Veicoli marini senza equipaggio: definizione di metodologie sperimentali

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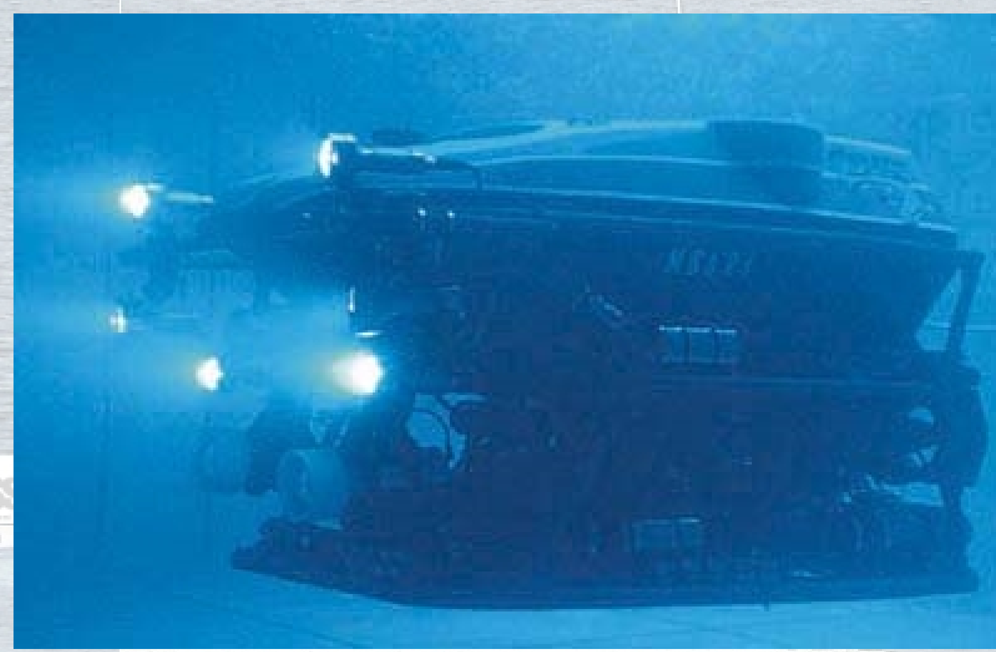
Unmanned Marine Vehicles

ROVs

Remotely
Operated
Vehicles



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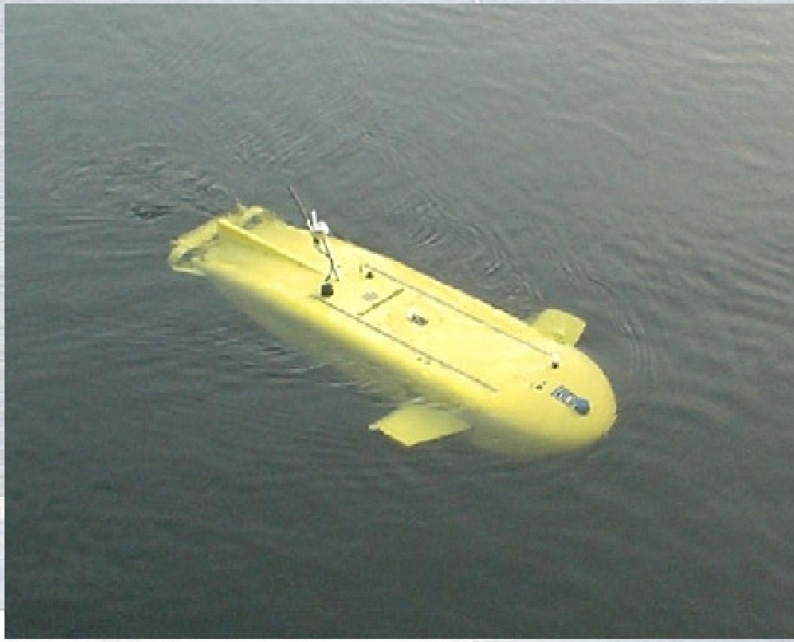
Unmanned Marine Vehicles



AUVs

Autonomous Underwater Vehicles

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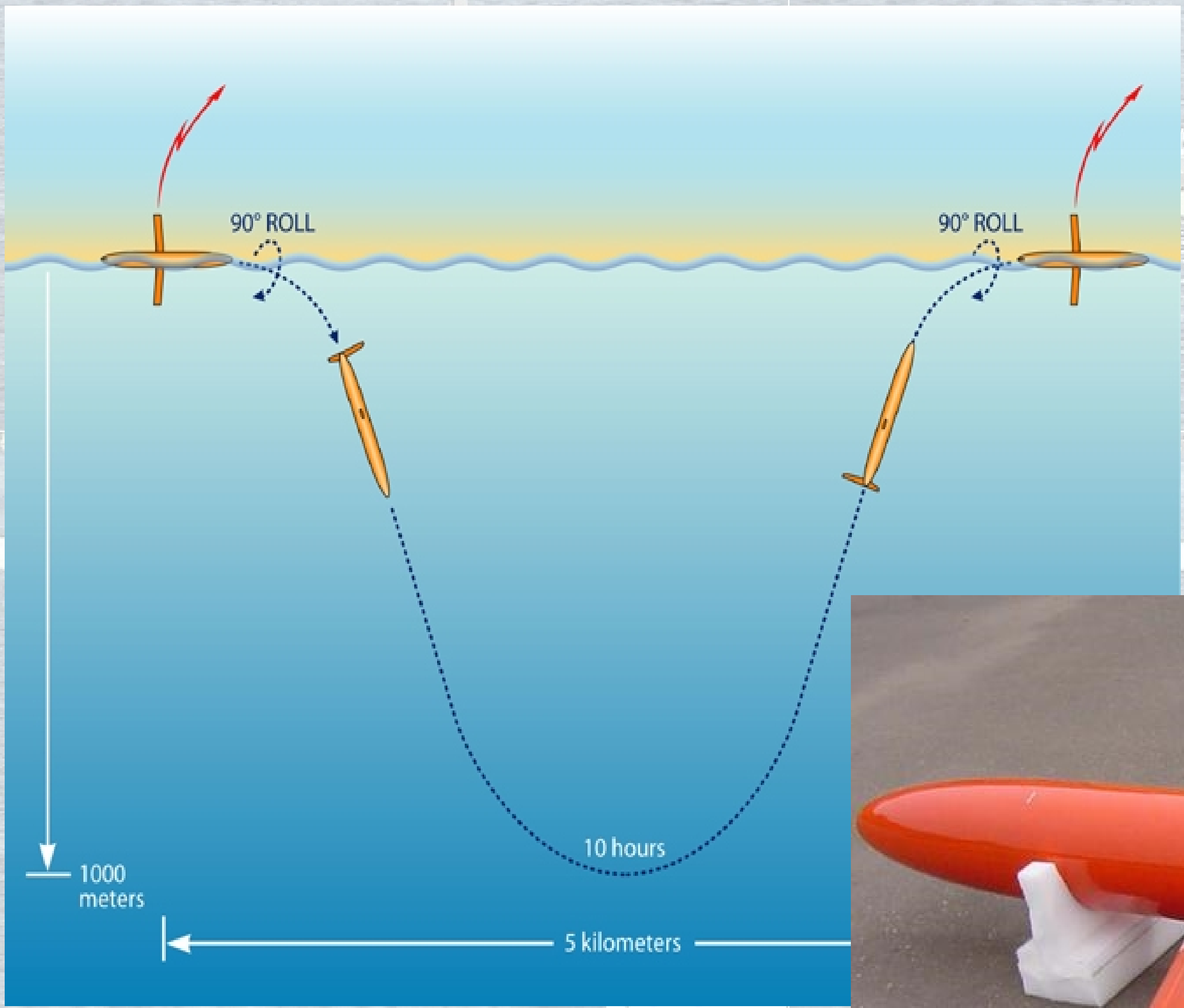
Unmanned Marine Vehicles



Gliders

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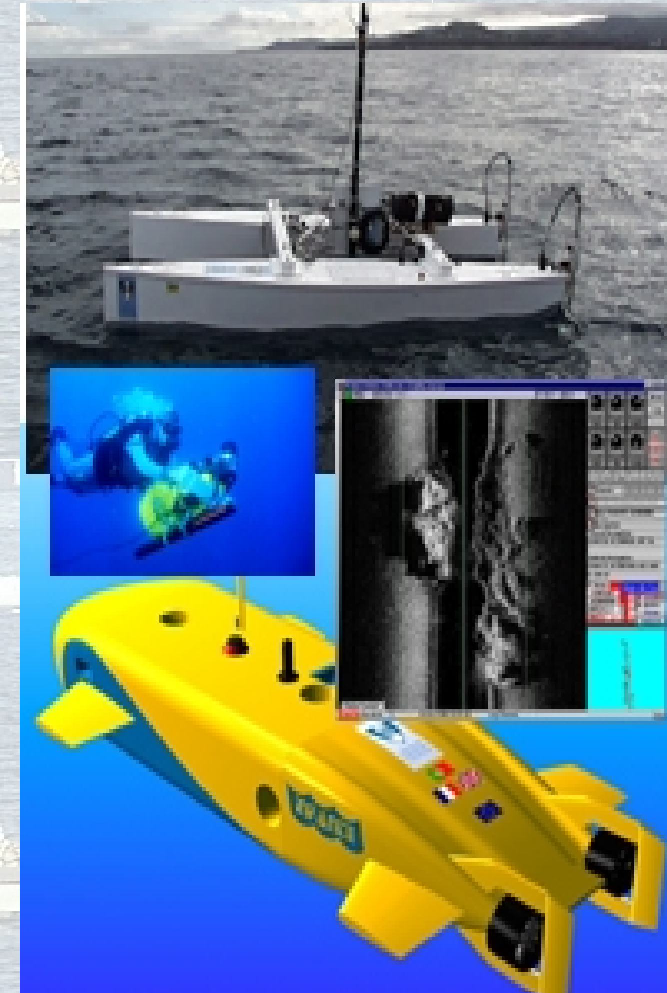
Unmanned Marine Vehicles

USVs

Unmanned
Surface
Vehicles



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CNR-ISSIA UMVs: Romeo ROV

Under-ice exploration & data collection with the Romeo ROV

Terra Nova Bay, Ross Sea, Antarctica 1997-'98

Length	1.30 m
Width	0.90 m
Height	0.96 m
Weight in air	500 kg
Max. depth	500 m
Speed	0.6 m/s forward

Electric propulsion

4 horizontal and 4 vertical thrusters

Tether/Communications

600 m electro-optical link with Ethernet 10 Mbps, 5 x RS232 @ 115 Kbps, 5 x RS422 @ 250 Kbps

Navigation/tracking

Simrad SSBL acoustic positioning system, echo-sounders; high frequency profiling sonar; depth sensor; compass; gyro; inclinometers; vision-based motion estimator

auto depth, heading, speed, altitude; way-point navigation

Cameras/video/lighting

pilot and scientist video cameras + 2 additional video links for custom toolsled instrumentation; video recorder; 6 x 50 W lights

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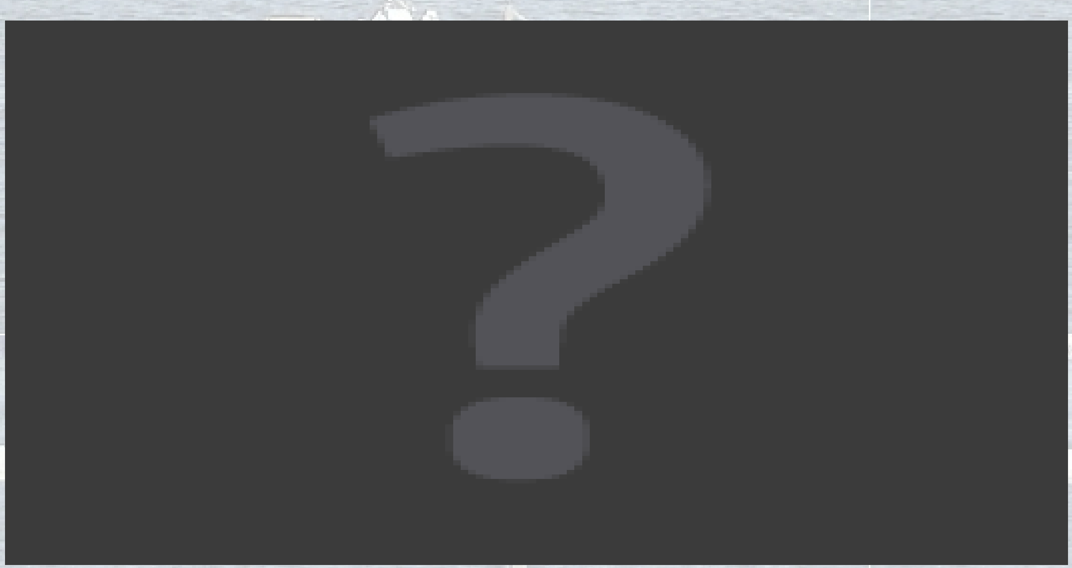
Research topics



Internet-based tele-operation of the Romeo ROV in polar regions
Svalbard islands, Arctic 2002

- **Modelling & identification**
  - identification of the dynamics of a propeller-propulsed UMV using onboard sensor measurements
    - derivation of ***practical*** models
    - definition of suitable maneouvres
      - decoupling identification of drag and steady-state disturbance vs. inertial terms
      - identification based on self-oscillations

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Research topics

Romeo ROV as Antarctic Benthic Shuttle
Terra Nova Bay, Ross Sea, Antarctica 2003-'04

- **Navigation, guidance & control**
  - accurate motion estimation
    - no available measurements of motion derivatives
    - multi-rate multi-resolution measurments
  - accurate motion control
    - heading
    - speed
    - position
    - depth/altitude

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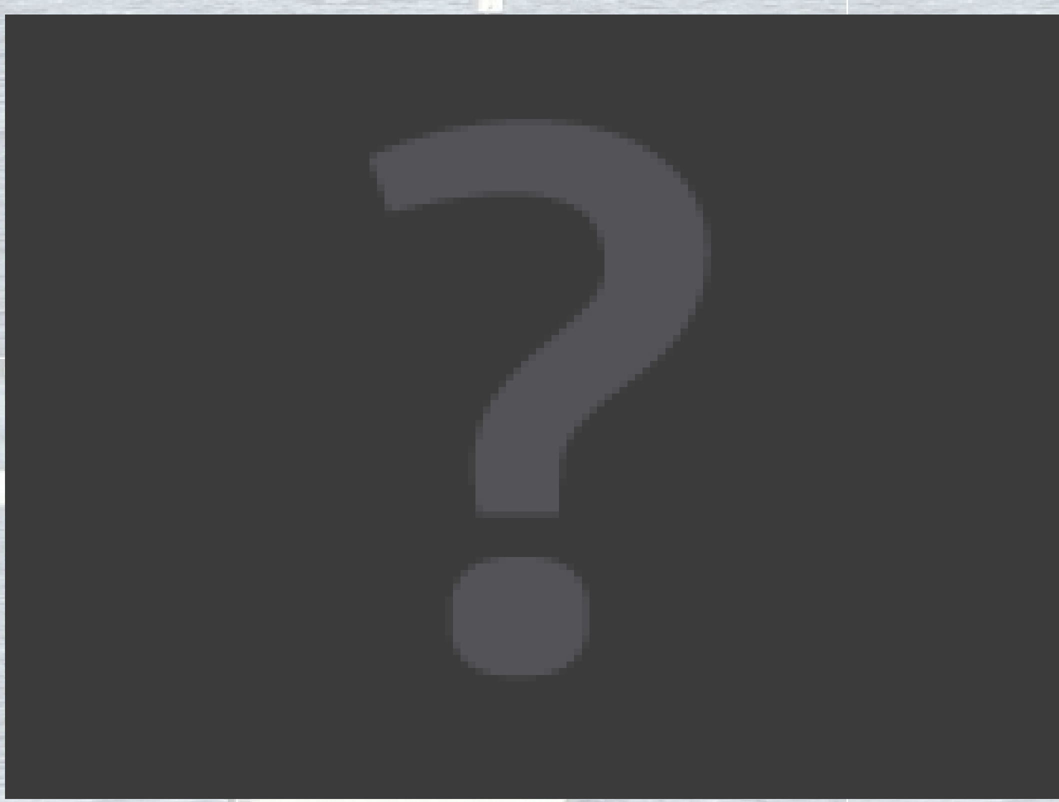
Research topics



Data collection and sampling on underwater thermal vents with the Romeo ROV
Milos island, Aegean Sea 2000

- **SLAM**
  - **Simulataneous Localization And Mapping**
  - vision-based motion estimation
  - video mosaicing

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CNR-ISSIA UMVs: Charlie USV

Charlie USV:
bathymetric survey in coastal area
Murter, Croatia, 2011

Length 2.40 m
Breadth 1.70 m
Weight in air 300 kg
Speed up to 2.0 m/s

Electric propulsion
- 2 DC motors for thrust
- 1 brushless motor for rudder

Communications
- Wireless Ethernet link (high bandwidth)
- Radio modem (safety)

Navigation
- GPS Ashtech
- Kvh Gyro compass
- inclinometer

Cameras
- “pilot” video camera

Sensors
- side-scan sonar
- anemometer

Remote sensor supervision
- on-board signal/image processing
- jpg image transmission on time-variant channel
- remote tuning of sensor parameters

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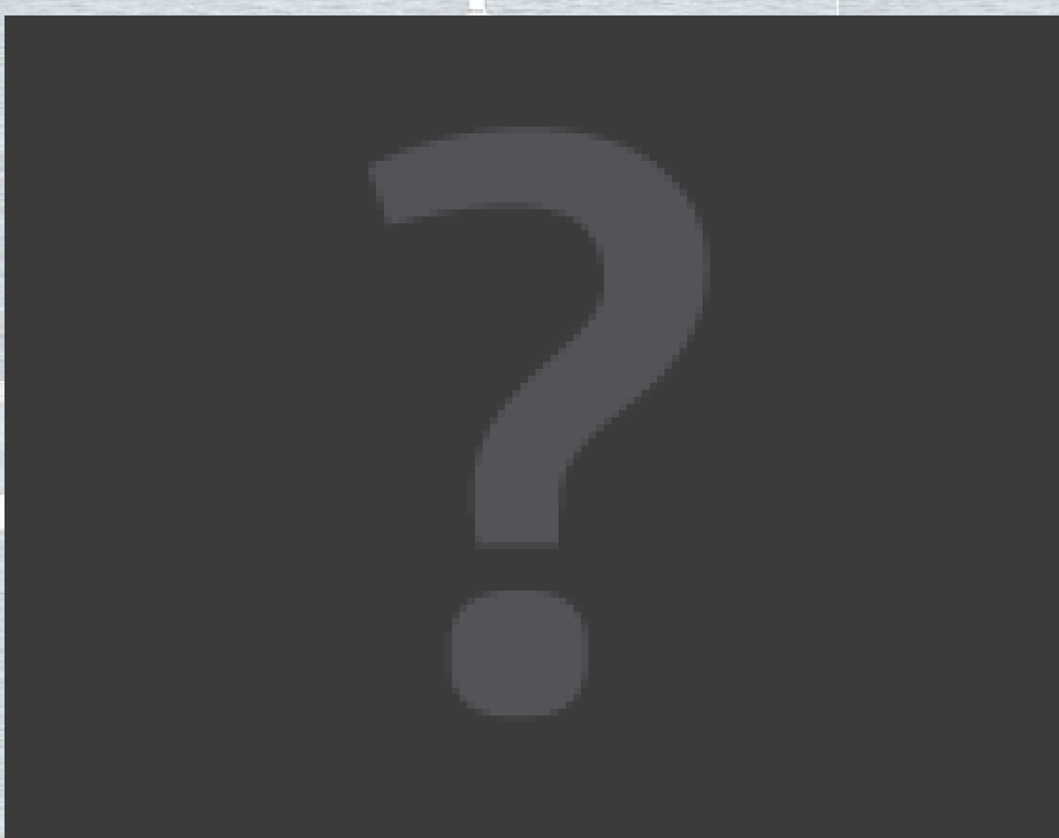
Research topics



Sampling of the sea surface micro-layer with the Charlie USV
Terra Nova Bay, Ross Sea, Antarctica 2004

- **Path-Following**
  - the vehicle is required to converge to and follow a path, without any time specification
- **Path-Tracking**
  - the vehicle is required to track a target that moves along a path
    - path-tracking gives priority to the spatial constraint with respect to the time constraint: the vehicle tries to move along the path and then to zero the range from the target

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USV applications & research topics

Charlie USV & ALANIS dual-mode vessel: cooperative USVs for Rapid Environmental Assessment
Genova Prà harbour, 2009

- **Cooperative guidance of heterogeneous UMVs**
  - vehicle-following
    - path-tracking
  - formation control
    - wing-man
    - collision avoidance
  - swarm

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Robotics in marine environment: main issues (1)

- **high impact logistical constraints** (time requirements, space, interactions with everyday traffic, environment and weather conditions, cost of the support vessel) to execute repeatable field experiments
  - environment and weather conditions can be measured
  - *optimal* experiments can be designed

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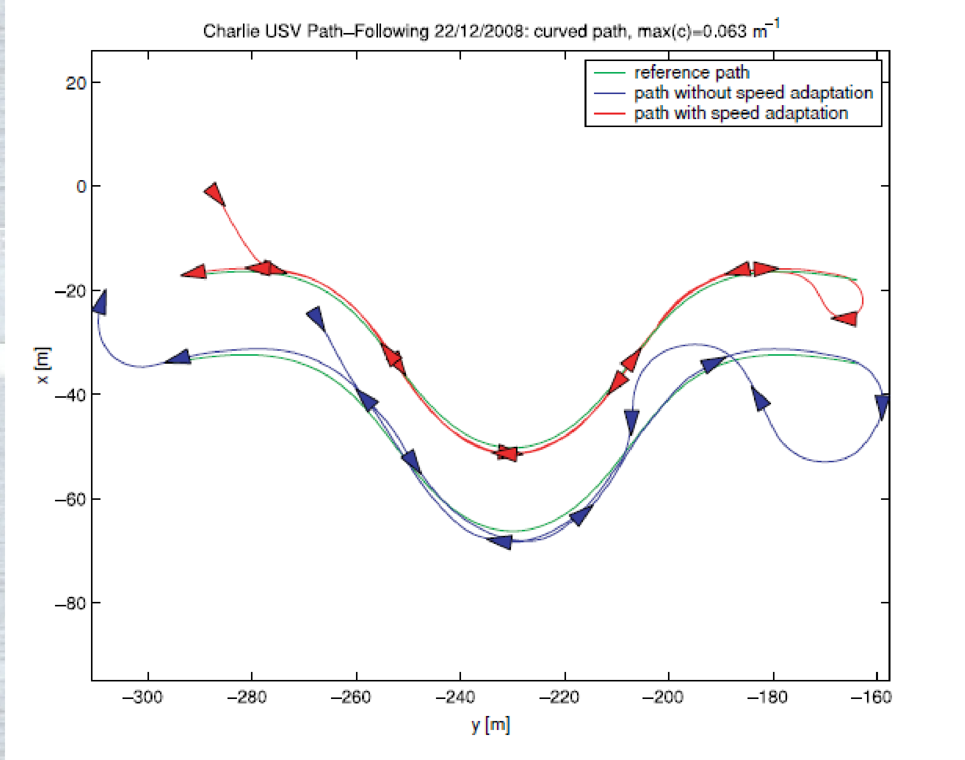
Robotics in marine environment: main issues (2)

- **repeatable initial conditions**
  - it is very difficult (impossible?) to drive a UMV in a pre-defined starting position and speed
    - *generic solution for path-following*: relative position of the target path with respect to the actual vehicle position
      - logistical constraints, e.g. free area available for tests
    - *feasible, verified solution for path-following*: moving along the same path in opposite directions
      - the vehicle is guaranteed to remain in a stripe around the target path



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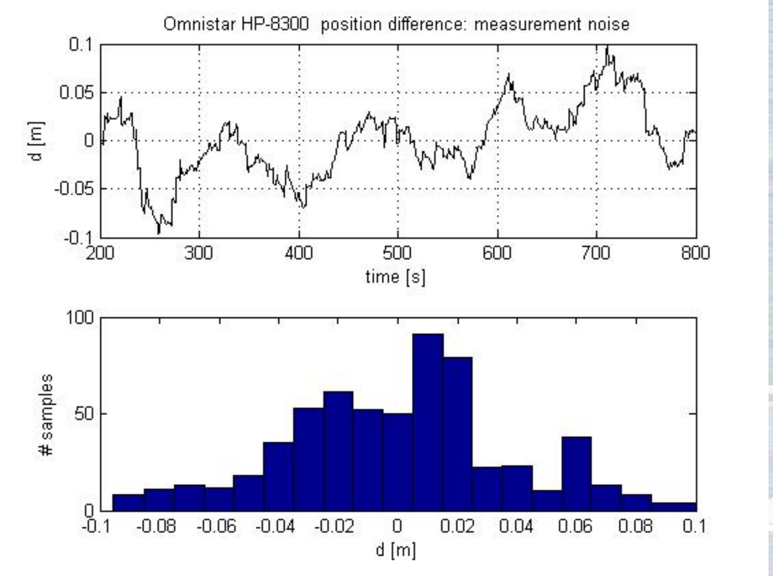
Robotics in marine environment: main issues (3)

- **ground-truthing**
  - case 1: artificial landmarks in the test site
    - example: surface vessel following
      - Goal: to guarantee that the two vehicles are in the same place according to their GPS devices
        - GPS devices could have different time-varying offsets
      - Step 1: measure the offset of two GPS devices
      - Step 2: use artificial landmarks, such as the buoys delimiting the lanes of a regatta field



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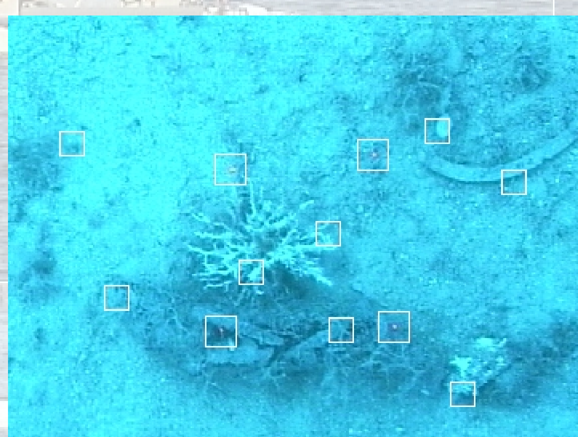
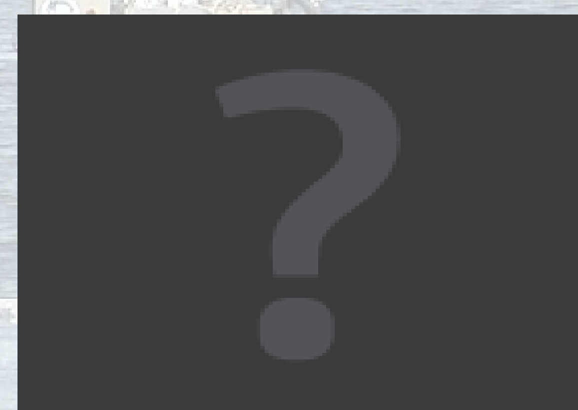
Robotics in marine environment: main issues (3)

- **ground-truthing**
  - case 2: natural landmarks in the test site
    - Example: vision-based motion estimation for ROVs
      - Goal: to check the precision of dead-reckoning based on visual odometry for estimating the motion of ROVs
      - Step 1: determining a human-detectable visual target
      - Step 2: maneouvring the ROV in order to periodically re-visit the detected visual target - **this step is not obvious**
      - Step 3: computing the displacement between two images containg the detected target and compare it with the estimated displacement with dead-reckoning





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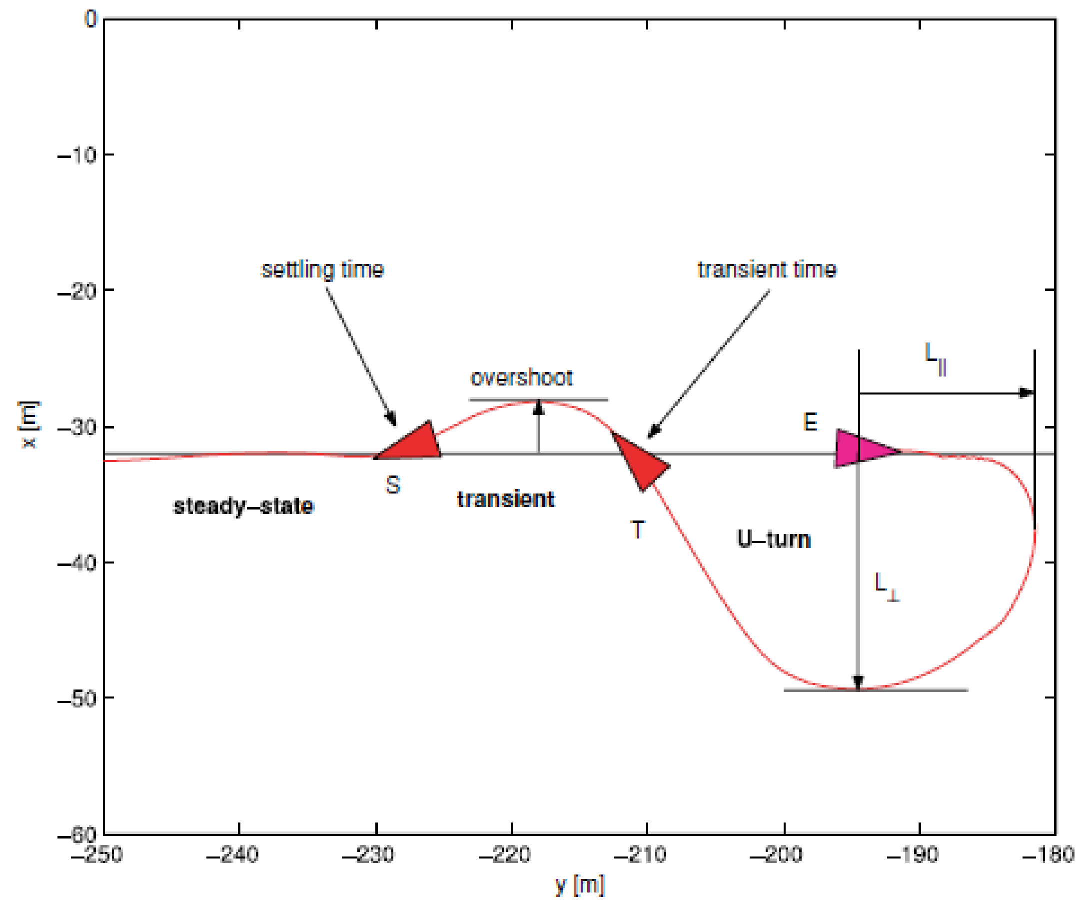
Robotics in marine environment: main issues (4)

- **metrics**
  - definition of quantitative performance index
    - maneouvring phases and measured quantities, e.g. line-following
      - U-turn (path-approach)
        - $L_{||}$, $L_{\perp}$, $A_{U\text{-turn}}$
      - Transient
        - overshoot
      - Steady-state
        - $$\bar{A}_{ss} = \frac{A_{ss}}{\Delta s_{ss}}$$



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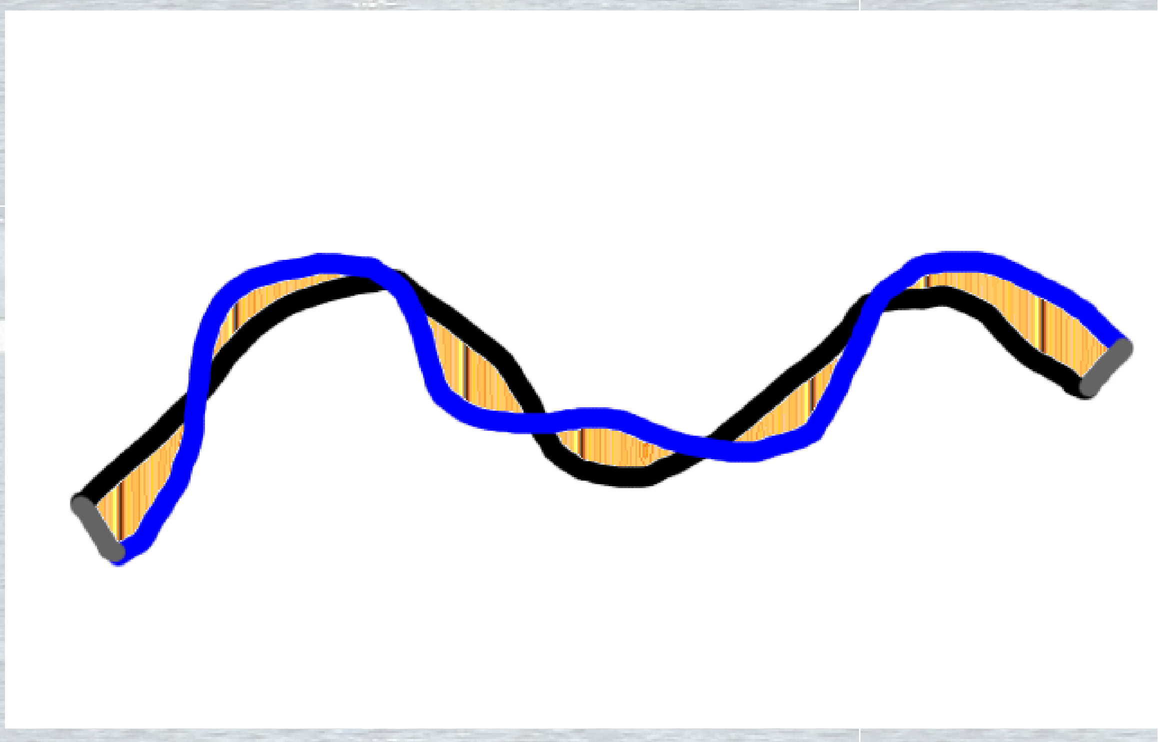
Robotics in marine environment: main issues (4)

- **metrics**
  - definition of quantitative performance index
    - **path-following**
      - given two paths in the horizontal plane defining their **distance**
      - **candidate metrics**
        - area between the two paths
    - **path-tracking**
      - need of combining the previous, high priority quantity, with the time position tracking error
        - ...



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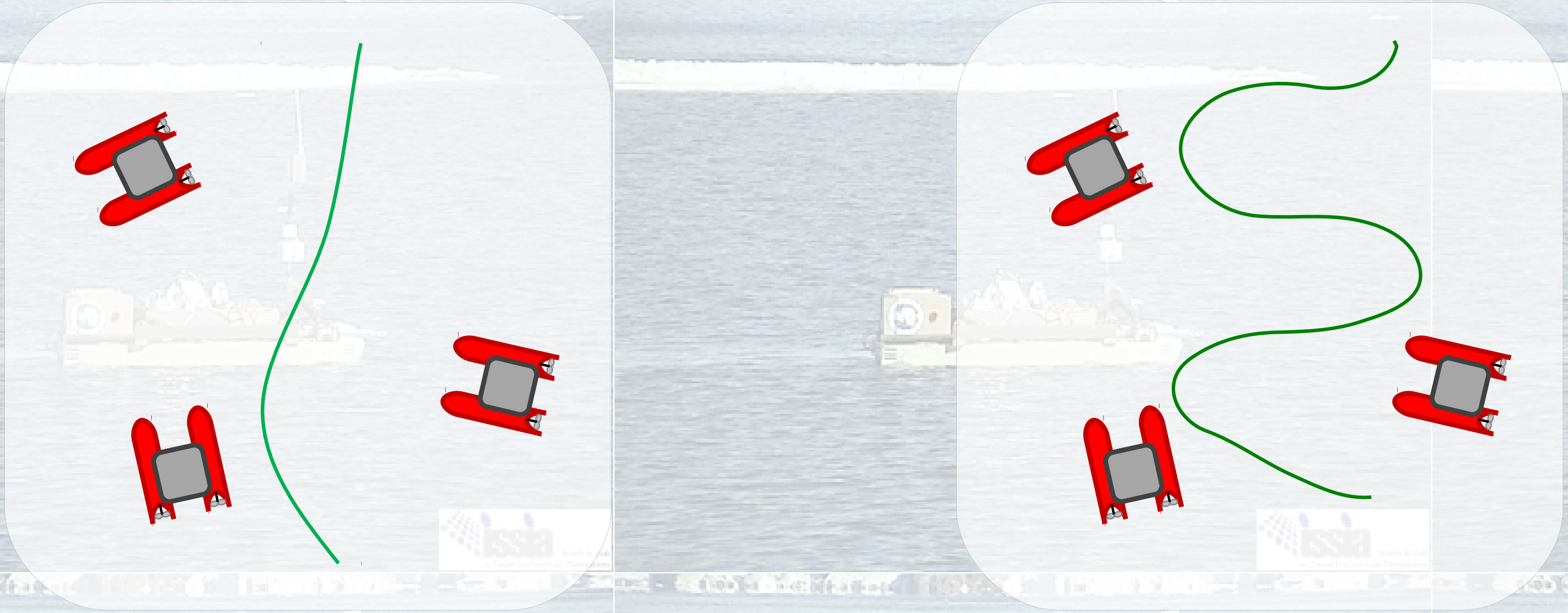
Robotics in marine environment: main issues (5)

- **Good Experimental Methodology**
  - definition of a minimum set of experiments (e.g. in the case of path-following, target paths & initial conditions) to evaluate performance



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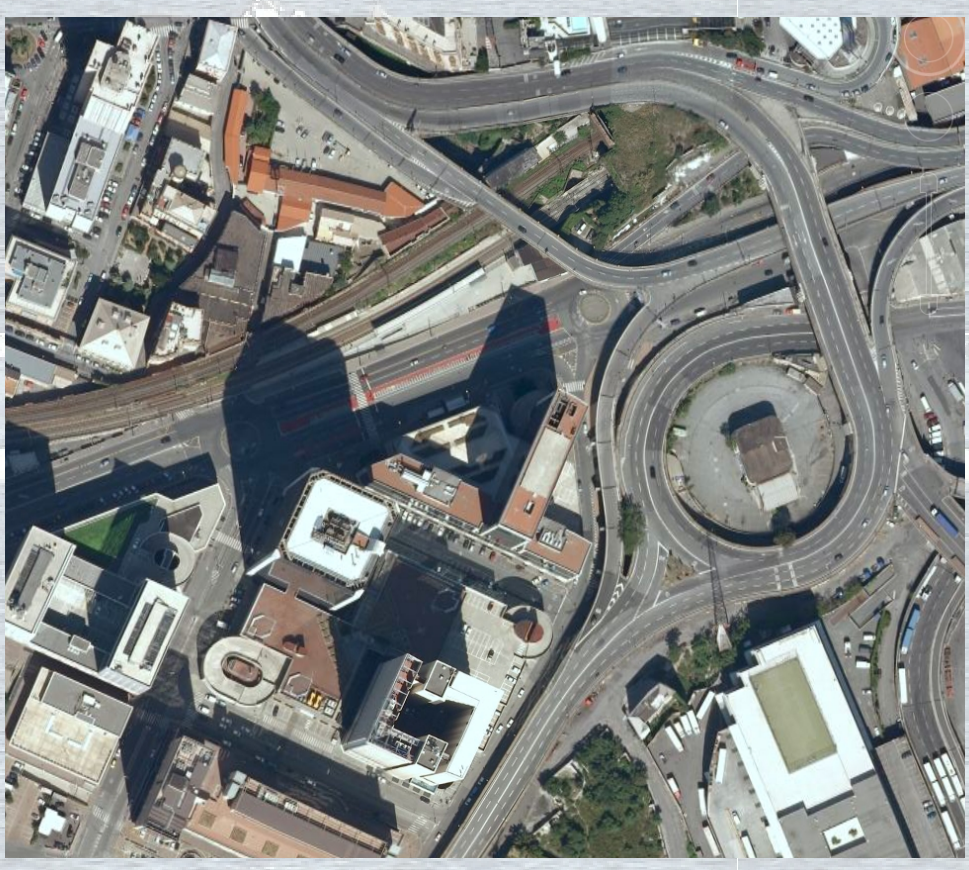
Visit to CNR-ISSIA Lab

- CNR-ISSIA Genova laboratory is located in Via De Marini 6, Genova Sampierdarena
- If you are interested in visiting the lab and/or discuss the topics of this presentation, please contact Prof. Eva Riccomagno or myself.



Hints from other disciplines

- From a talk with Silvio Parodi, Professor of Oncology, School of Medicine, Università di Genova
  - “The scientist should not neglect the experiments that do not match the expected/hoped behavior of the investigated phenomenon. Not infrequently, at least in the bio-medical world, they are much more than possible outliers. The objective complexity, resource and time requirements of some crucial experiments, make practically difficult to repeat the entire procedure more than 3-5 times. Discarding one of these repeated experiments because of adduced deficiencies / improprieties, *established however only a posteriori*, is formally unacceptable. Even intuitively, a result that could be confirmed only 3/5 times is totally different from a result that could be confirmed 3/3 times!”

focus on *bad* experiments

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Conclusions

- Complex logistics, unforeseen environmental conditions, structural uncertainty, determining high resource and time requirements for the execution of experiments, contribute to keep marine robotics results at the level of **naive demonstration of successful case studies**

- **Goal**: **making marine robotics an experimental science**

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Why I am here

- What can be done towards the goal of **making marine robotics an experimental science**?
  - **improving metrics definition**
  - defining protocols for the measurement of environmental conditions
  - defining procedures for the repetition of experiments
    - automation of event-based task sequences, i.e. basic mission control, can dramatically help
    - **defining methodologies for statistical characterisation of experiments**
  - **discussing *unexpected* results**