Théorie de la robotique

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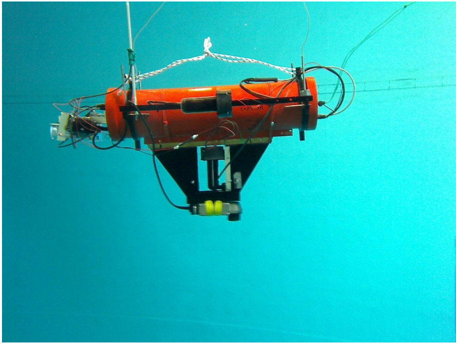
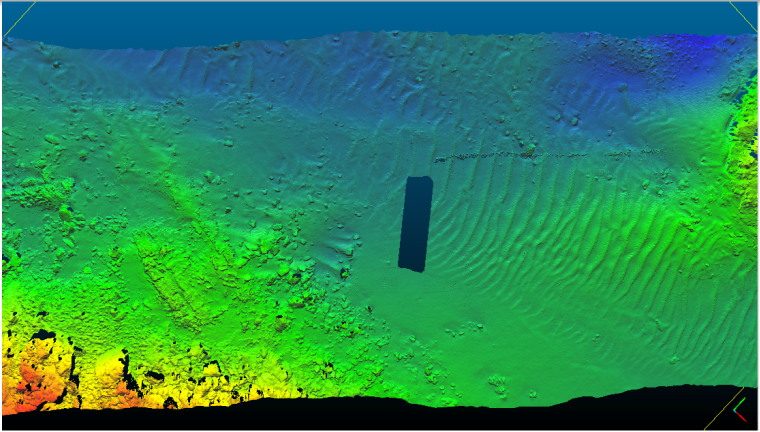
Brest, ANF TeCH-MAR, 21 novembre 2017

What is a robot ?

A robot is a mechanical system equipped with actuators, sensors and a brain.[1]



Saucisse (ENSTA Bretagne). First at SAUCE'2016



Pris au R2Sonic à 700kHz.

Gouelack (ENSTA Bretagne)

Second at WRSC'2016

Premier catégorie lourde HYDROcontest 2016

Vaimos at the WRSC (ENSTA Bretagne-IFREMER)
with F. Le Bars, O. Ménage, P. Rousseau

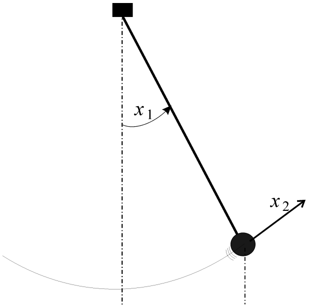
A robot is a dynamical system

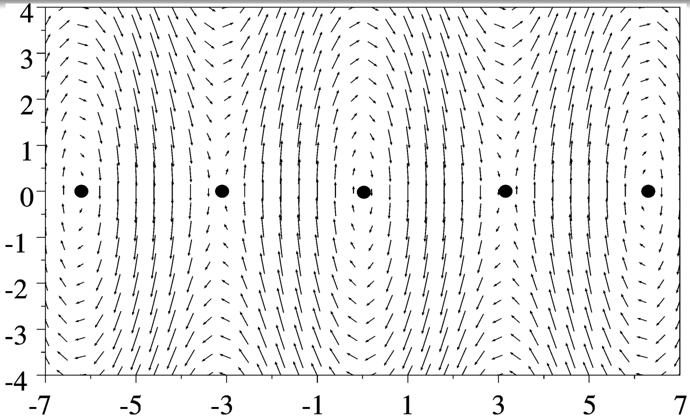
A dynamical system can be written as [Newton 1690]

$$\dot{x} = f(x).$$

Example: The pendulum

$$\begin{cases} \dot{x}_1 = x_2 \\ \dot{x}_2 = -\sin x_1. \end{cases}$$




4
3
2
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7

A robot is a vehicle

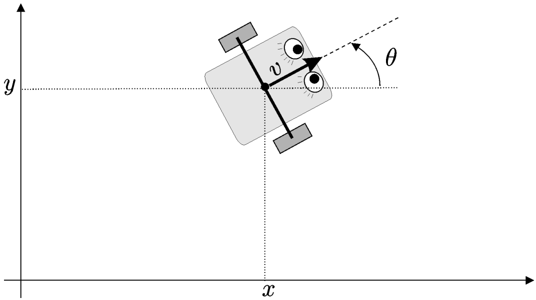
A **vehicle** is a controlled mechanical system [2]

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u}).$$

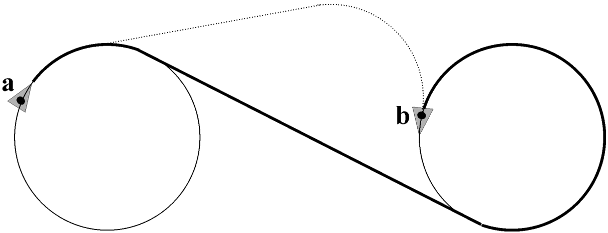
Example. Dubin's car (1957).

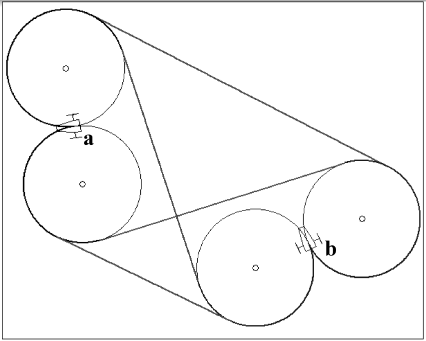
$$\left\{\begin{array}{lcl} \dot{x} & = & \cos\theta \\ \dot{y} & = & \sin\theta \\ \dot{\theta} & = & u \end{array}\right.$$

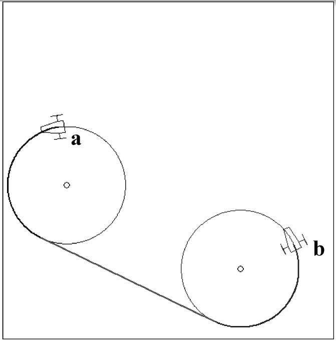
with $u \in [-1, 1]$.



Dubin's paths




a
b


a
b

A robot is an intelligent vehicle

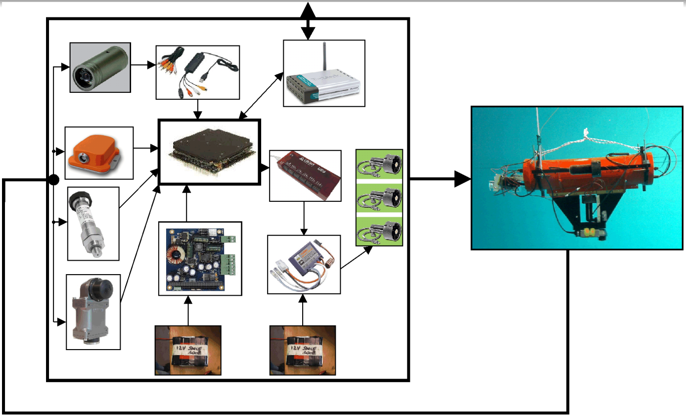
A robot is a vehicle with actuators, sensors, and a brain

$$\begin{array}{lllr} \dot{\mathbf{x}} & = & \mathbf{f}(\mathbf{x},\mathbf{u}) & \text{(evolution)} \\ \mathbf{y} & = & \mathbf{g}(\mathbf{x}) & \text{(observation)} \\ \mathbf{u} & = & \mathbf{h}(\mathbf{y}). & \text{(control)} \end{array}$$

We have

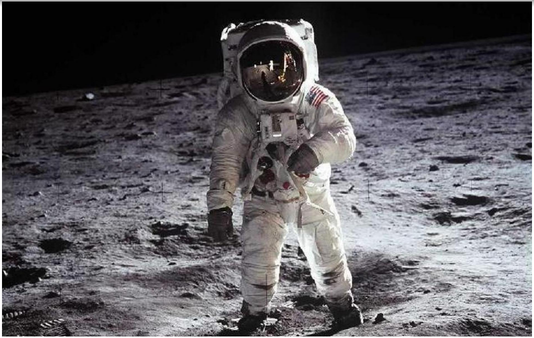
$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x},\mathbf{h}(\mathbf{g}(\mathbf{x}))) = \psi(\mathbf{x})$$

and thus a robot is a dynamical system.



Why do we need robots ?

Ocean satellites ?



Robots are needed for dirty, dangerous and dull jobs

Curiosity

About 3,600 satellites in orbit (1,000 are operational).
In the ocean, we have gliders, drifting buoys.
In the ocean, a robot could be autonomous in energy, and could survive for years (persistent autonomy).

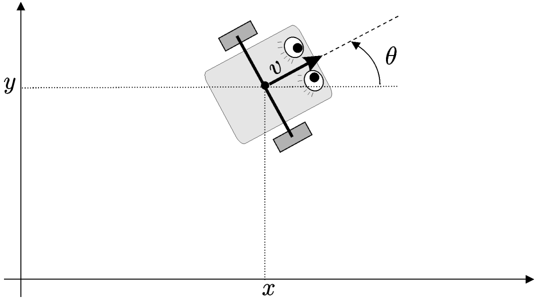
Théorie

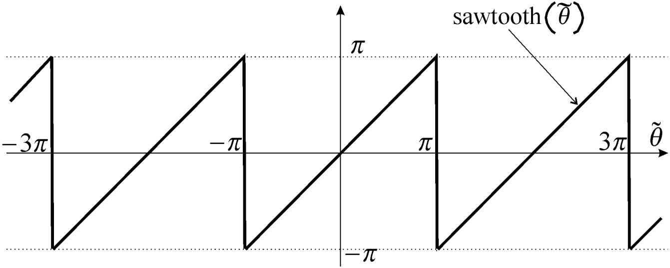
Control of a Dubin's car

Dubin's car (1957).

$$\begin{cases} \dot{x} & = & \cos\theta \\ \dot{y} & = & \sin\theta \\ \dot{\theta} & = & u \end{cases}$$

with $u \in [-1, 1]$.



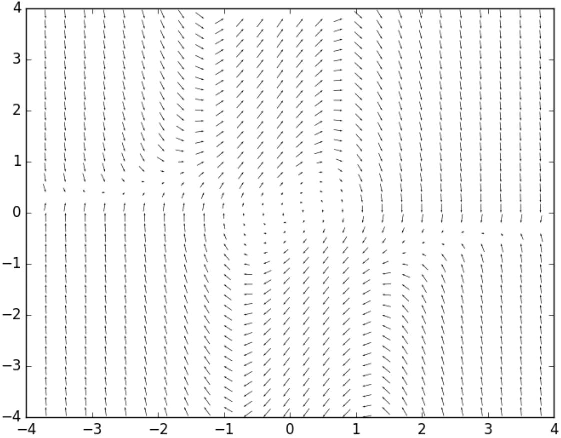

sawtooth$(\tilde{\theta})$
π
-3π
$-\pi$
π
3π
$\tilde{\theta}$
$-\pi$

Security

A robot $\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x})$.

Example: The Van der Pol system

$$\begin{cases} \dot{x}_1 & = & x_2 \\ \dot{x}_2 & = & \left(1 - x_1^2\right) \cdot x_2 - x_1 \end{cases}$$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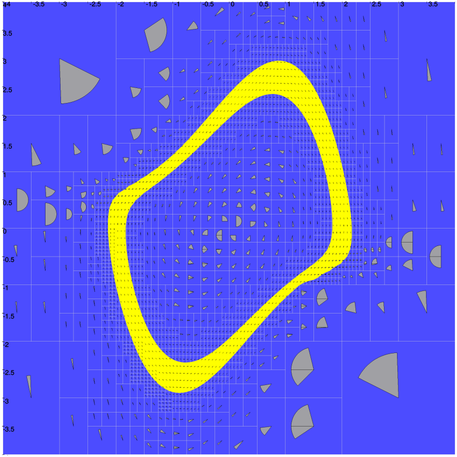
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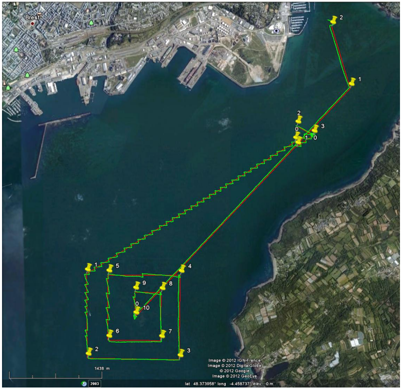
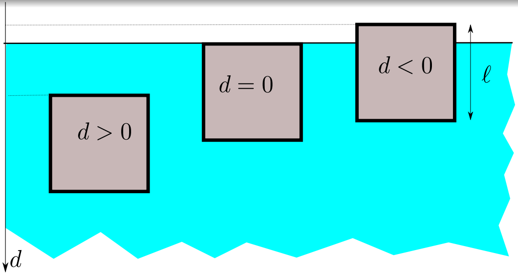
-3.5


Brest
1438 m
Image © 2012 IGN-France
Image © 2012 DigitalGlobe
© 2012 Google
Image © 2012 GeoEye
lat 48.373958° long -4.458737° elev 0 m

Control of a buoy


$d > 0$
$d = 0$
$d < 0$
ℓ
d

The state equations are thus

$$\left\{\begin{array}{lcc} \dot{d} & = & v \\ \dot{v} & = & g - \frac{g \cdot \ell + \frac{1}{2} v \cdot |v| c_x}{(1+\beta b)\ell} \\ \dot{b} & = & u \end{array}\right.$$

The two first derivatives of the output $y = d$ are

$$\begin{aligned} \dot{y} &= \dot{d} = v \\ \ddot{y} &= g - \frac{g \cdot \ell + \frac{1}{2} v \cdot |v| c_x}{(1+\beta b)\ell} \end{aligned}$$

We choose the sliding surface:

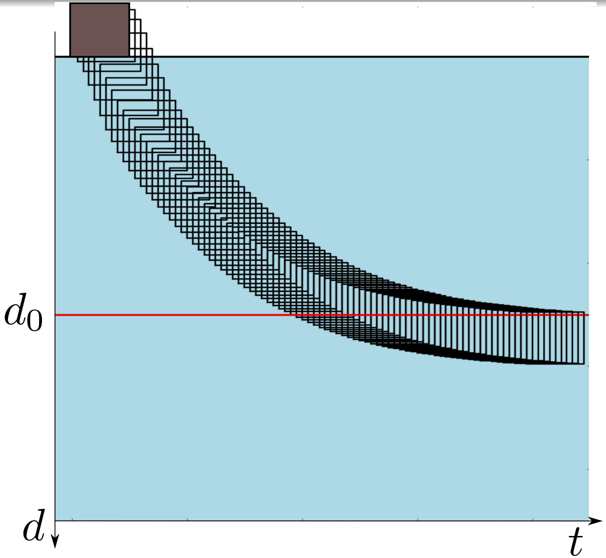
$$s(\mathbf{x},t) = \underbrace{\ddot{y}_d - \ddot{y}}_{\ddot{e}} + 2\underbrace{(\dot{y}_d - \dot{y})}_{\dot{e}} + \underbrace{(y_d - y)}_{e} = 0,$$

i.e.,

$$\ddot{d}_0 - \left(g - \frac{g\cdot\ell + \frac{1}{2}v\cdot \mid v \mid c_x}{(1+\beta b)\,\ell}\right) + 2\left(\dot{d}_0 - v\right) + (d_0 - d) = 0.$$

We choose

$$u \quad = \quad \text{sign}\left(\ddot{d}_0 - \left(g - \tfrac{g\cdot\ell+\frac{1}{2}v\cdot|v|c_x}{(1+\beta b)\ell}\right) + 2\left(\dot{d}_0 - v\right) + d_0 - d\right).$$


d_0
d
t

MOOCs and books


Rob Mooc

Experiments


Argo
ENSTA


D36 918
SURVEY
HONDA
HONDA


caribe
ENSTA

L. Jaulin.
Automation for Robotics.
ISTE editions, 2015.

L. Jaulin.
Mobile Robotics.
ISTE editions, 2015.