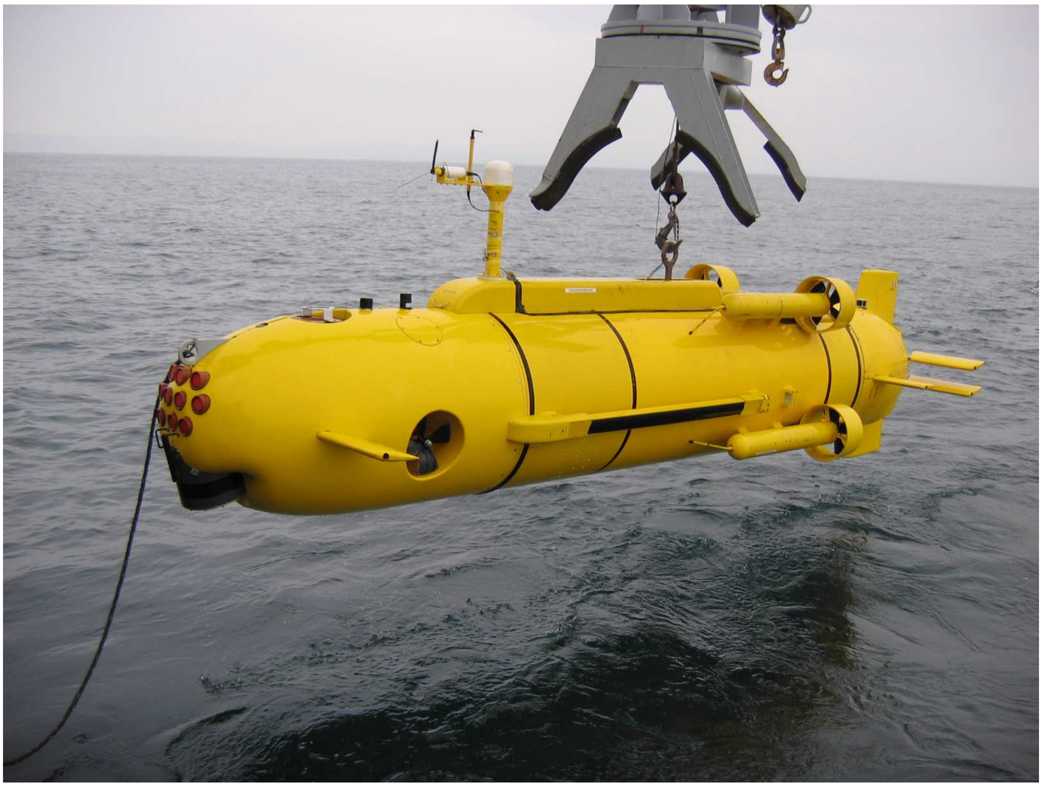


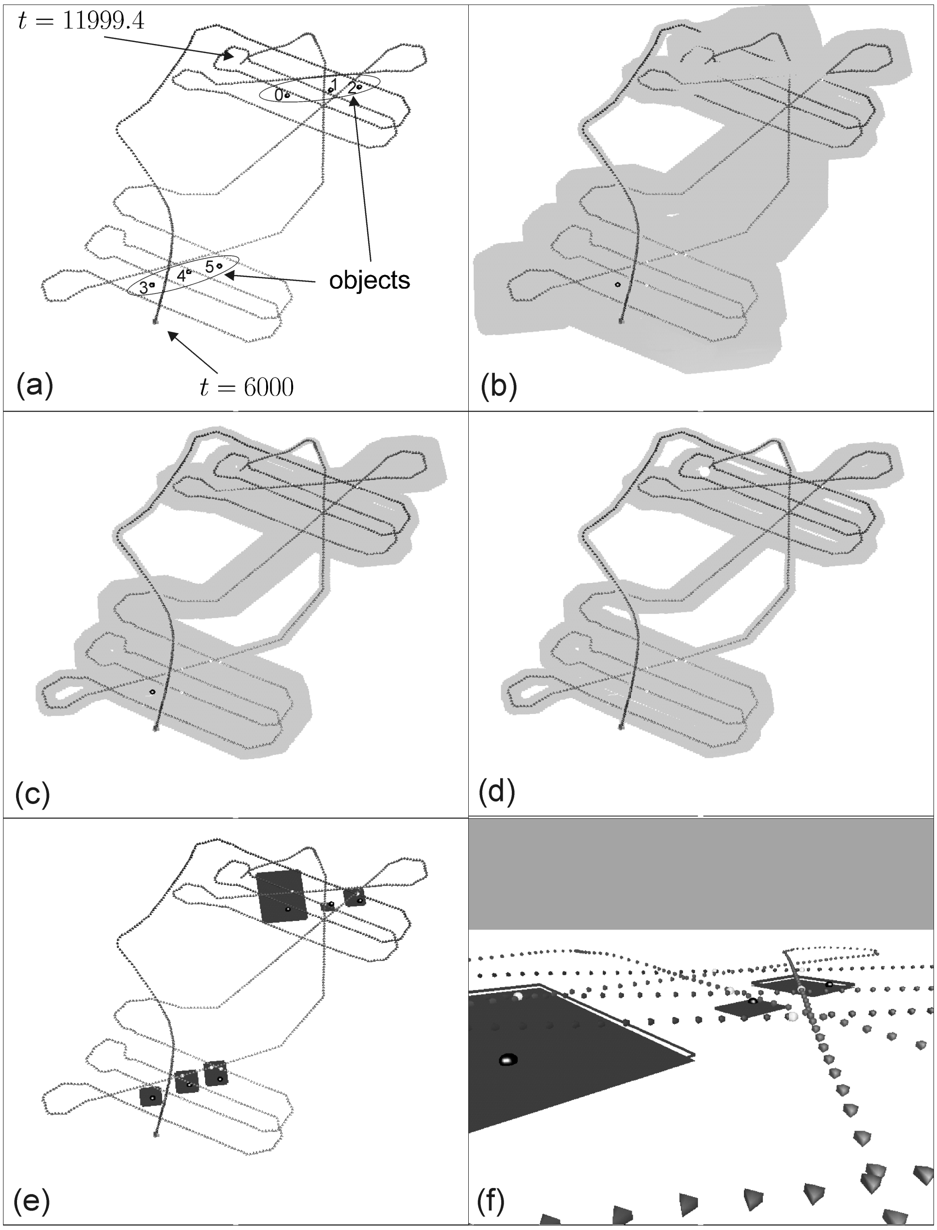
Robot built by the robotics team of ENSIETA

8 SLAM of an AUV

Collaboration with the GESMA (Groupe d'Etude Sous-Marine de l'Atlantique, SLAM)






$t = 11999.4$
0
1
2
3
4
5
objects
$t = 6000$
(a)
(b)
(c)
(d)
(e)
(f)