Suivi de route pour un robot voilier

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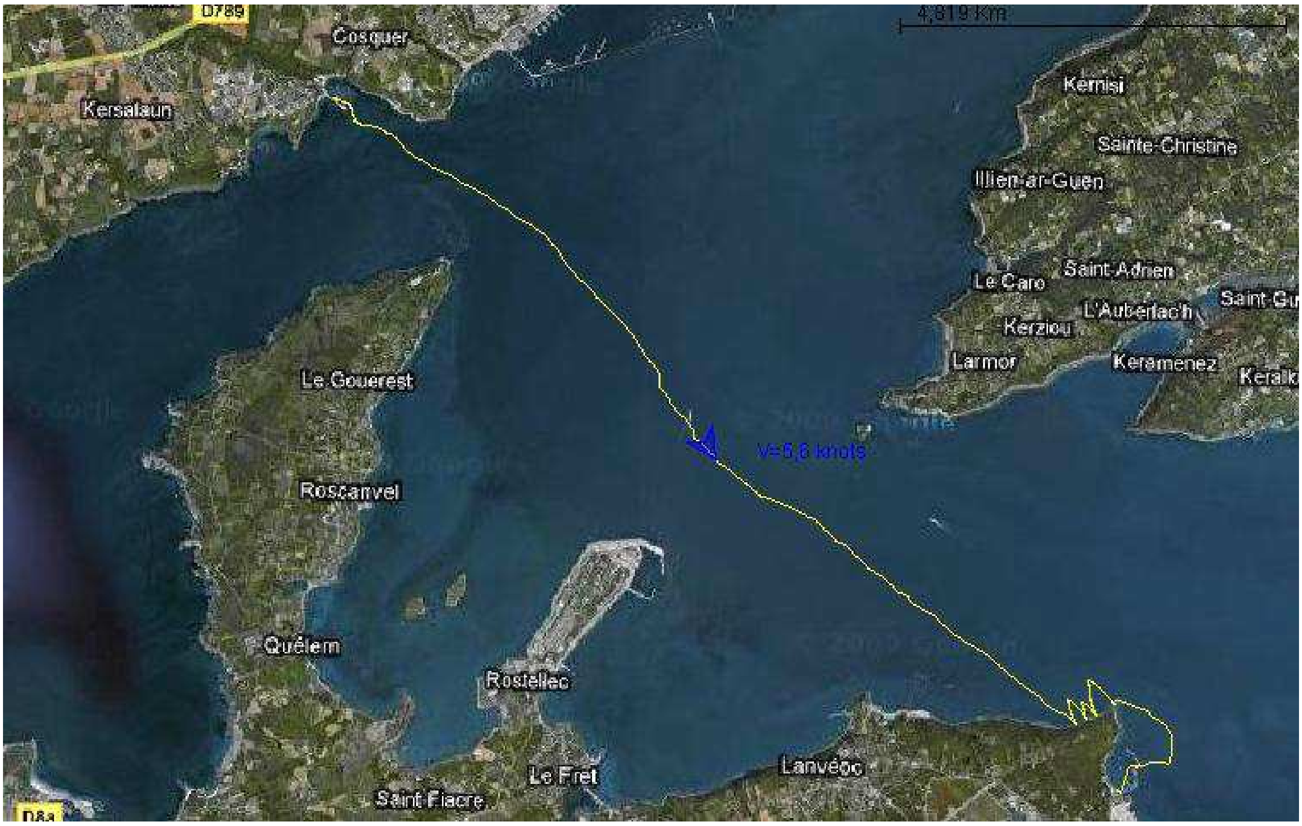
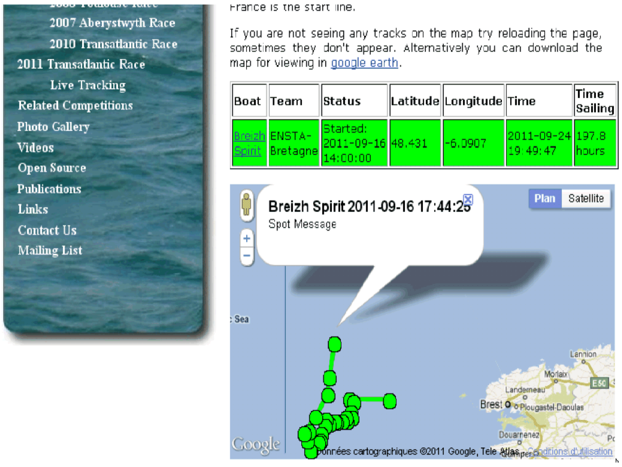
...
ENSTA-Bretagne, IFREMER, Brest.
LabSTICC, IHSEV, OSM.

1 Sailboat robotics


BREIZH
ENSIETA
SPIRIT



4,819 Km
D789
Cosquer
Kersalaun
Kernisi
Sainte-Christine
Illien-ar-Guen
Saint-Adrien
Le Caro
L'Auberlac'h
Kerziou
Larmor
Keramenez
Le Gouerest
V=5,6 knots
Roscanvel
Quélern
Rostellec
Le Fret
Lanvéoc
Saint-Fiacre



2007 Aberystwyth Race
2010 Transatlantic Race
2011 Transatlantic Race
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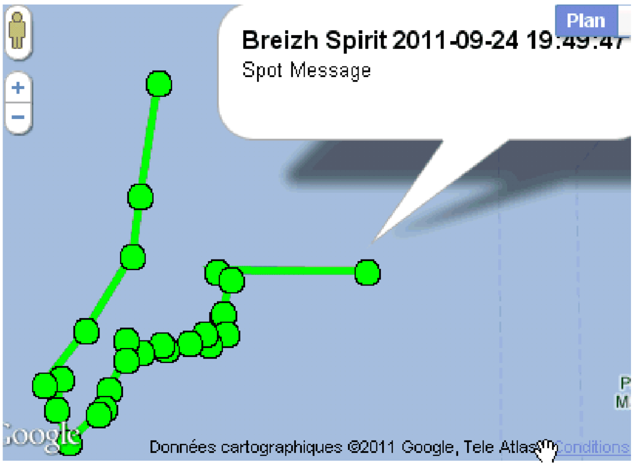
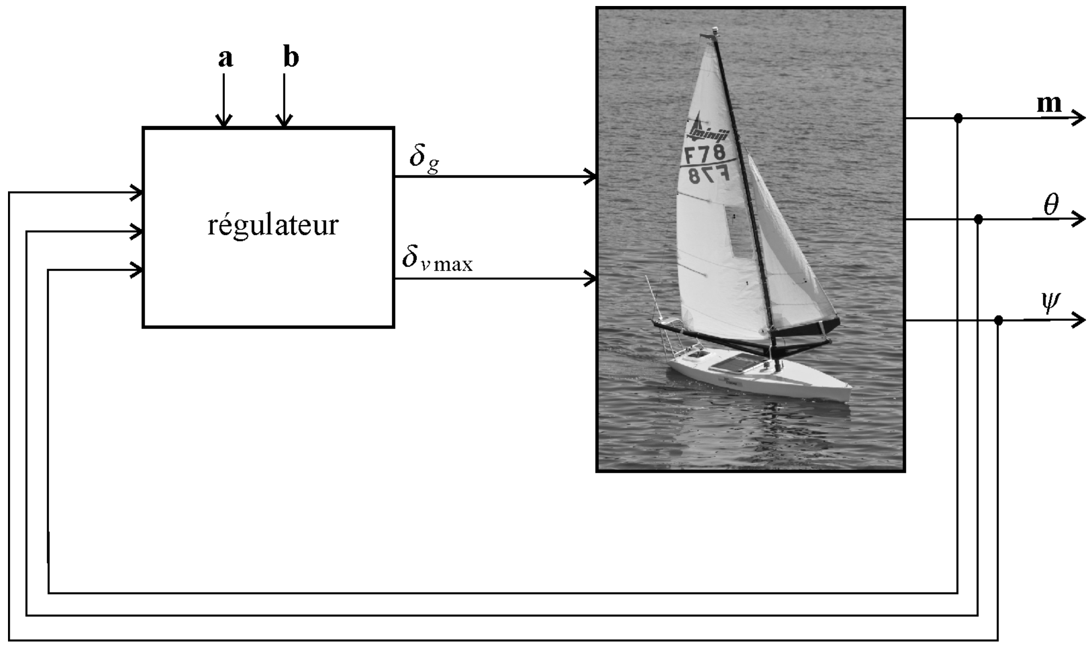
France is the start line.

If you are not seeing any tracks on the map try reloading the page, sometimes they don't appear. Alternatively you can download the map for viewing in google earth.

Boat	Team	Status	Latitude	Longitude	Time	Time Sailing
Breizh Spirit	ENSTA-Bretagne	Started: 2011-09-16 14:00:00	48.431	-6.0907	2011-09-24 19:49:47	197.8 hours





a
b
régulateur
δ_g
$\delta_{v\max}$
F78
m
θ
ψ

2 Brest-Douarnenez

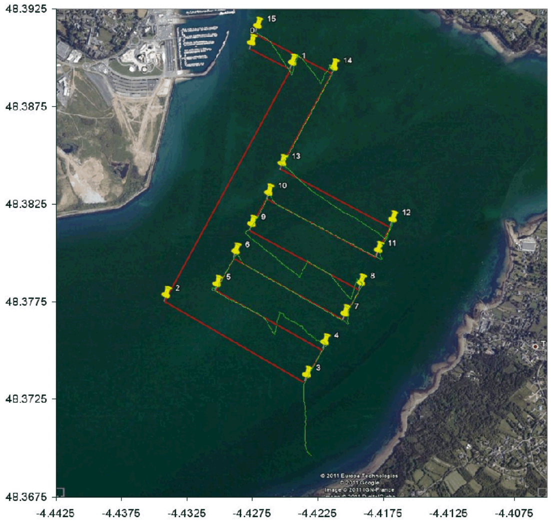
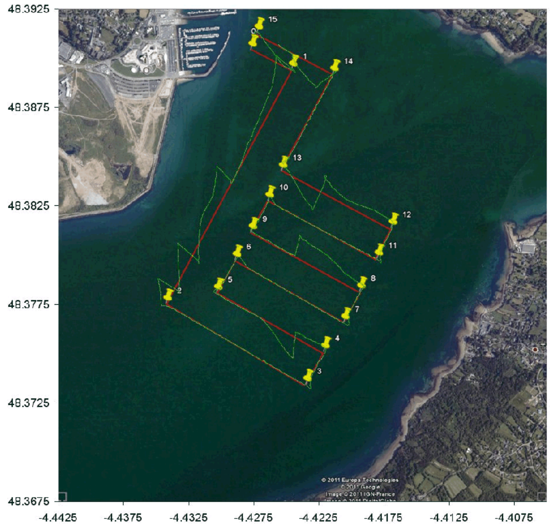
Départ le 17 janvier 2012 à 8h.


Challenger


Brest
PRO
BR D98 505
YAMAHA


minij
F78


Google Earth
Fichier Édition Affichage Outils Ajouter Aide
Brest
Plouzané
Plougastel-Daoulas
Le Conquet
Crozon
Douarnenez
12.4 km
Image © 2012 GeoEye
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 IGN-France
lat 48.230580° long -4.564526° élév. 6 m
Altitude 53.47 km
©2010 Google
Start
Logs
data
Google Earth
98%
01:42


48.3925
48.3875
48.3825
48.3775
48.3725
48.3675
-4.4425
-4.4375
-4.4325
-4.4275
-4.4225
-4.4175
-4.4125
-4.4075
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

48.3925
48.3875
48.3825
48.3775
48.3725
48.3675
-4.4425
-4.4375
-4.4325
-4.4275
-4.4225
-4.4175
-4.4125
-4.4075
1
2
3
4
5
6
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8
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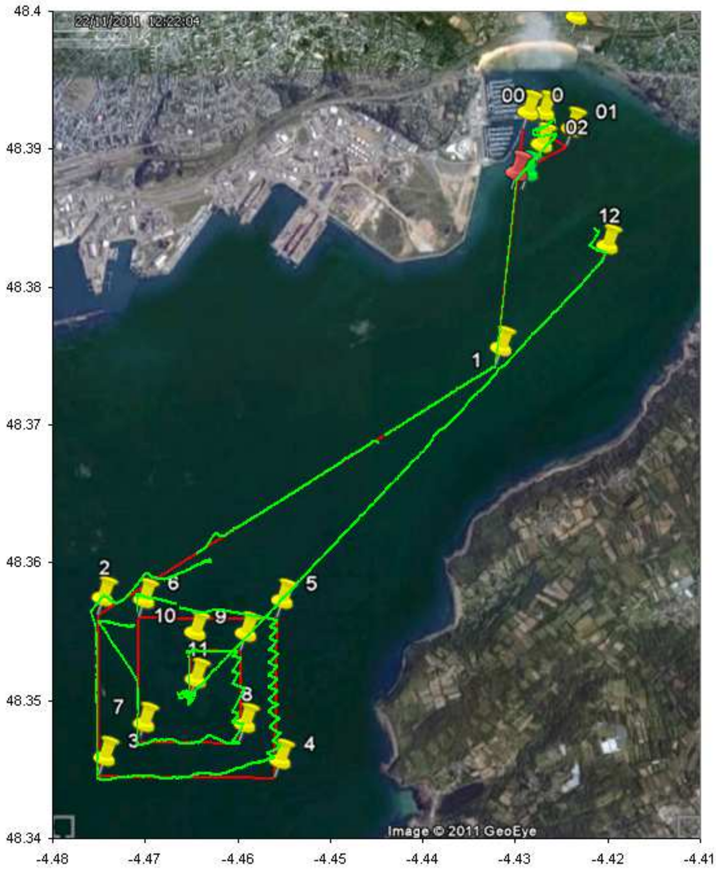
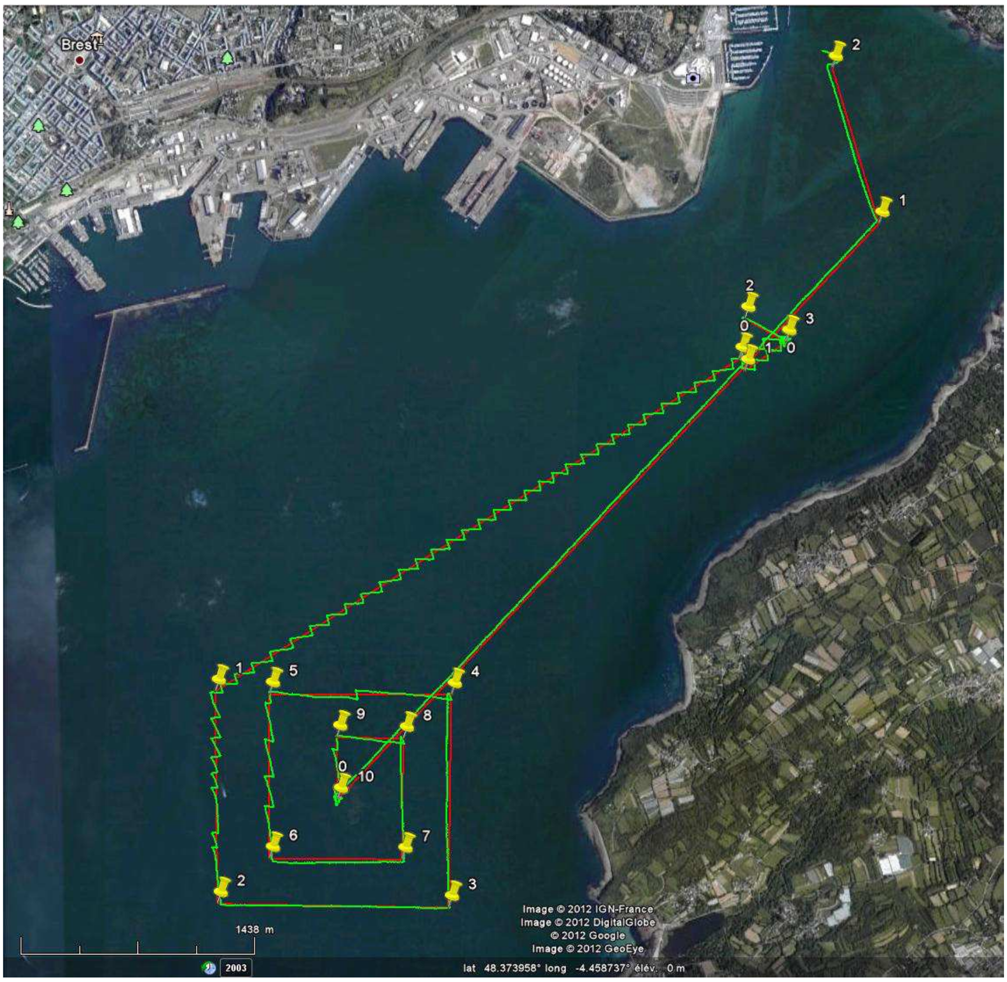
12
13
14
15



22/11/2011 12:22:04
00
0
01
02
12
1
2
6
5
10
9
11
7
8
3
4
Image © 2011 GeoEye
48.4
48.39
48.38
48.37
48.36
48.35
48.34
-4.48
-4.47
-4.46
-4.45
-4.44
-4.43
-4.42
-4.41

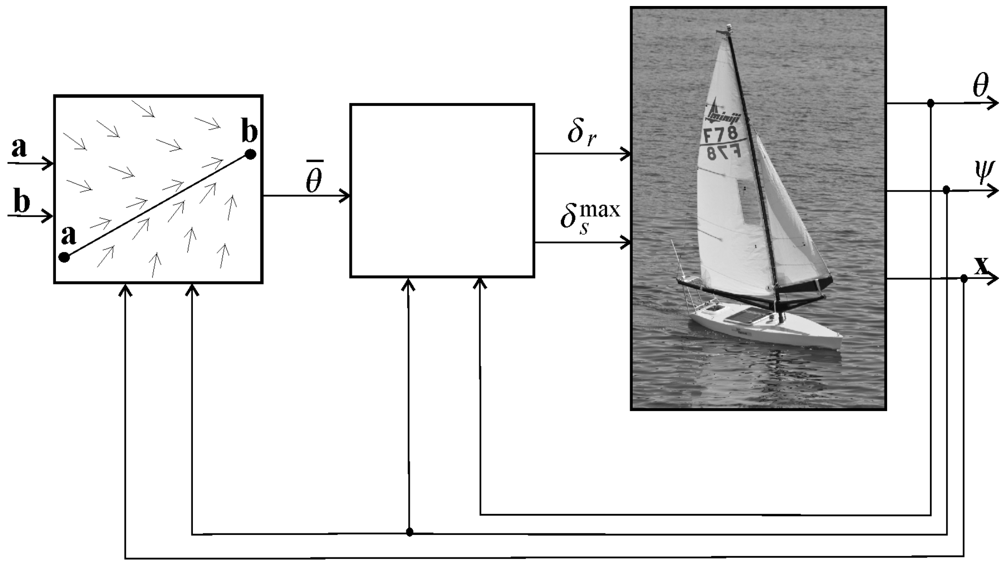

Brest
2
1
2
0
3
1
0
1
5
4
9
8
0
10
6
7
2
3
1438 m
Image © 2012 IGN-France
Image © 2012 DigitalGlobe
© 2012 Google
Image © 2012 GeoEye
2003
lat 48.373958° long -4.458737° élév. 0 m

Il est donc possible pour un robot voilier de rester dans sa bande.

Indispensable pour créer des règles de circulation lorsqu'on travaille avec des meutes.

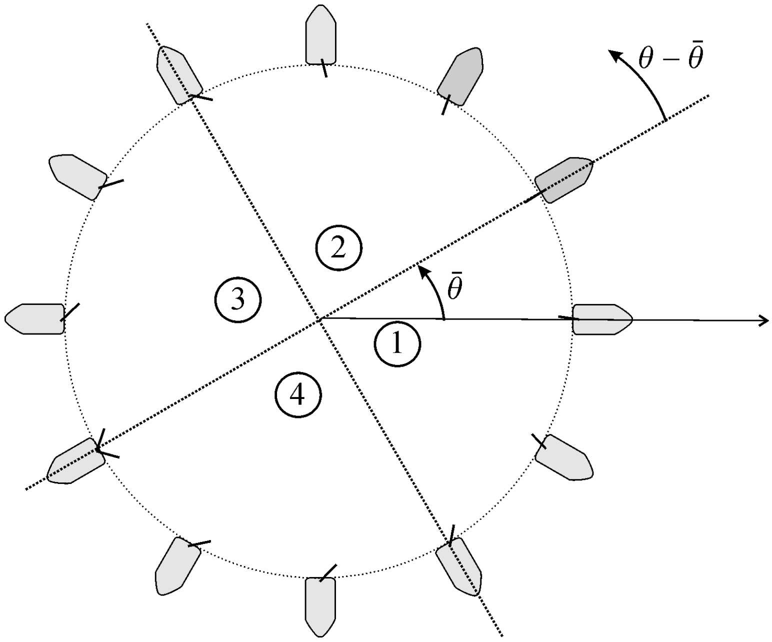
Indispensable pour déterminer les responsabilités en cas d'accident.

3 Line following

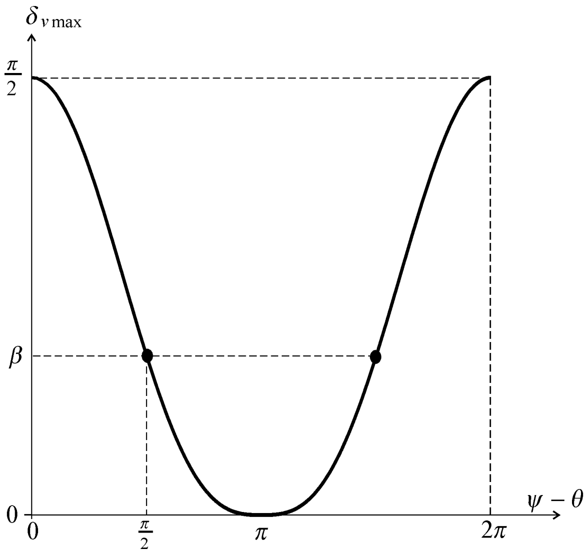


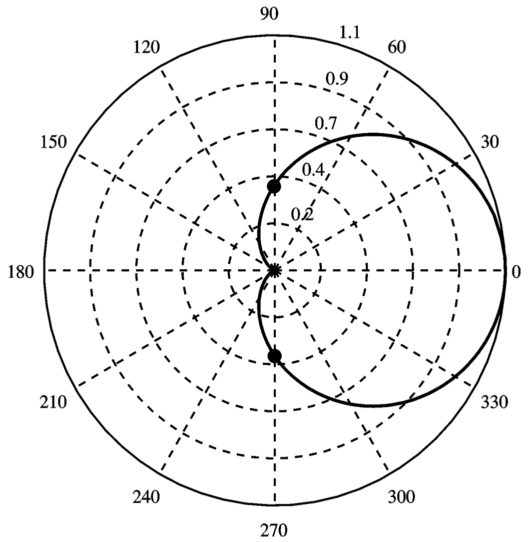
a
b
a
b
$\bar{\theta}$
δ_r
$\delta_s^{\max}$
θ
ψ
$\mathbf{x}$

$$\left\{\begin{array}{lll} \delta_r & = & \left\{\begin{array}{ll} \delta_r^{\mathsf{max}}.\,\mathsf{sin}\left(\theta-\bar{\theta}\right) & \text{if } \mathsf{cos}\left(\theta-\bar{\theta}\right)\geq 0 \\ \delta_r^{\mathsf{max}}.\mathsf{sign}\left(\mathsf{sin}\left(\theta-\bar{\theta}\right)\right) & \text{otherwize} \end{array}\right. \\ \delta_s^{\mathsf{max}} & = & \frac{\pi}{2}.\left(\frac{\mathsf{cos}\left(\psi-\bar{\theta}\right)+1}{2}\right)^q. \end{array}\right.$$

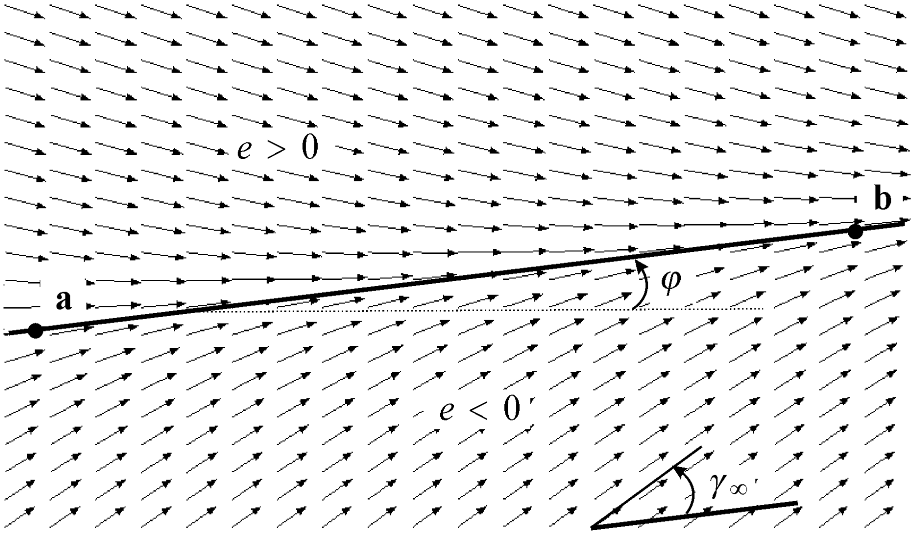


$\theta - \bar{\theta}$
2
$\bar{\theta}$
3
1
4



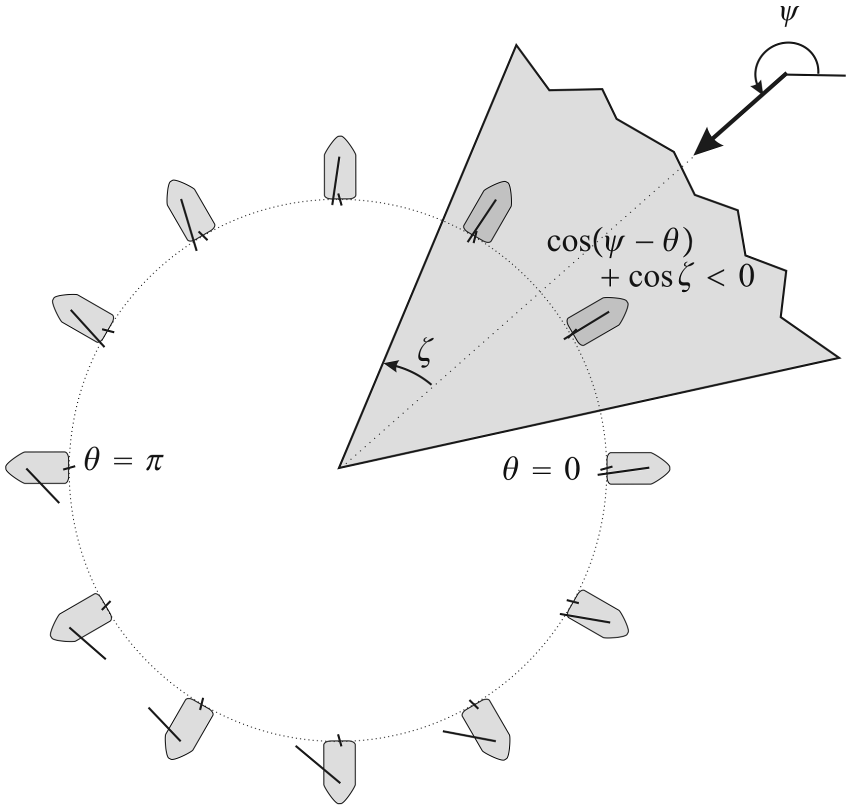


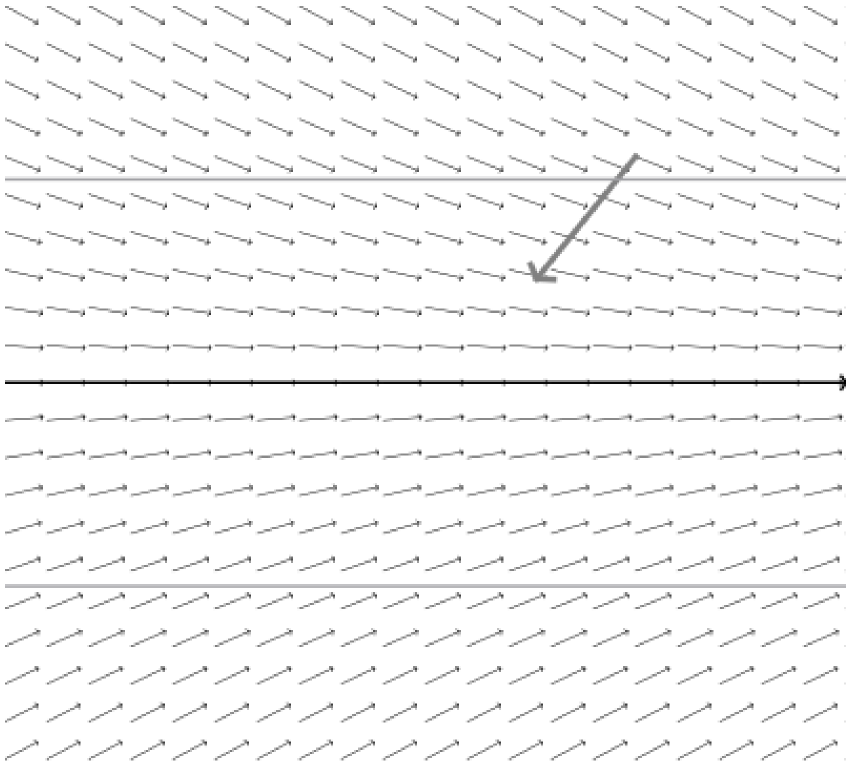
$$q = \frac{\log\left(\frac{\pi}{2\beta}\right)}{\log(2)}$$

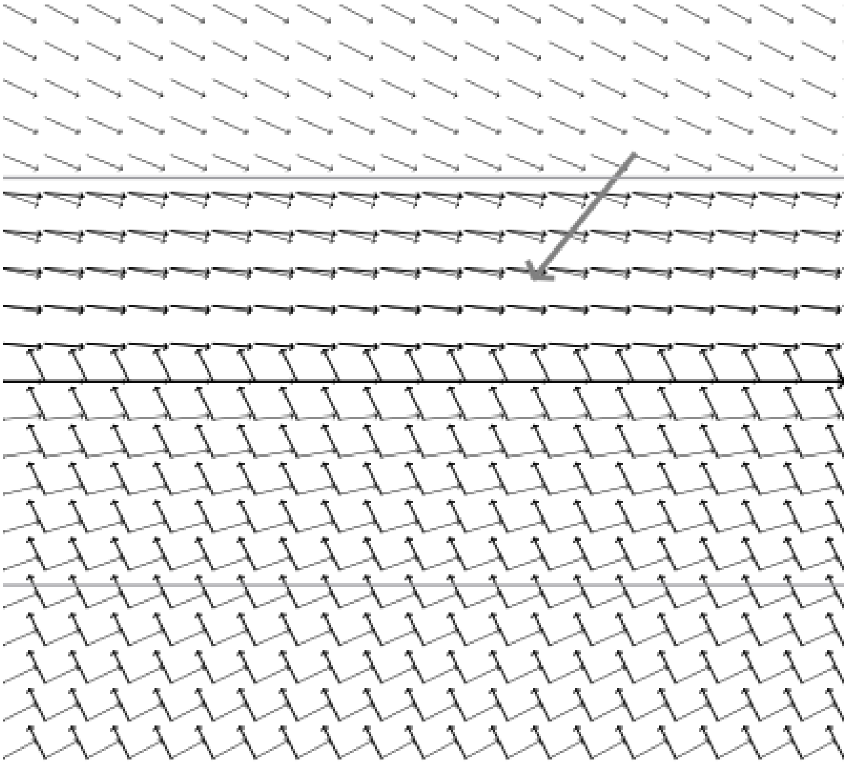


$$\theta^* = \varphi - \frac{2.\gamma_\infty}{\pi}.\mathsf{atan}\left(\frac{e}{r}\right).$$

A course θ^* may be unfeasible







Keep close hauled strategy.

http://youtu.be/pHteidmZpnY

4 Régulateur

Régulateur $\bar{\theta}\left(\mathbf{m},\mathbf{a},\mathbf{b},\psi,\gamma_{\infty},r,\zeta\right)$

$e = \det\left(\frac{\mathbf{b}-\mathbf{a}}{\|\mathbf{b}-\mathbf{a}\|},\mathbf{m}-\mathbf{a}\right)$
$\varphi = \text{atan2}(\mathbf{b}-\mathbf{a})$
$\theta^* = \varphi - \frac{2.\gamma_{\infty}}{\pi}.\text{atan}\left(\frac{e}{r}\right)$
if $\cos\left(\psi-\theta^*\right)+\cos\zeta<0$
  or $(|e|<r$ and $(\cos(\psi-\varphi)+\cos(\zeta)<0))$
    then $\bar{\theta}=\pi+\psi-\zeta.\text{sign}(e)$;
    else $\bar{\theta}=\theta^*$;
end

Sans hystérésis

Régulateur in: $\mathbf{m},\theta,\psi,\mathbf{a},\mathbf{b}$; out: $\delta_r,\delta_s^{\mathsf{max}}$; inout: q

$e = \mathsf{det}\left(\frac{\mathbf{b}-\mathbf{a}}{\|\mathbf{b}-\mathbf{a}\|},\mathbf{m}-\mathbf{a}\right)$

if $|e| > \frac{r}{2}$ then $q = \mathsf{sign}(e)$

$\varphi = \mathsf{atan2}(\mathbf{b}-\mathbf{a})$

$\theta^* = \varphi - \frac{2.\gamma_\infty}{\pi}.\mathsf{atan}\left(\frac{e}{r}\right)$

if $\cos(\psi - \theta^*) + \cos\zeta < 0$

  or $(|e| < r$ and $(\cos(\psi - \varphi) + \cos\zeta < 0))$

    then $\bar{\theta} = \pi + \psi - q.\zeta.$

    else $\bar{\theta} = \theta^*$

end

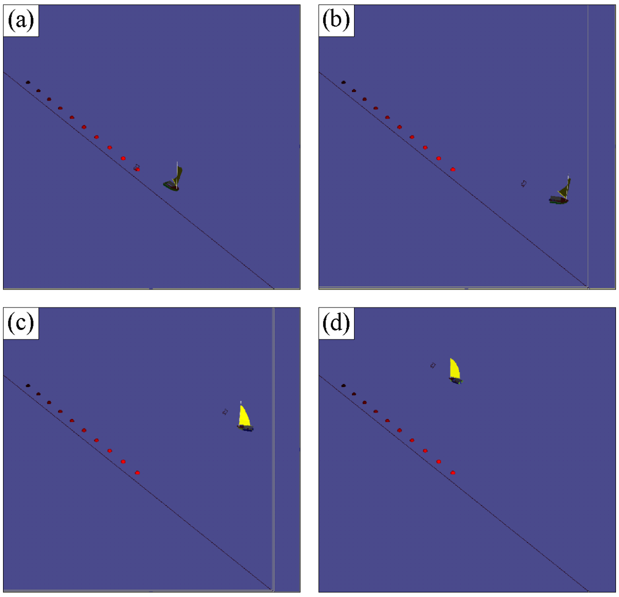
if $\cos\left(\theta - \bar{\theta}\right) \geq 0$ then $\delta_r = \delta_r^{\mathsf{max}}.\sin\left(\theta - \bar{\theta}\right)$

else $\delta_r = \delta_r^{\mathsf{max}}.\mathsf{sign}\left(\sin\left(\theta - \bar{\theta}\right)\right)$

$\delta_s^{\mathsf{max}} = \frac{\pi}{2}.\left(\frac{\cos(\psi-\bar{\theta})+1}{2}\right)^q.$

Avec hystérésis

5 Validation par simulation



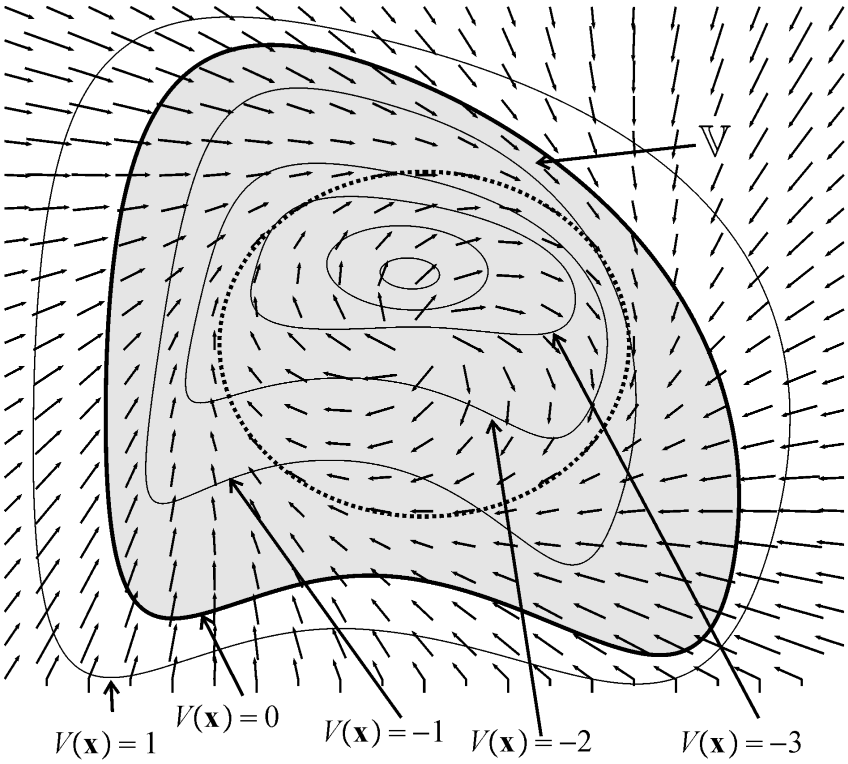
6 Validation théorique

The controlled robot:

$$\dot{\mathbf{x}} = \mathbf{f}\left(\mathbf{x}\right).$$

Definition. Consider a differentiable function $V(\mathbf{x})$. The system is V-stable if $\exists \varepsilon > 0$ such that

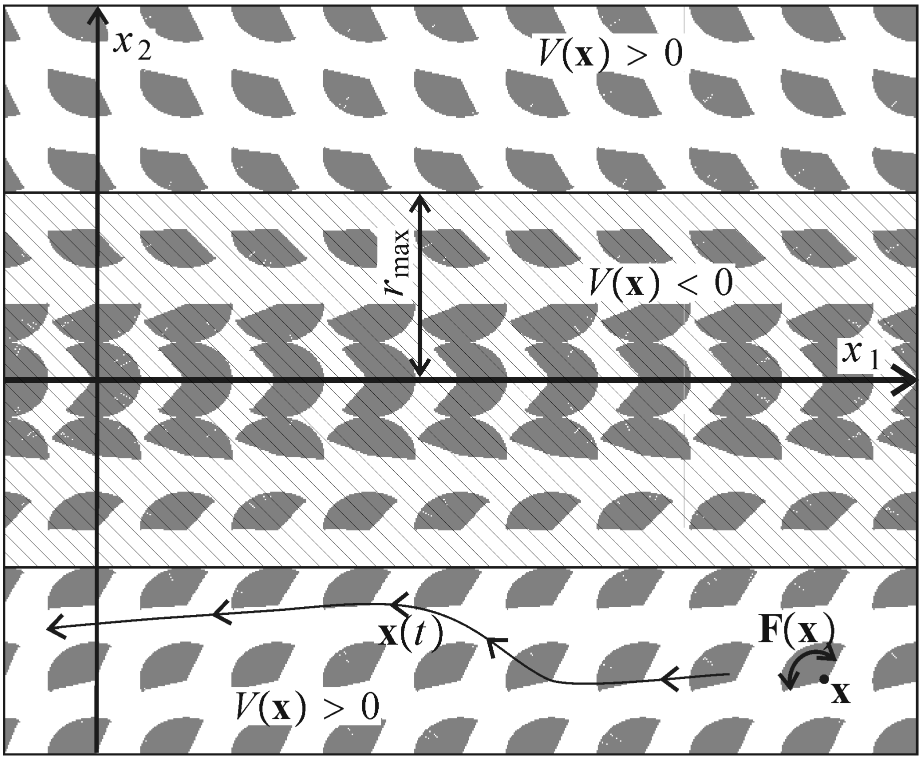
$$\Big(V\left(\mathbf{x}\right) \geq 0 \ \Rightarrow \ \dot{V}\left(\mathbf{x}\right) \leq -\varepsilon\Big).$$



$\mathbb{V}$
$V(\mathbf{x}) = 1$
$V(\mathbf{x}) = 0$
$V(\mathbf{x}) = -1$
$V(\mathbf{x}) = -2$
$V(\mathbf{x}) = -3$

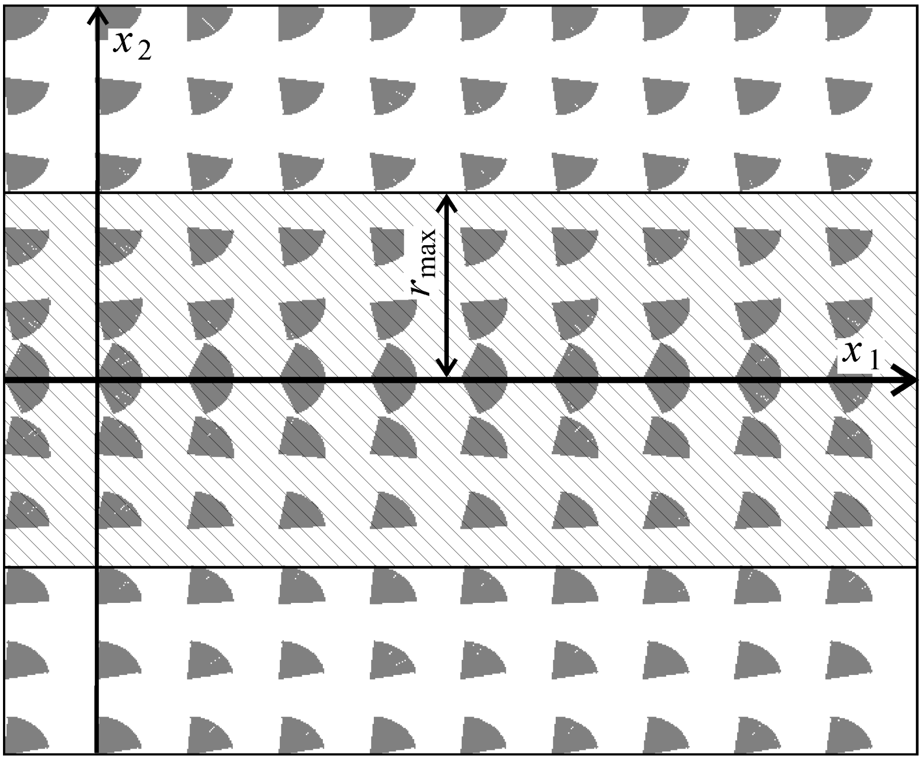
Theorem. If the system is V-stable then

(i) $\forall \mathbf{x}(0), \exists t \geq 0$ such that $V(\mathbf{x}(t)) < 0$
(ii) if $V(\mathbf{x}(t)) < 0$ then $\forall \tau > 0,\ V(\mathbf{x}(t+\tau)) < 0$.



x_2
$V(\mathbf{x}) > 0$
$r_{\max}$
$V(\mathbf{x}) < 0$
x_1
$\mathbf{x}(t)$
$\mathbf{F}(\mathbf{x})$
$\mathbf{x}$
$V(\mathbf{x}) > 0$

.



x_2
$r_{\max}$
x_1

7 Validation expérimentale