An experimental validation of a robust controller on the VAIMOS autonomous sailboat

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VAIMOS, an autonomous sailboat for oceanography

- VAIMOS = Voilier Autonome Instrumenté pour Mesures Océanographiques de Surface
  - Collaboration between Ifremer (mechanics and electronics) / ENSTA Bretagne (automatics and embedded computer science)

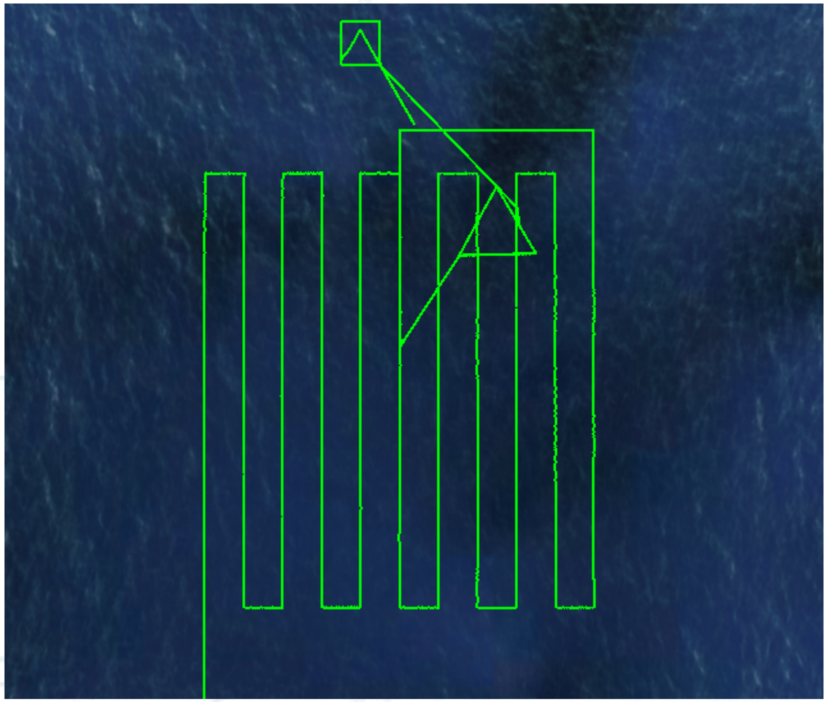
VAIMOS, an autonomous sailboat for oceanography

- Purpose
  - Oceanographic measurements of various parameters near the water surface and at a depth of about one meter (temperature, salinity, chlorophyll, turbidity…)
  - Assist and / or replace oceanographic boats, fixed or floating buoys, towed instruments currently used

VAIMOS, an autonomous sailboat for oceanography

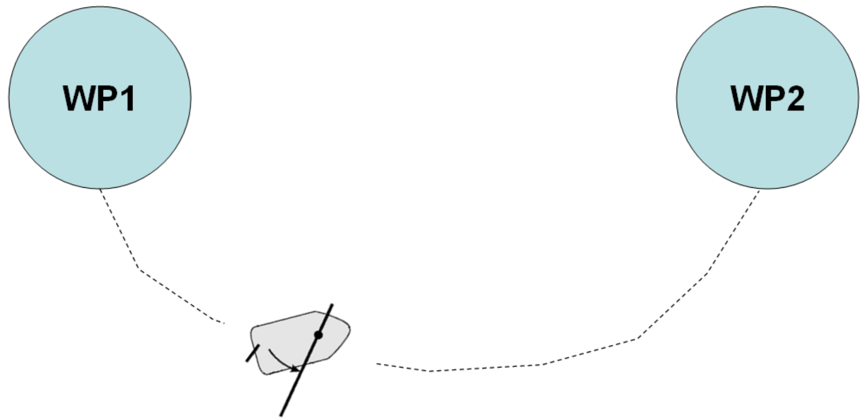
Autonomy / control

- Purpose
  - Cover autonomously an area as accurately as possible while the accompanying oceanographic ship has other activities



Autonomy / control

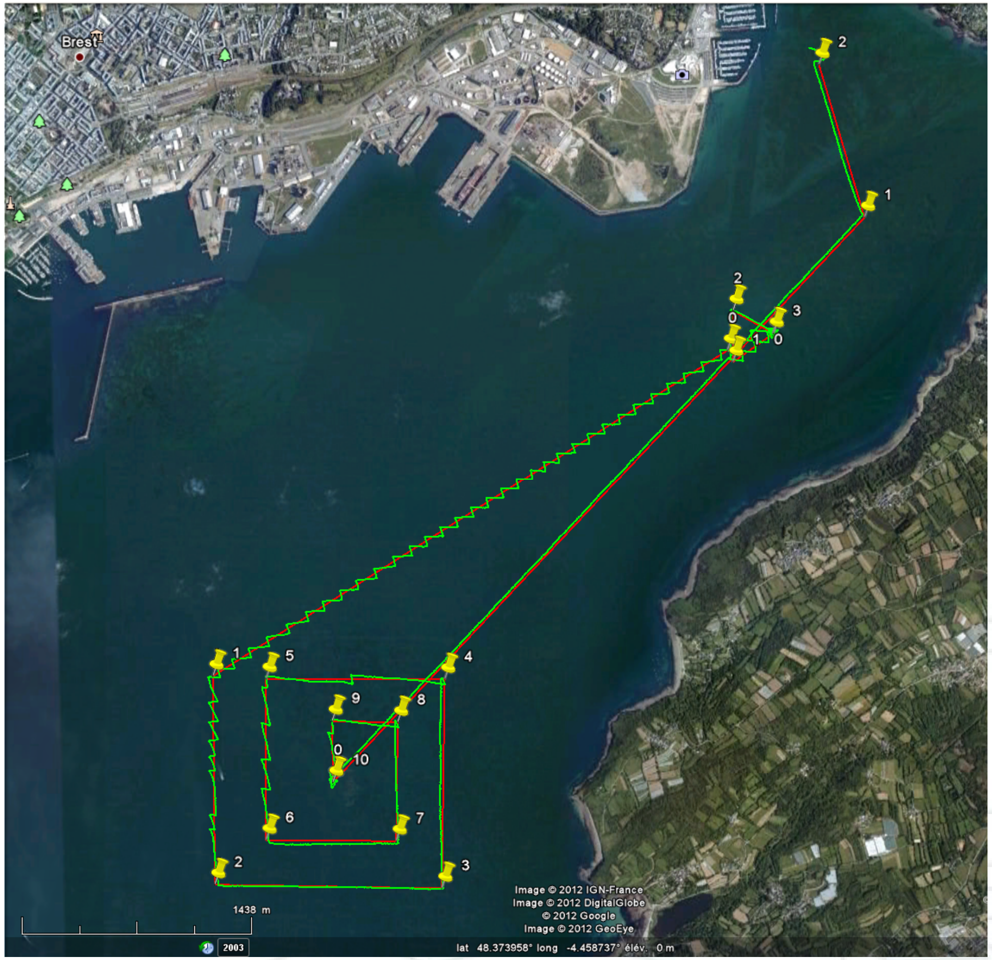
- From waypoints following to line following
  - Primitive heading control loop
  - Existing approaches : basic waypoint following
    - The robot follows a heading in direction of its waypoint
    - Waypoint reached when in a predefined radius
    - Problem : nothing prevent the drift between waypoints (because of currents...)

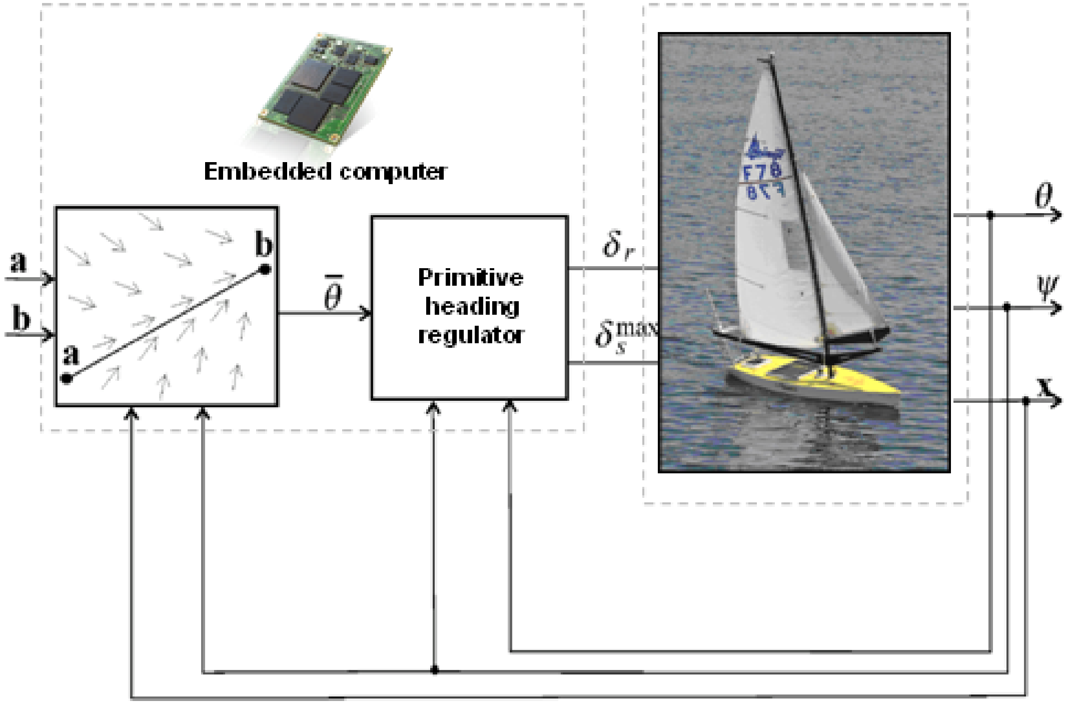


Autonomy / control

ENSTA Bretagne

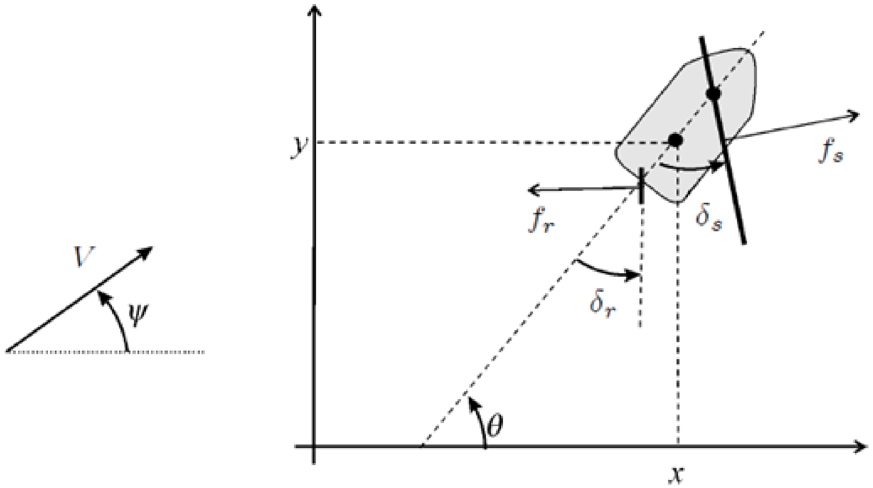
- Line following

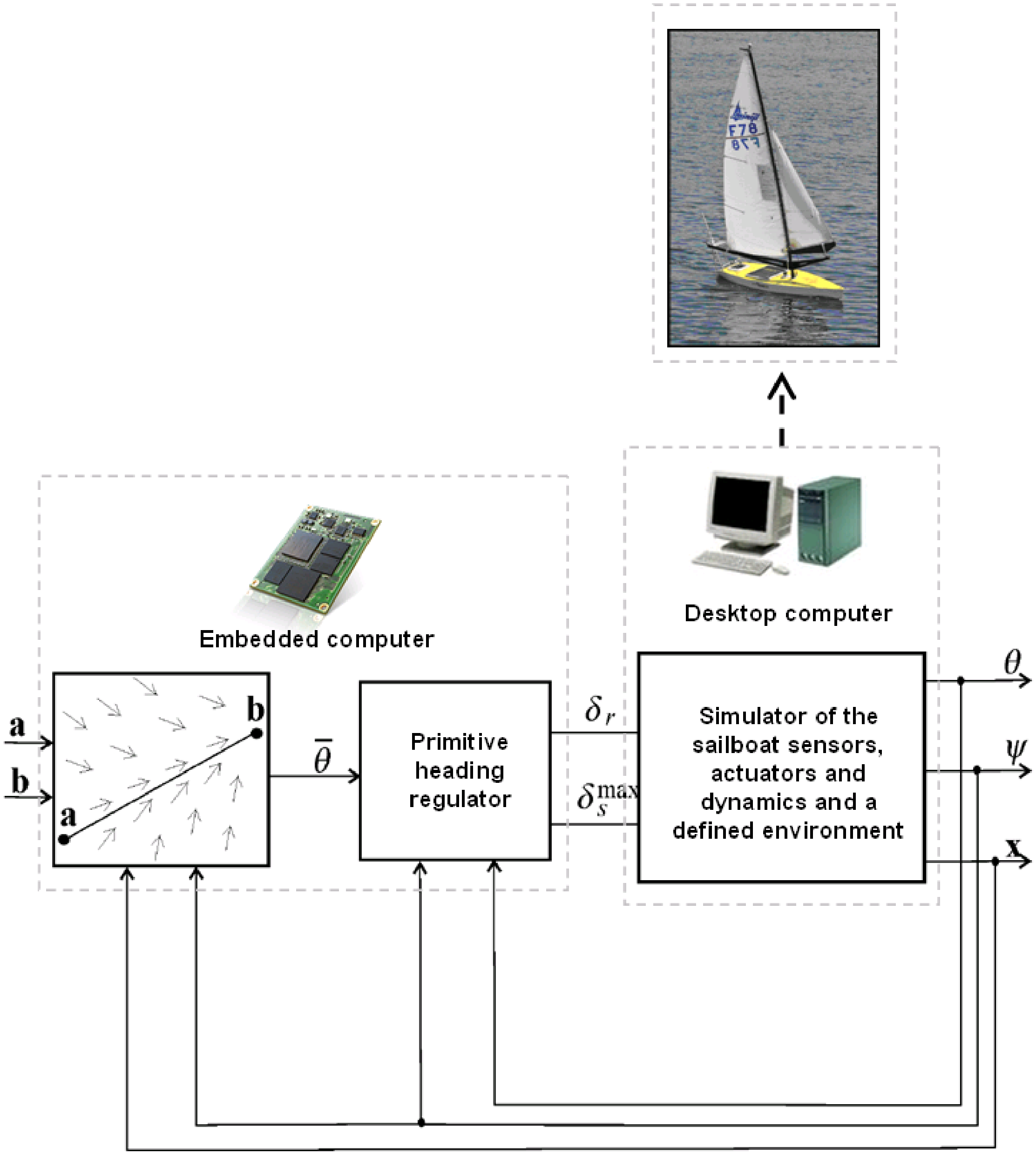




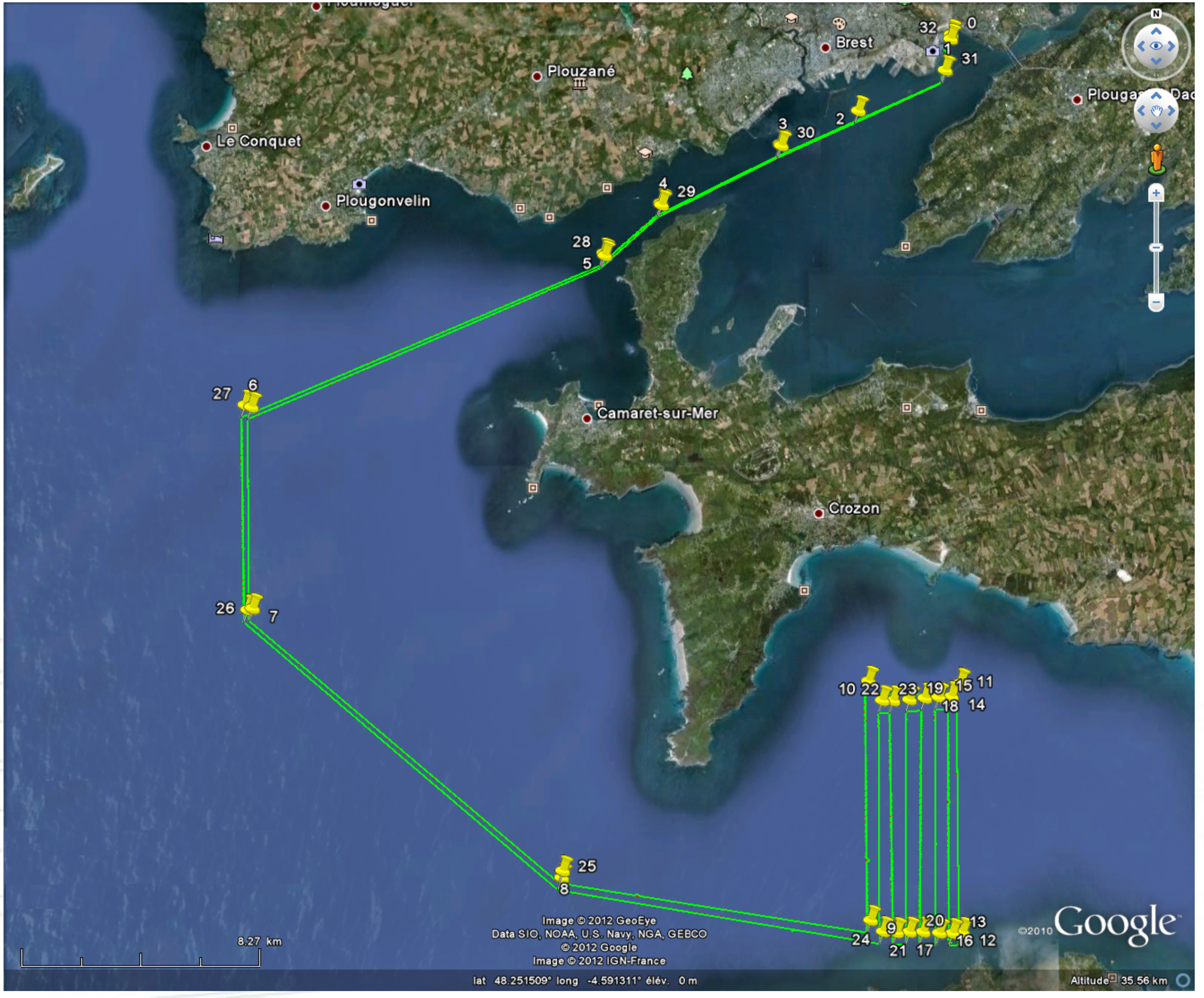
HIL simulation

$$
\begin{cases}
\sigma = \cos(\theta - \psi) + \cos(\delta_{s\,\max}) \\
\delta_s = \begin{cases} \pi - \theta + \psi & \text{if } \sigma < 0 \\ \delta_{s\,\max}\operatorname{sign}(\sin(\theta - \psi)) & \text{otherwise} \end{cases} \\
f_r = \alpha_r v \sin(\delta_r) \\
f_s = \alpha_s V \sin(\theta + \delta_s - \psi) \\
\dot{x} = v\cos(\theta) + \beta V \cos(\psi) + V_c \cos(\psi_c) \\
\dot{y} = v\sin(\theta) + \beta V \sin(\psi) + V_c \sin(\psi_c) \\
\dot{\theta} = \omega \\
\dot{\omega} = \frac{(l - r_s\cos(\delta_s))f_s - r_r\cos(\delta_r)f_r - \alpha_\theta\omega + \alpha_w h_w}{J_z} \\
\dot{v} = \frac{\sin(\delta_s)f_s - \sin(\delta_r)f_r - \alpha_f v^2}{m} \\
\ddot{\varphi} = \frac{-\alpha_\varphi\dot{\varphi} + f_s h_s \cos(\delta_v)\cos(\varphi) - m_{eq} l_{eq} g \sin(\varphi)}{J_x} \\
\dot{\varphi} = \dot{\varphi}
\end{cases}
$$

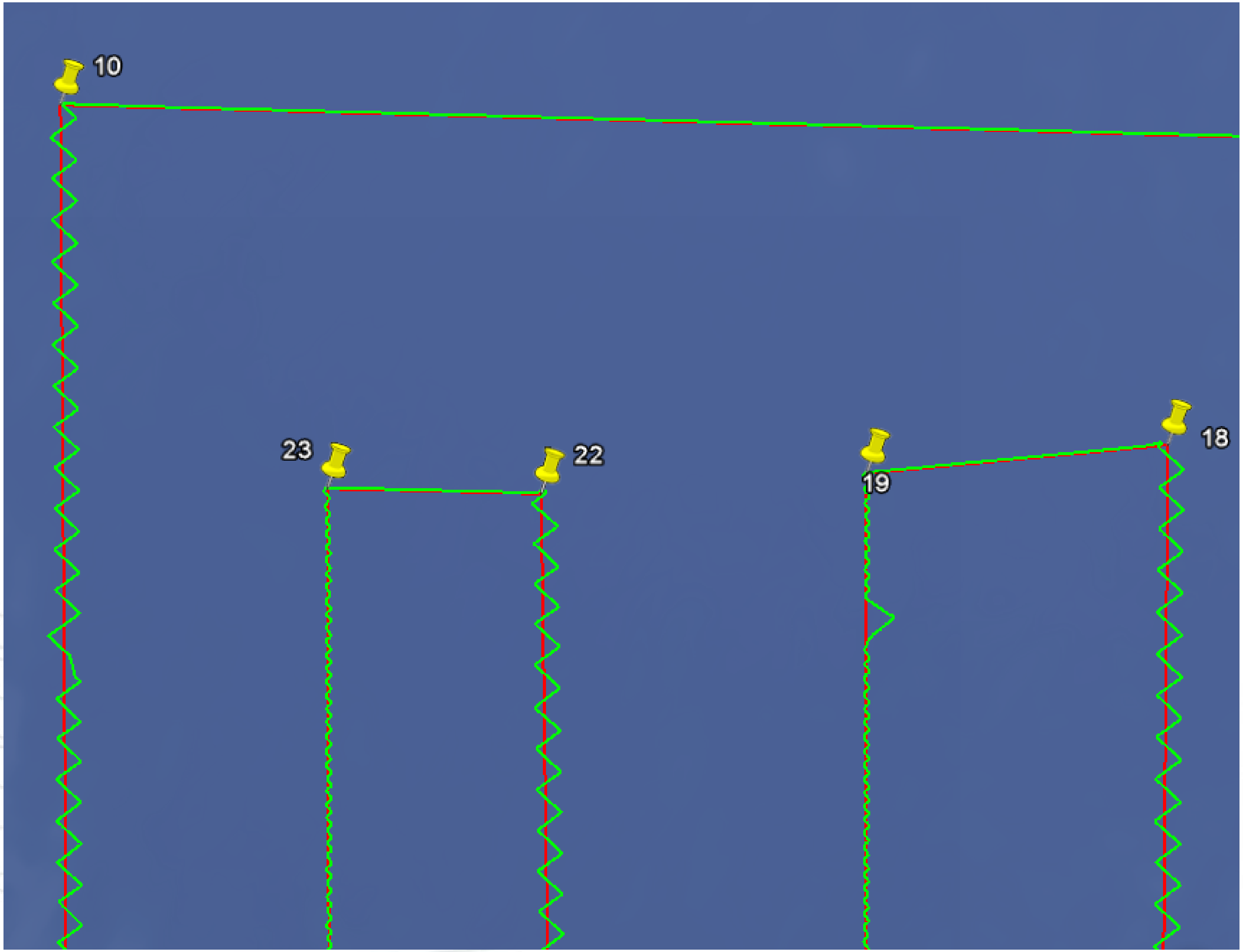




HIL simulation

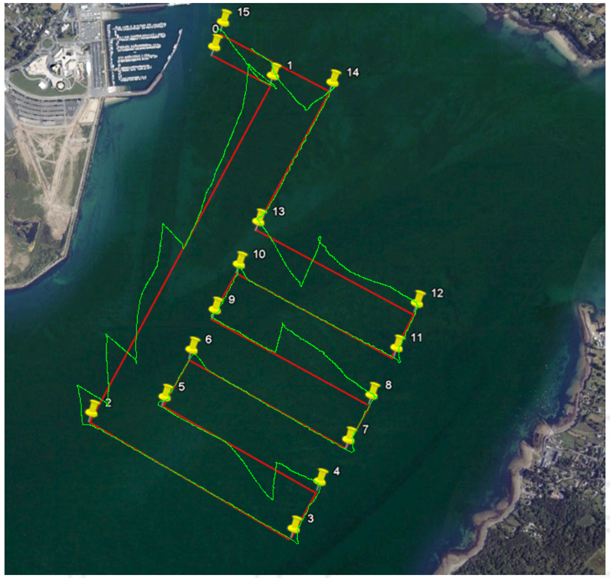


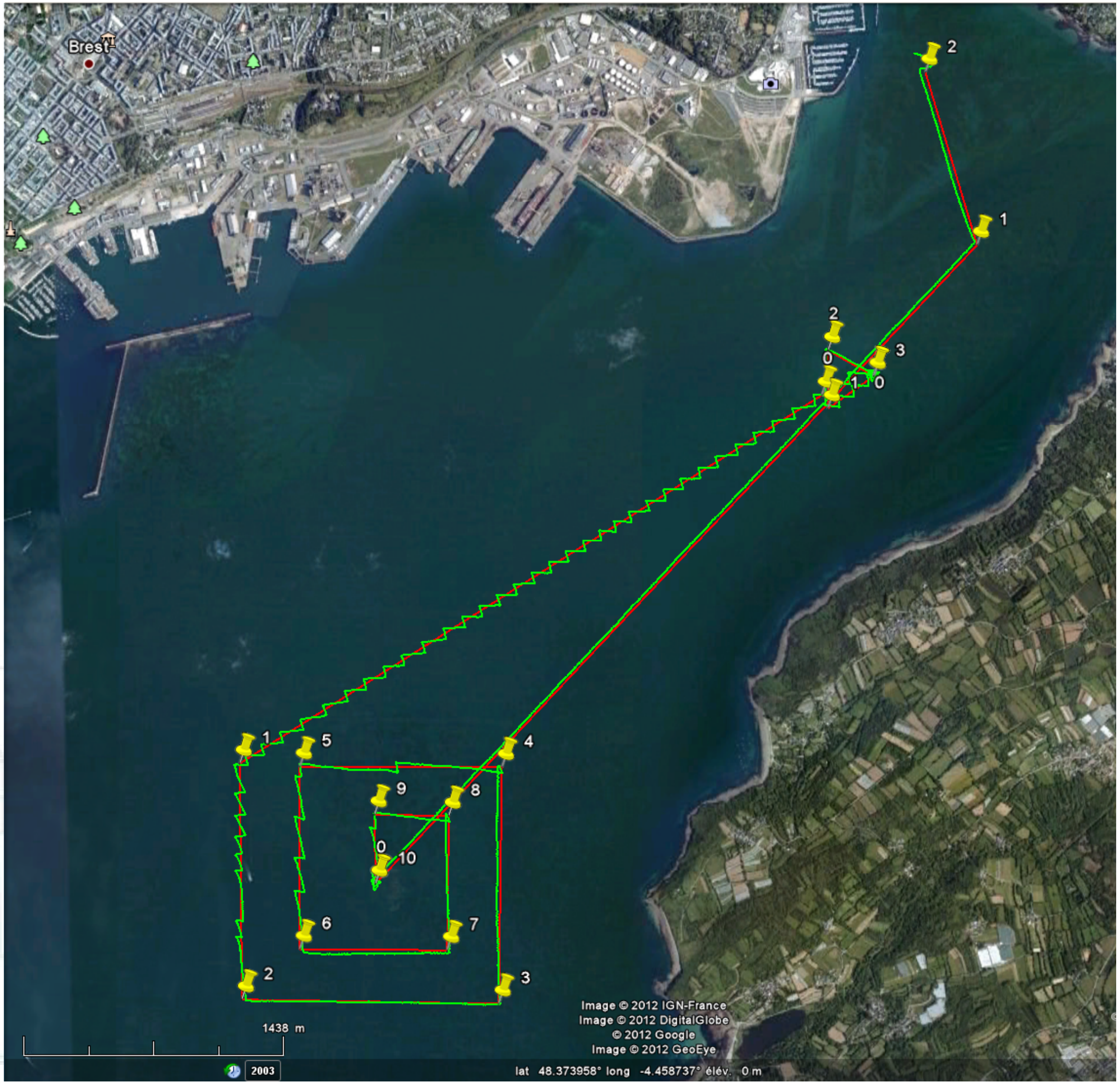
HIL simulation



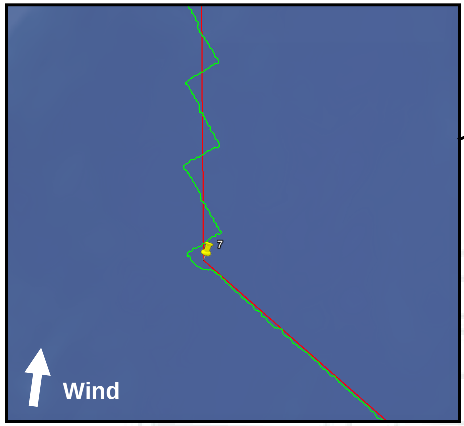
HIL simulation

Real tests




Brest
1438 m
Image © 2012 IGN-France
Image © 2012 DigitalGlobe
© 2012 Google
Image © 2012 GeoEye
2003
lat 48.373958° long -4.458737° élév. 0 m

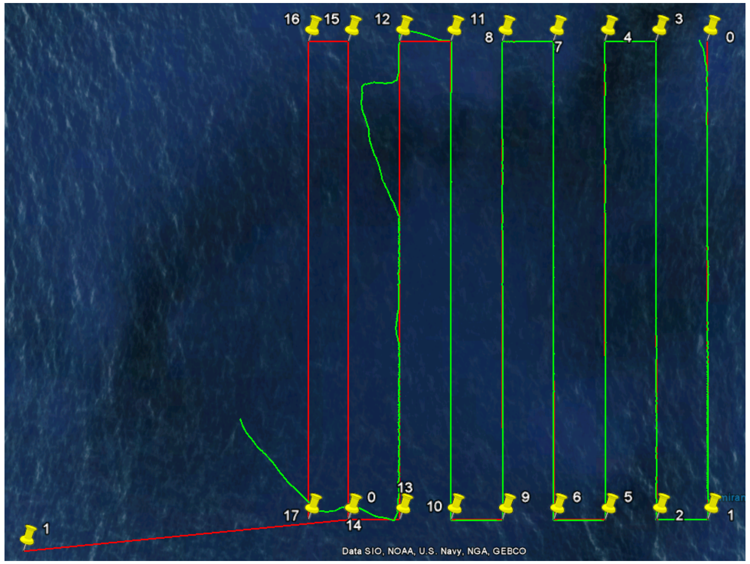
Real tests

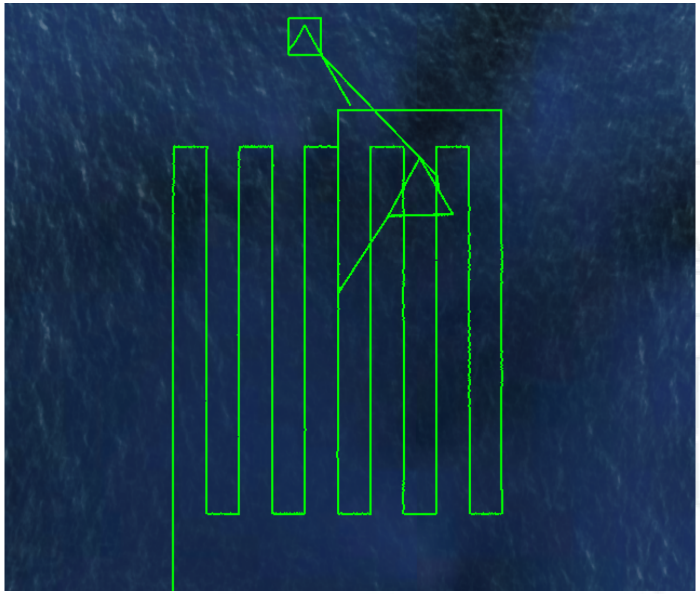


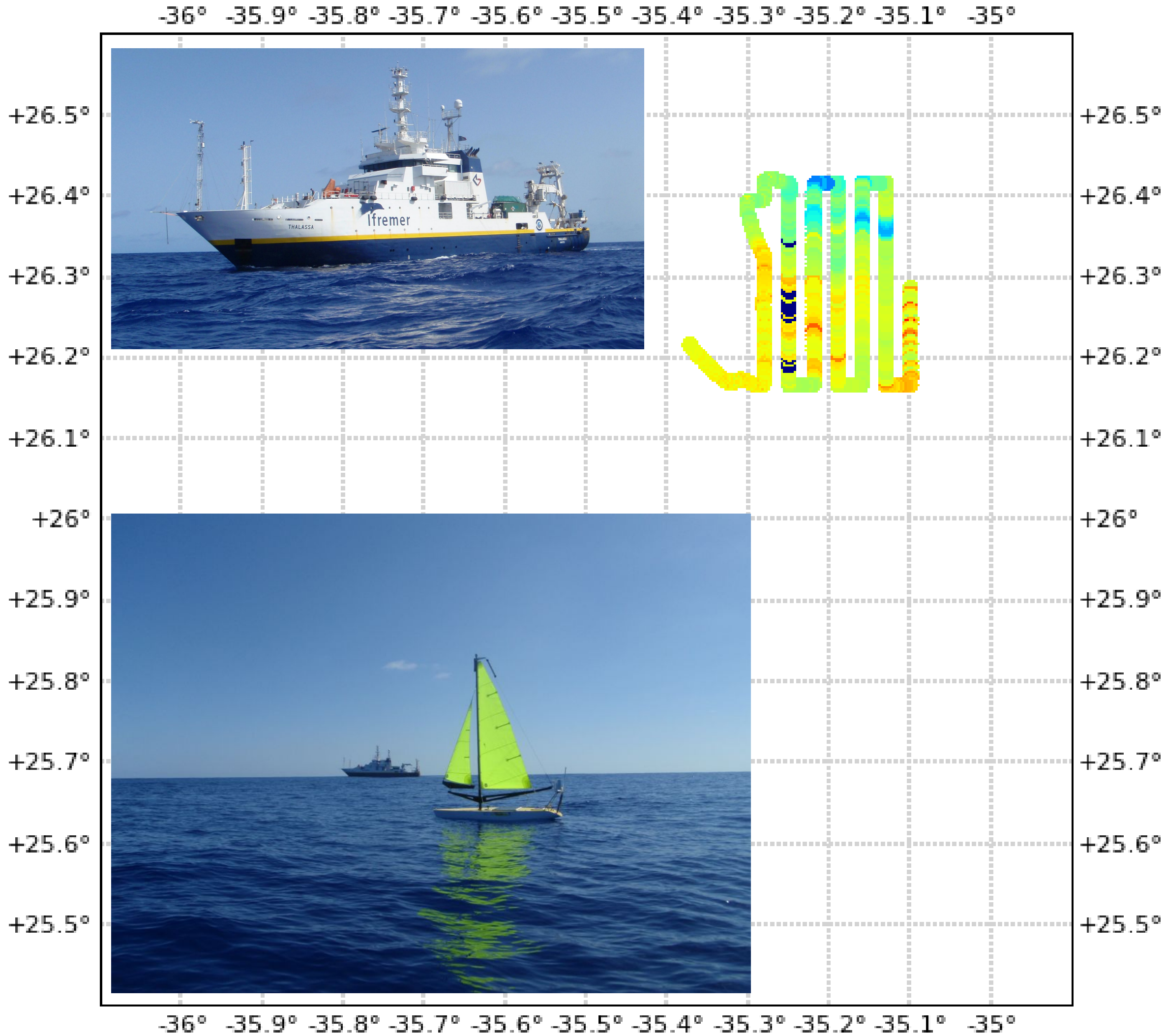
Details of a change between tack and nominal route, decided by the robot

Desired Brest-Douarnenez trajectory (red lines made by yellow waypoints) and effective trajectory (green)

Real tests

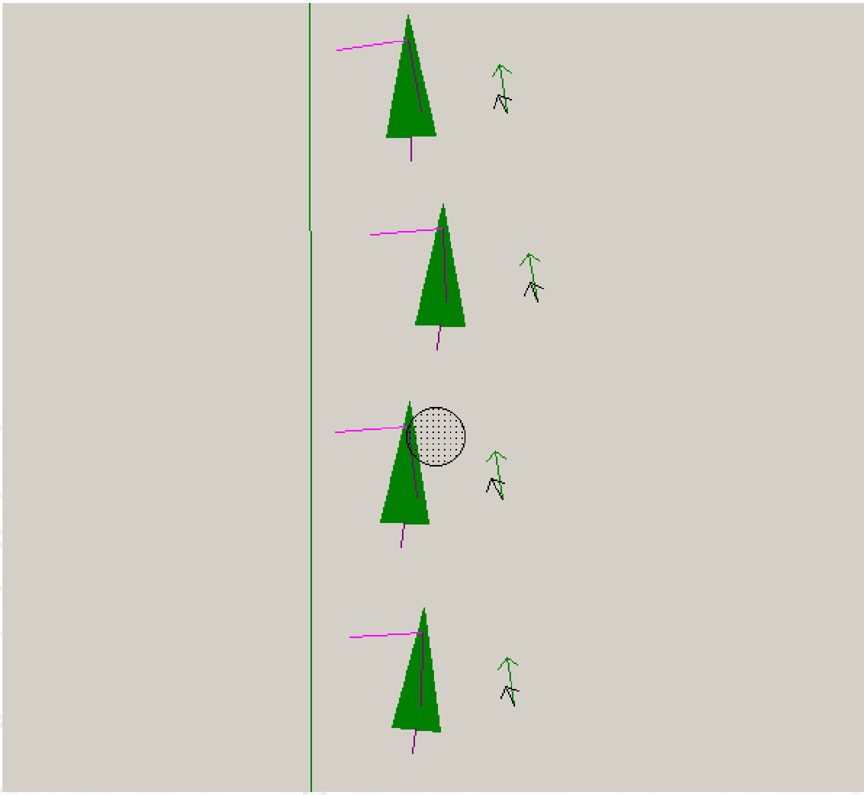

Data SIO, NOAA, U.S. Navy, NGA, GEBCO




-36° -35.9° -35.8° -35.7° -35.6° -35.5° -35.4° -35.3° -35.2° -35.1° -35°
+26.5°
+26.4°
+26.3°
+26.2°
+26.1°
+26°
+25.9°
+25.8°
+25.7°
+25.6°
+25.5°
Ifremer

Real tests

- Analysis of data from the experiments using a dashdoard (during the tests and after)



Questions?