

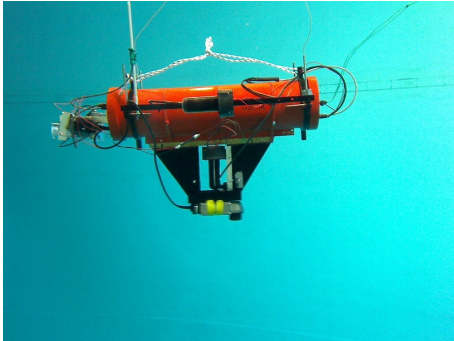
# Introduction to robotics for hydrographers

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Moqesm Brest, Oct 11, 2016



# What is a robot ?

A robot is a mechanical system equipped with **actuators**, **sensors** and a **brain**.



Saucisse (ENSTA Bretagne)



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

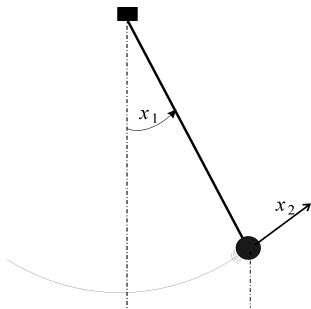
# A robot is a dynamical system

A dynamical system can be written as [Newton 1690]

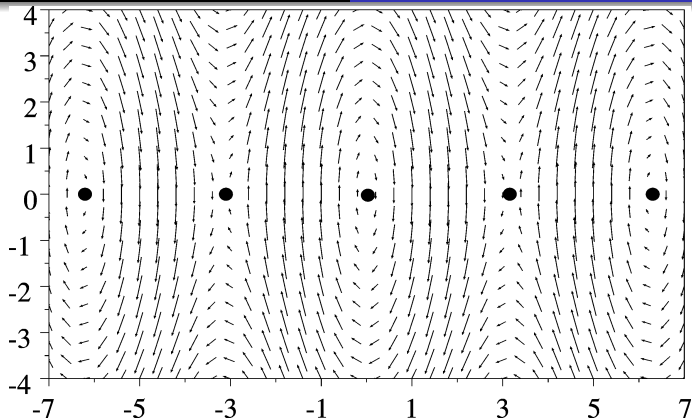
$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}).$$

## Example: The pendulum

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







# A robot is a vehicle

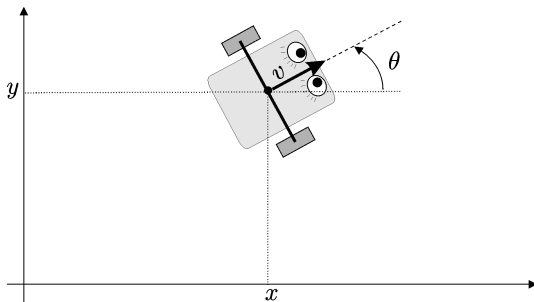
A **vehicle** is a controlled mechanical system

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

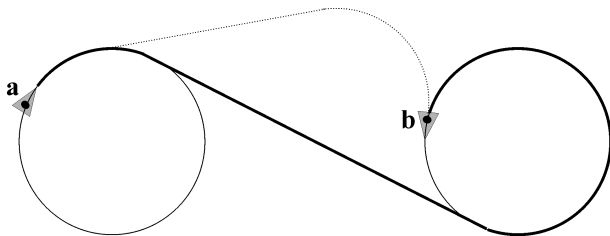
Example. Dubin's car (1957).

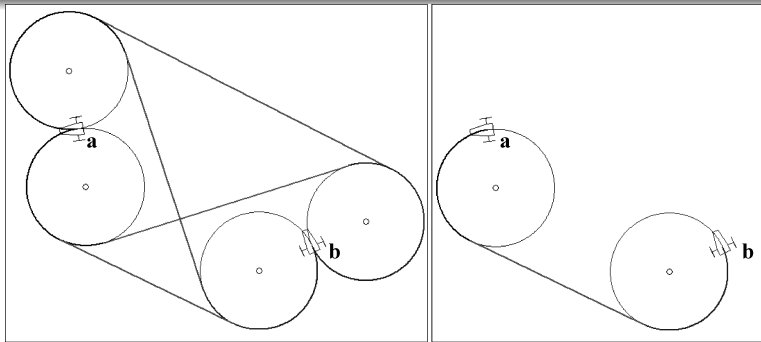
$$\begin{cases} \dot{x} = \cos \theta \\ \dot{y} = \sin \theta \\ \dot{\theta} = u \end{cases}$$

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



## Dubin's paths





## Simulation (Euler, 1770)

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u}) \quad \sim \quad \mathbf{x}(t + dt) = \mathbf{x}(t) + dt \cdot \mathbf{f}(\mathbf{x}(t), \mathbf{u}(t))$$

# A robot is an intelligent vehicle



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

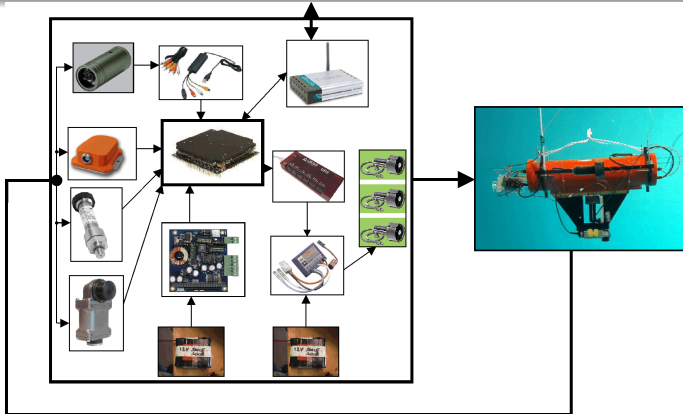
$$\begin{aligned}\dot{\mathbf{x}} &= \mathbf{f}(\mathbf{x}, \mathbf{u}) && \text{(évolution)} \\ \mathbf{y} &= \mathbf{g}(\mathbf{x}) && \text{(observation)} \\ \mathbf{u} &= \mathbf{h}(\mathbf{y}). && \text{(contrôle)}\end{aligned}$$

We have

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

and thus a robot is a dynamical system.

# What is a robot ? Why do we need robots? Security



# Why do we need robots ?

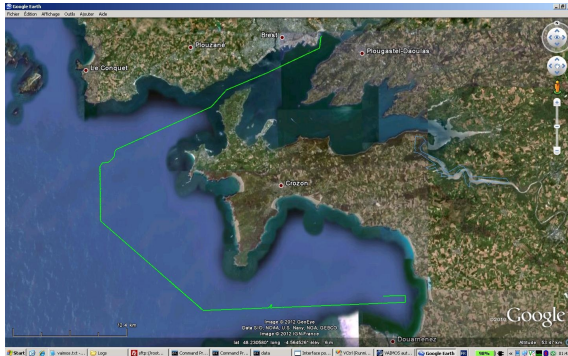


Brest-Douarnenez. January 17, 2012



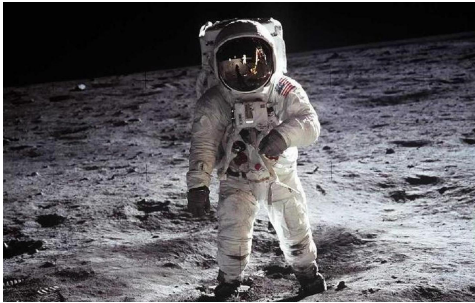


# What is a robot ? Why do we need robots? Security



# Ocean satellites ?





Robots are needed for dirty, dangerous and dull jobs



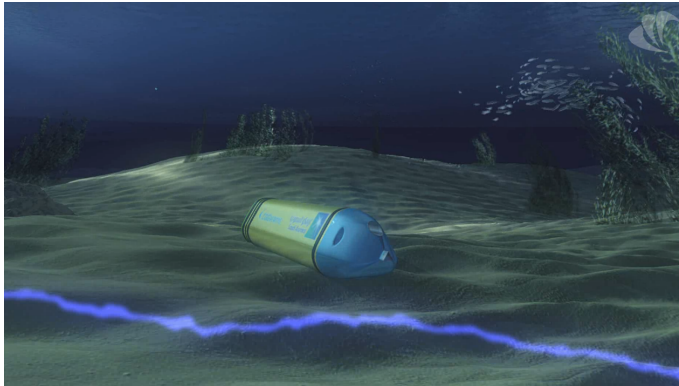
Curiosity



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**).

Montrer Vaimos dans l'océan Atlantique.

# An example (with CGG)



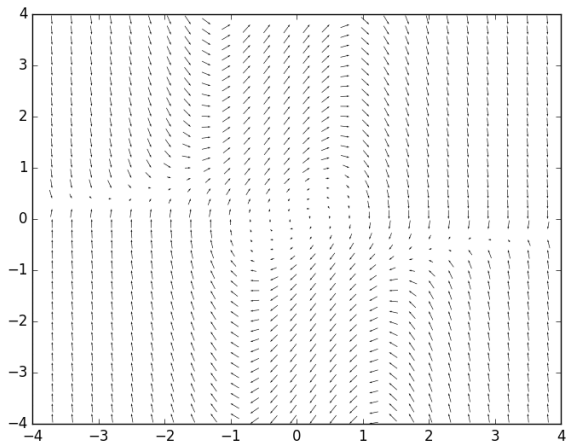
# Security

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

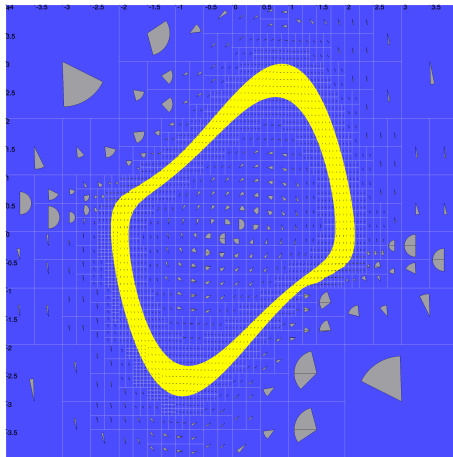
**Example:** The Van der Pol system

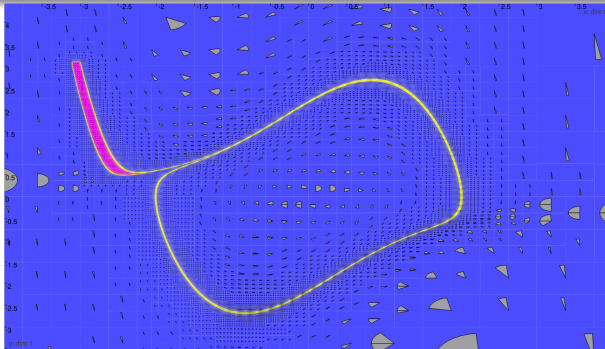
$$\begin{cases} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= (1 - x_1^2) \cdot x_2 - x_1 \end{cases}$$





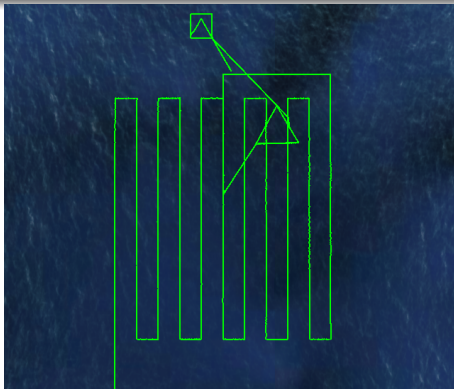
What is a robot ?  
Why do we need robots?  
Security





Reachable set





Middle of Atlantique ocean, 350 km made by Vaimos, sept. 6-9, 2012.