Robotics activities at ENSIETA

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"Solving Simultaneous Localization And Mapping problems in the field of underwater robotics using set membership methods"

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Our school ENSIETA

- In Brest – FRANCE – on the Ocean shore
- Military/Civilian school
- Multidisciplinary
  - Mechanics (Naval and offshore architecture, automotive architecture)
  - Oceanography
  - Electronics
  - Signal processing (image/sonar/radar)
  - Telecommunication
  - Automatics
  - Computer science
  - Other non scientific (humanities, sport,…)

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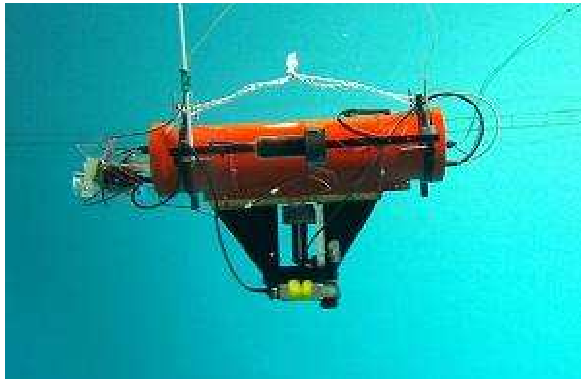
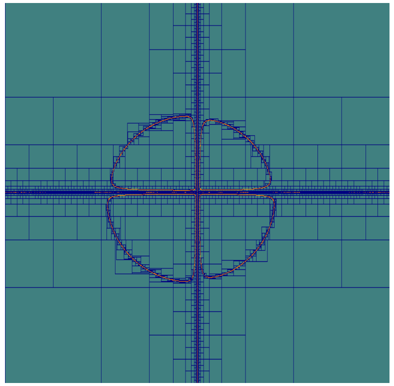
> Outline of the presentation



AUV: “La Sauc’isse”



Set membership methods
•AUV localization

Other robots

Sailboat: “Breizh Spirit”

Ground Robot Swarm

Quadcopter

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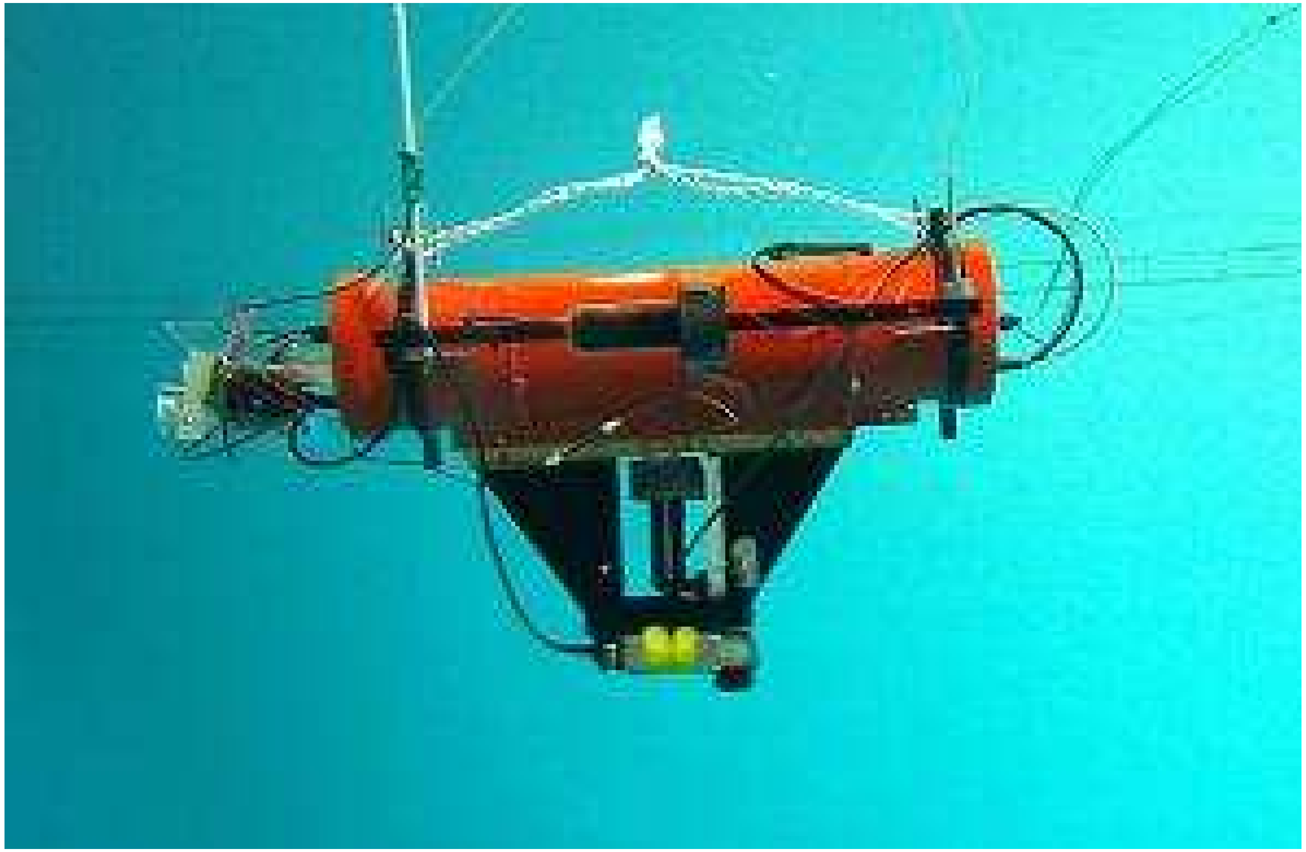
Three principles

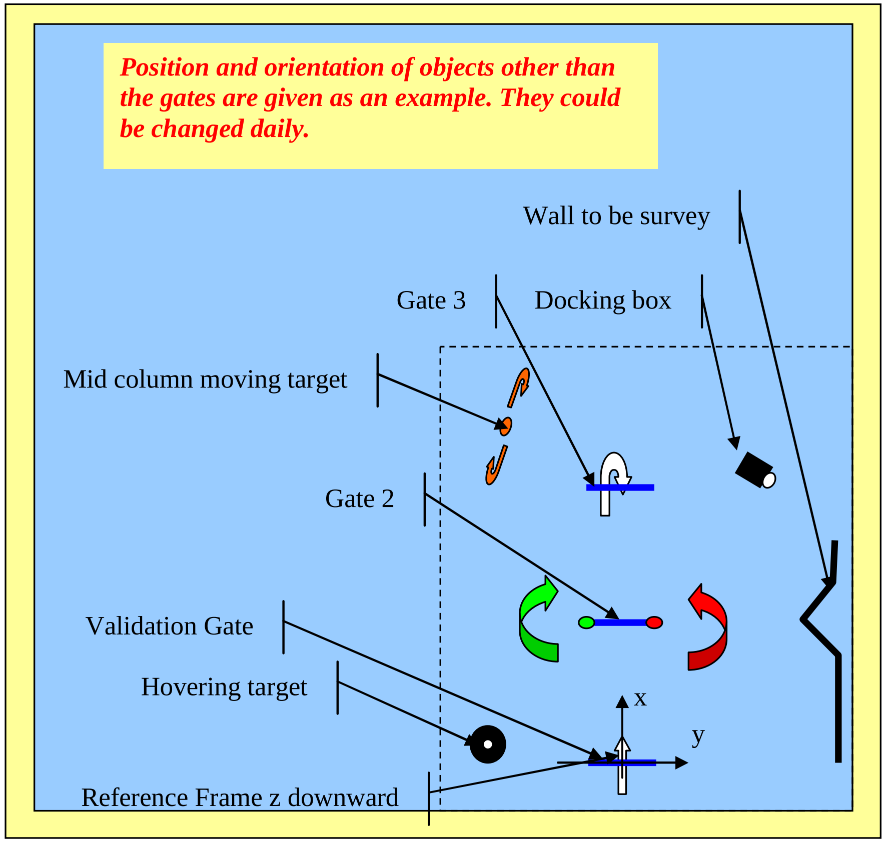
1. Always try to participate to a challenge (be it international or national) →**Boost the motivation of students**
2. Use **COTS** –Commercial Off The Shelf- components →**Reliability, repeatability**
3. The third principle is the KISS -Keep It Simple, Stupid- principle.

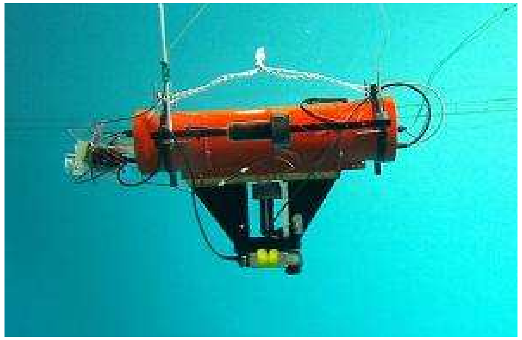
> AUV : Autonomous Underwater Vehicle



Our AUV : “La Sauc’isse”

AUV : SAUCE Competition





Our AUV : “La Sauc’isse”

SAUCE (Student Autonomous Underwater Challenge Europe)
2009 rules (Gosport-UK)

AUV : Mechanical design

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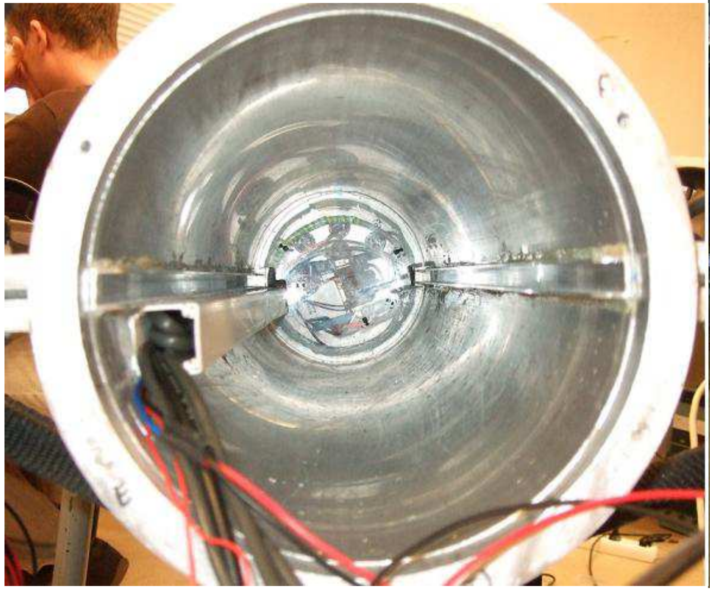
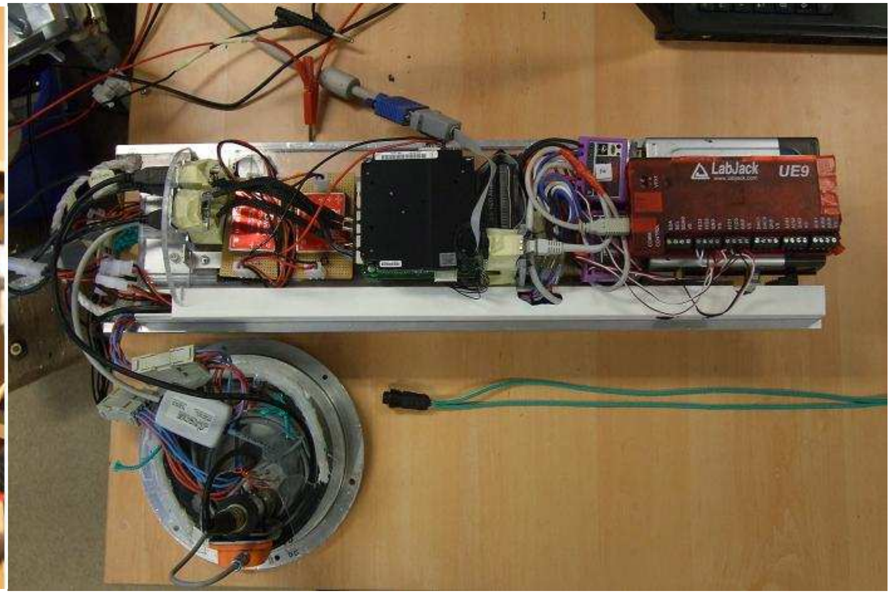
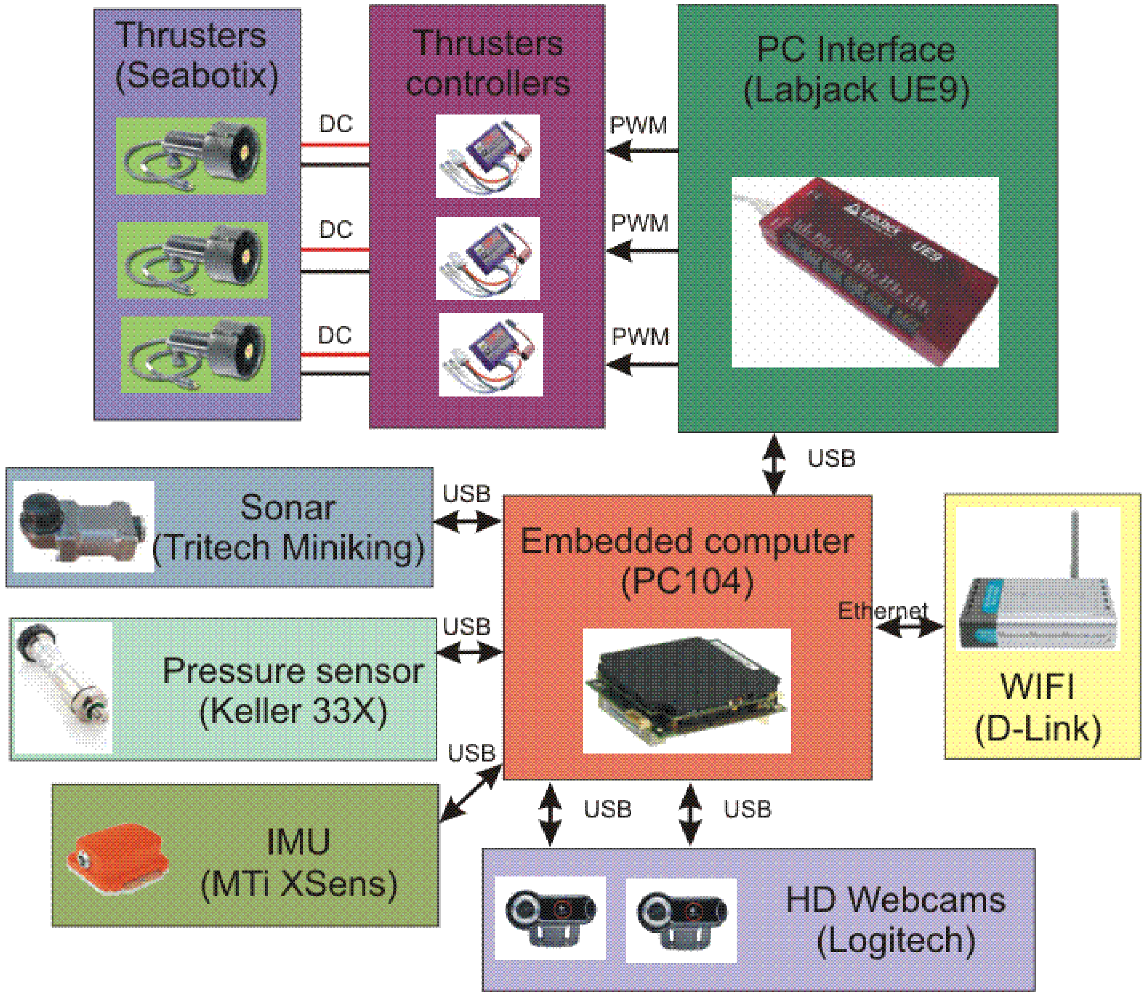
> AUV : Mechanical design





AUV : Electronics



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AUV : Operating System

- Operating System : **Normal** Windows XP
  - Same program everywhere
- Use **mstsc**: remote desktop connection to
  - Control the AUV
  - Configure the AUV program
  - Test the sensors using proprietary software

AUV : Software

- Ensure : Modifiability, Usability, Testability…
- Current 3rd year student project
  - Making a **Software Architecture**
    - Inspired by DoDAF(Department of Defence Architecture Framework)
    - Uses clean interfaces based on design patterns (MVC, factory…)
    - Be transparent as much as possible
  - Making **Automatic code generation** of
    - The intelligence : Using scripts/Graphical framework…(state charts)
    - The GUI : From GUI configuration files…

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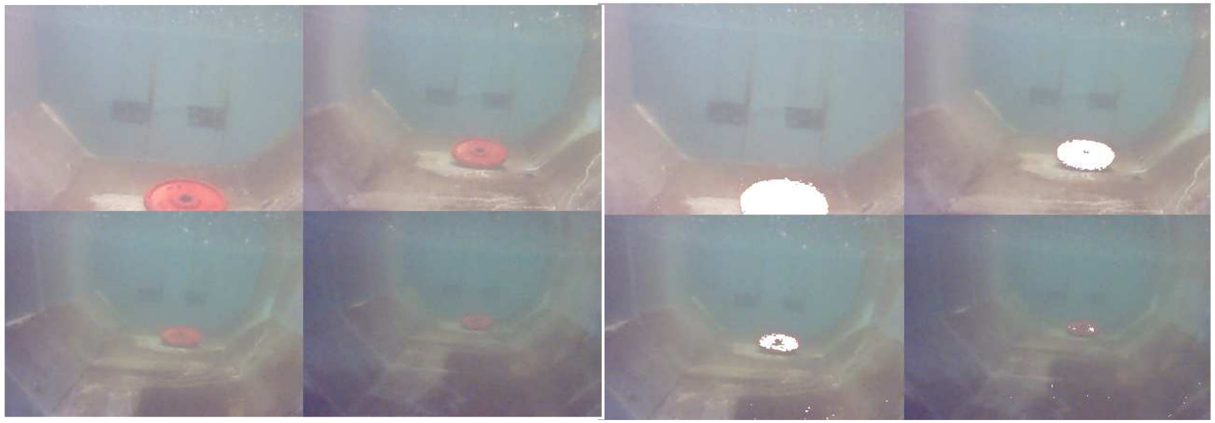
AUV : Algorithms : Vision



Underwater object detection based on color detection taking color fading into consideration

Work of Stéphane Bazeille, ex PhD student at ENSIETA

> AUV : Algorithms : Localization

- Uses Sonar and compass data
- 2 modes
  - Static localization (robot is immobile)
  - Dynamic localization (position tracking)

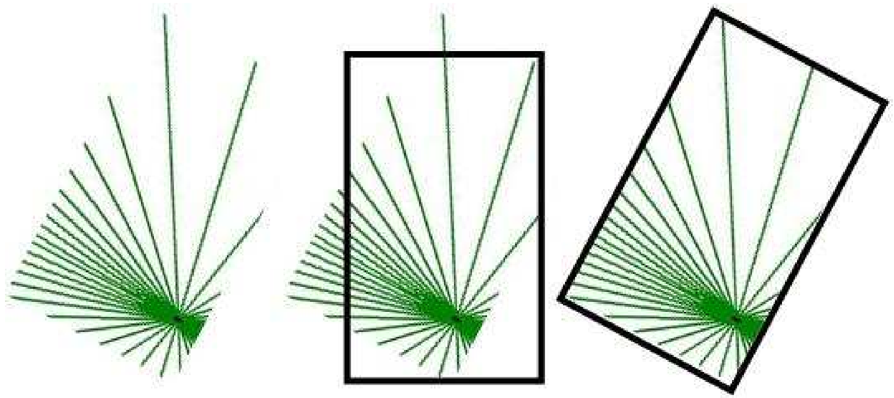


Illustration of the Static localization algorithm

>video<

AUV : video

Sailboat : Purpose : Cross the Atlantic Ocean (Microtransat Challenge)

2 rules

- **Give the global position every 24h**
- **Have safety light signalisation**

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Our first challenge

Crossing Brest Harbour with "Breizh Spirit" sailboat

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> # Our first challenge

>video<

Crossing Brest Harbour with "Breizh Spirit" sailboat

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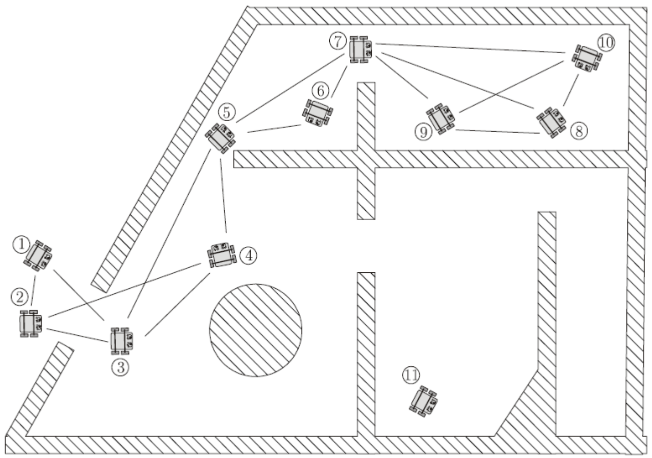
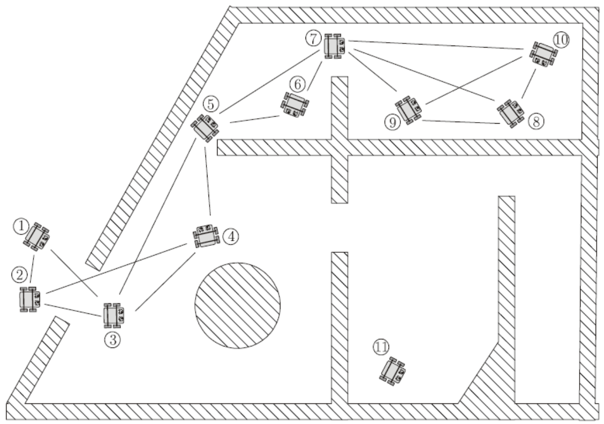
> AGV Swarm : Purpose

- Participating in the national competition **CAROTTE** organized by the DGA (French Department of Defense) and ANR (National Research Agency) which aim is to develop **Mapping and Object recognition** algorithms using **Autonomous Ground Vehicles** (AGV)



AGV Swarm : Algorithms

- Still at baby stage <Video of red following>
- But **Future**
  - Use **set membership theory** (interval analysis…) based algorithms for SLAM (Simultaneous Localization And Mapping)



>video<

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AGV Swarm : Video

Quadcopter : Purpose

- No competition, as a substitute →AGV Swarm assistance from above

Our reference model is the German MicroKopter

Interval analysis

- Show the demonstration of the localization

>Software Demo<

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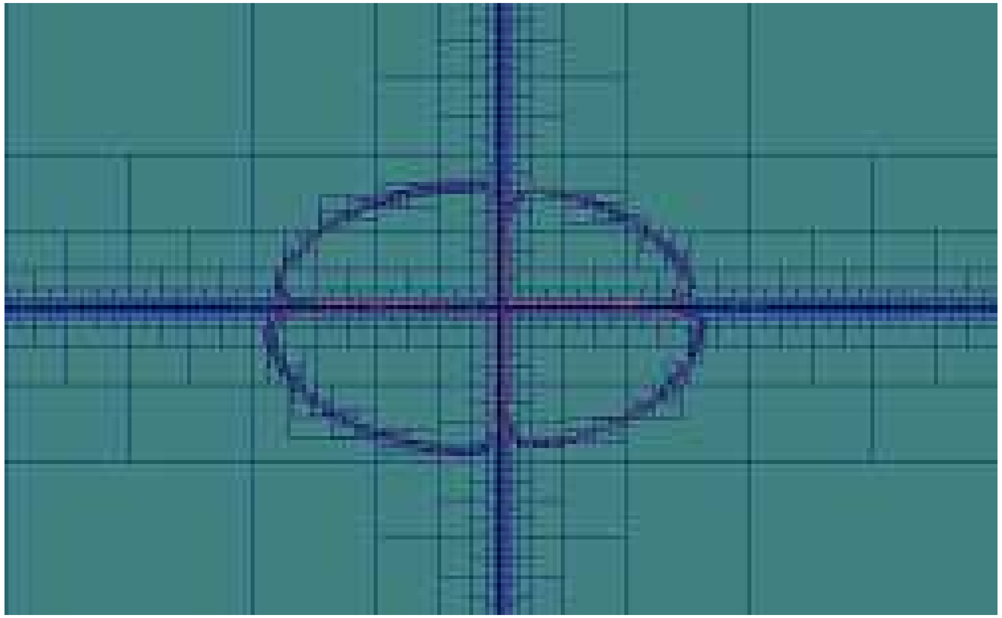
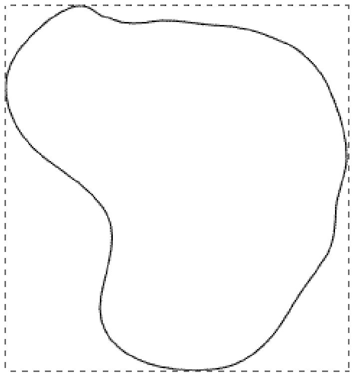
Interval analysis

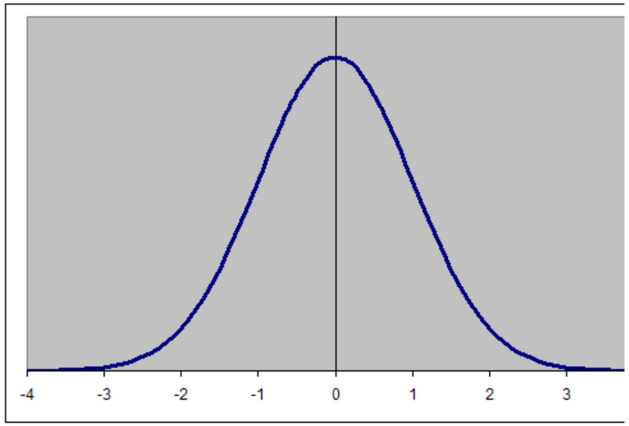


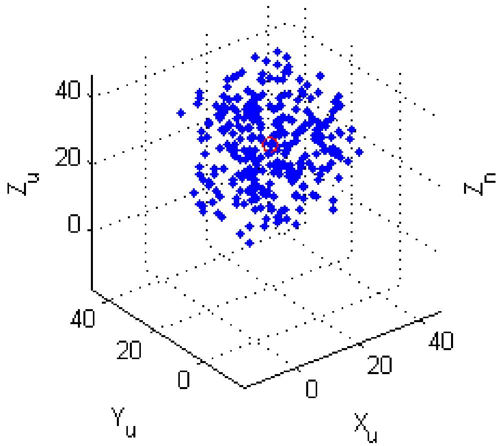
Interval Art created with Proj2D

Introduction

All sensor measurements / variables used to describe a robot are not punctual.
continuous set, Probabilistic distribution, set of points







Our case, we suppose the variables are bounded
ex: $value_0 + / - \epsilon \Rightarrow value \in [value_0 - \epsilon, value_0 + \epsilon]$

Advantages

- Often, sensor measures are considered bounded and the bounds are given by the manufacturer (the precision).
- Well adapted to non linear problem solving
- Powerful parallelizable algorithms
- Guaranteed result (we do not loose any solution)
- Robust to outliers

Solvable Problems

Set inversion problem : $\mathbf{f}:\mathbb{R}^n \to \mathbb{R}^m, Y \subset \mathbb{R}^m$,
find $X = \{\mathbf{x} \in \mathbb{R}^n, \mathbf{f(x)} \in Y\}$
In case $Y = \{\mathbf{0}\}$, the problem becomes

$$\begin{cases} f_1(x_1, x_2, \ldots, x_n) = 0 \\ f_2(x_1, x_2, \ldots, x_n) = 0 \\ \ldots \\ f_m(x_1, x_2, \ldots, x_n) = 0 \end{cases}$$

$$\mathbf{x} = (x_1, x_2, \ldots, x_n) \in \mathbb{R}^n$$

Solvable Problems

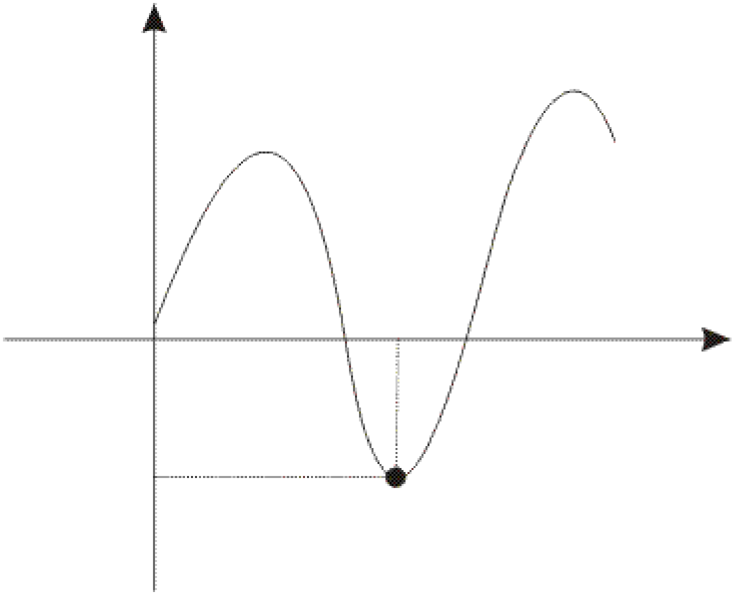
$$\text{Set inversion problem}: \mathbf{f}: \mathbb{R}^n \to \mathbb{R}^m, Y \subset \mathbb{R}^m,$$
$$\text{find } X = \{\mathbf{x} \in \mathbb{R}^n, \mathbf{f(x)} \in Y\}$$
$$\text{In case } Y = \{\mathbf{0}\}, \text{ the problem becomes}$$

$$\begin{cases} f_1(x_1, x_2, \dots, x_n) = 0 \\ f_2(x_1, x_2, \dots, x_n) = 0 \\ \dots \\ f_m(x_1, x_2, \dots, x_n) = 0 \end{cases}$$
$$\mathbf{x} = (x_1, x_2, \dots, x_n) \in \mathbb{R}^n$$

Solvable Problems II

Optimization problem

$$\text{find } \hat{f} = \min_{x \in [x]} f(x)$$



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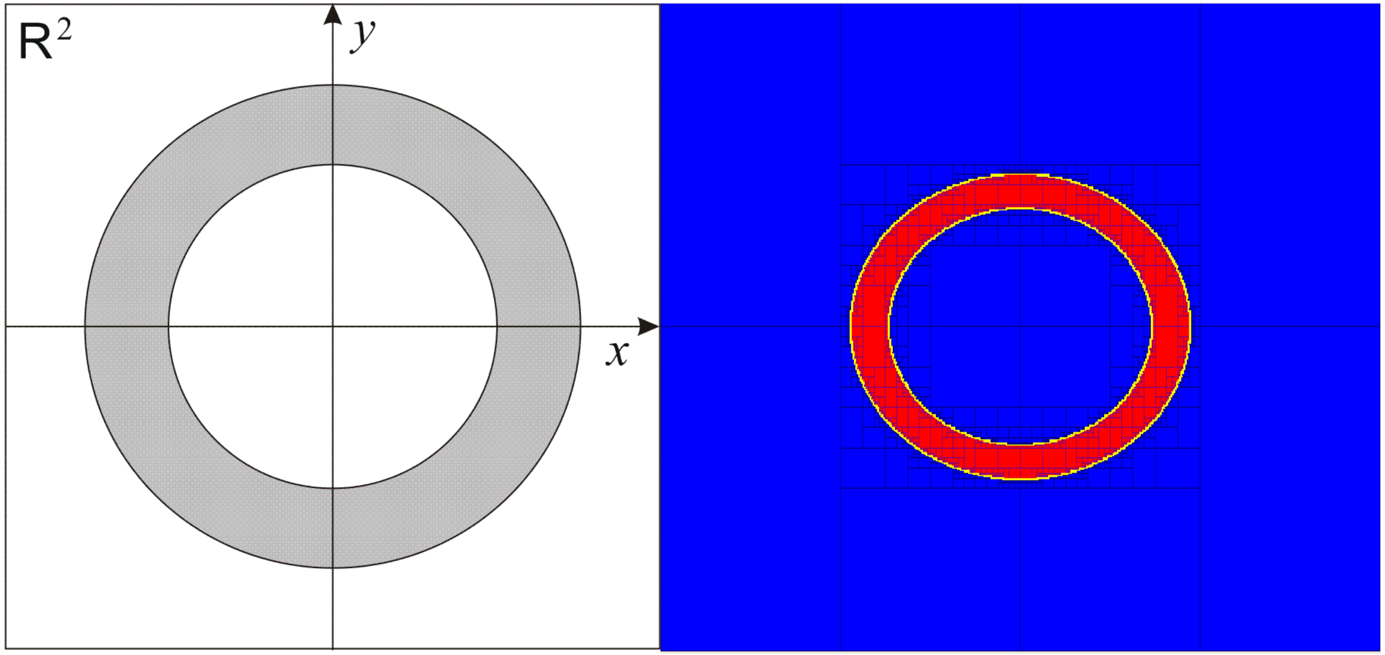
Example

Solve $f(x,y) = x^2 + y^2 = r^2$

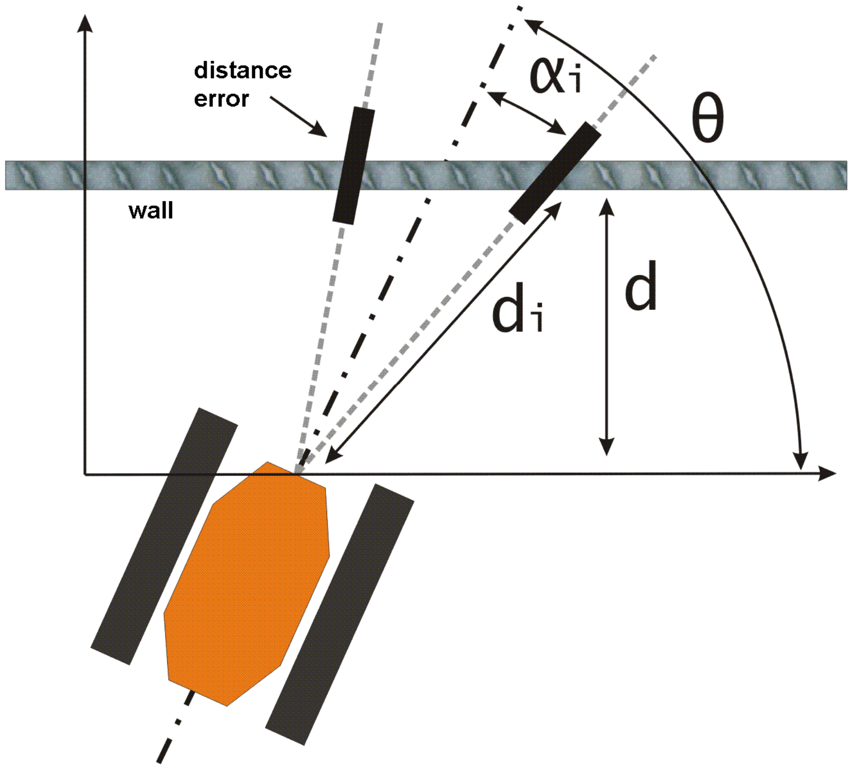
where $r \in [r_{\min}, r_{\max}]$ ex: $r \in [5,10]$

Note that $f : \mathrm{R}^2 \to \mathrm{R}$

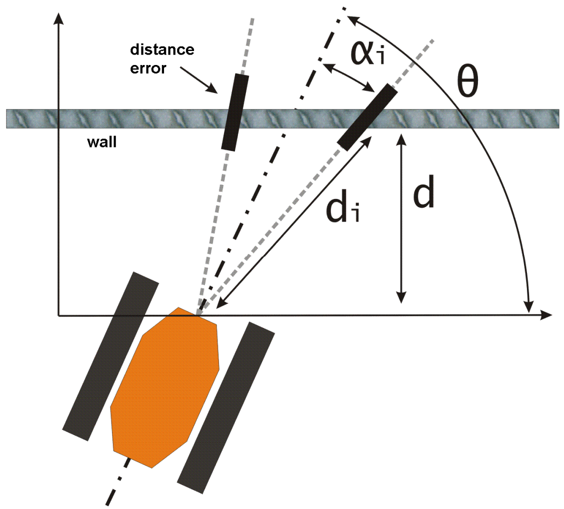


Theoretical solution — Solution using Proj2D Solver

Application to localization



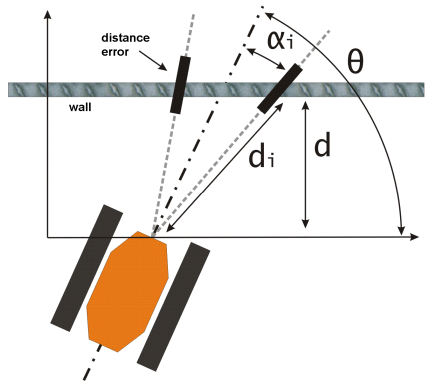
Application to localization



Foreach measure :

$$d = d_i \cos(\theta + \alpha_i)$$

Application to localization



Set of equations to be solved

$$\begin{cases} d - d_1 \cos(\theta + \alpha_1) = 0 \\ d - d_2 \cos(\theta + \alpha_2) = 0 \\ \dots \\ d - d_m \cos(\theta + \alpha_m) = 0 \end{cases}$$

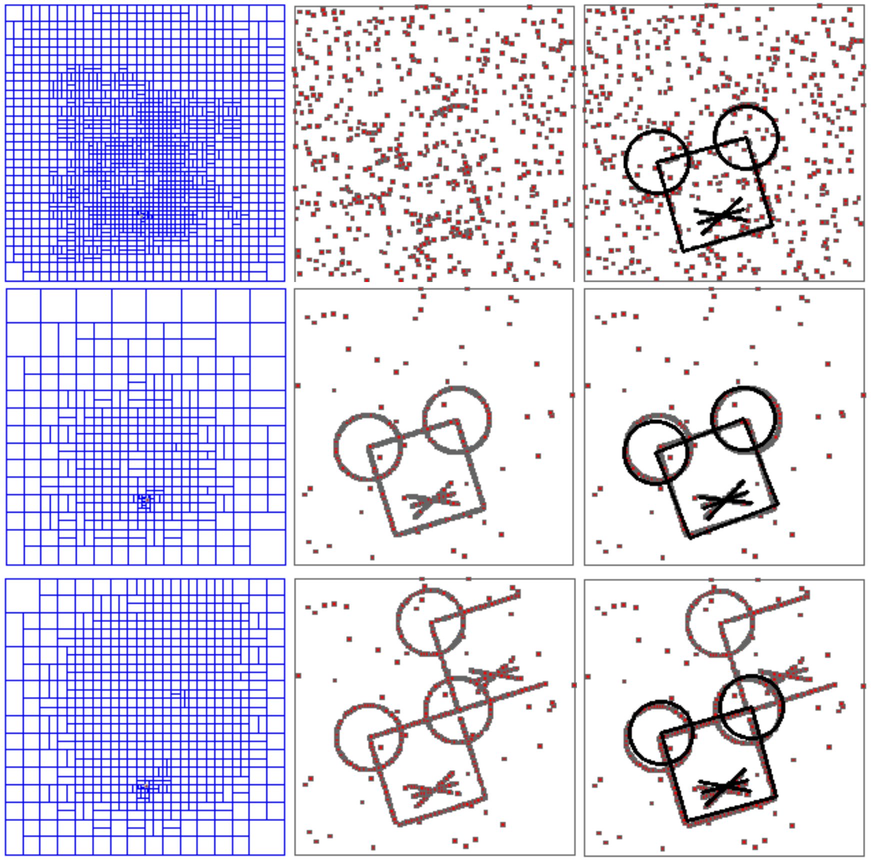
> Demo

- Demo IPOS

>Software Demo<

Other Applications

- Image processing
- Mapping
- SLAM
- …



Conclusion

- Building a robot is easier than in the past
- Still huge software problems
- Interval analysis is suited mathematical tool for solving robotics related problems

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??? Any questions ???

Thank you for your attention