Marine Systems & Robotics
Biomimetic Robotics

Prof. Dr. Maarja Kruusmaa

http://impact.uni-bremen.de/

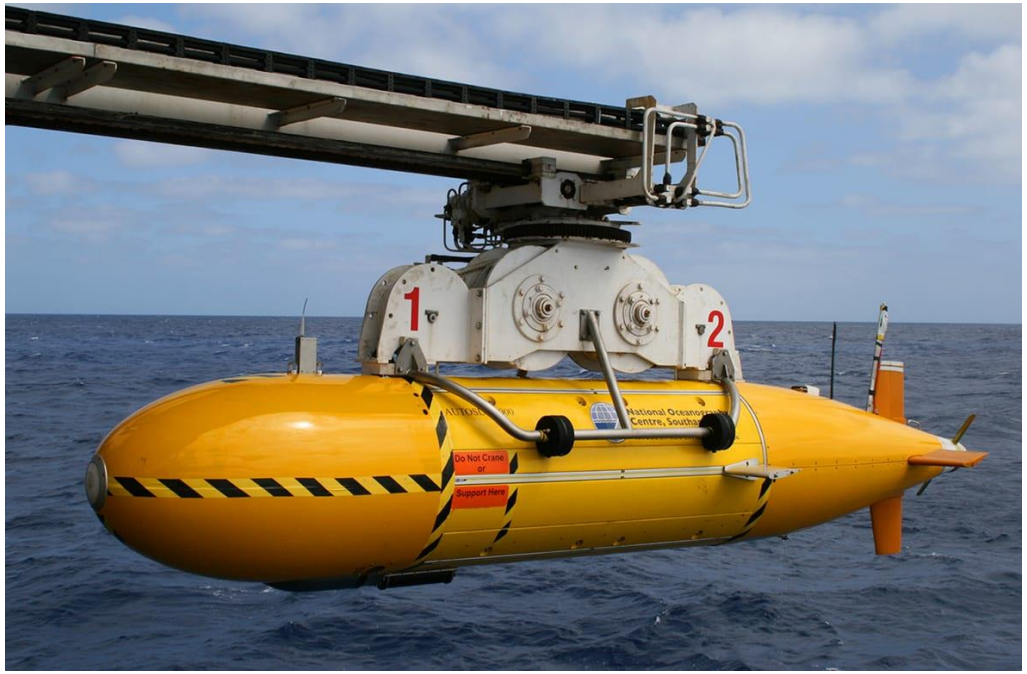
Trends and Megatrends

1962

2008

2012

Trends and Megatrends



Autosub 6000

ROV Hercules

Trends and Megatrends

Blueye

iBubble

Quadrion

Challenges of close and shallow

ice

vegetation

rapids

waves

mud

confined spaces

marum

JACOBS UNIVERSITY

TAL TECH

National Technical University of Athens

University of Zagreb

Universitat de Girona

IST TÉCNICO LISBOA

Design challengies of shallow water

- **Disturbances** – waves, currents, swell
- **Low visibility** – visual inspection needs to be close to surfaces
- **Sensor noise** – reflections, attenuation, aliasing
- **Small size** – miniaturisation of hardware and payload
- **Control** – high maneuverability

New challenge for AUVs: close and shallow

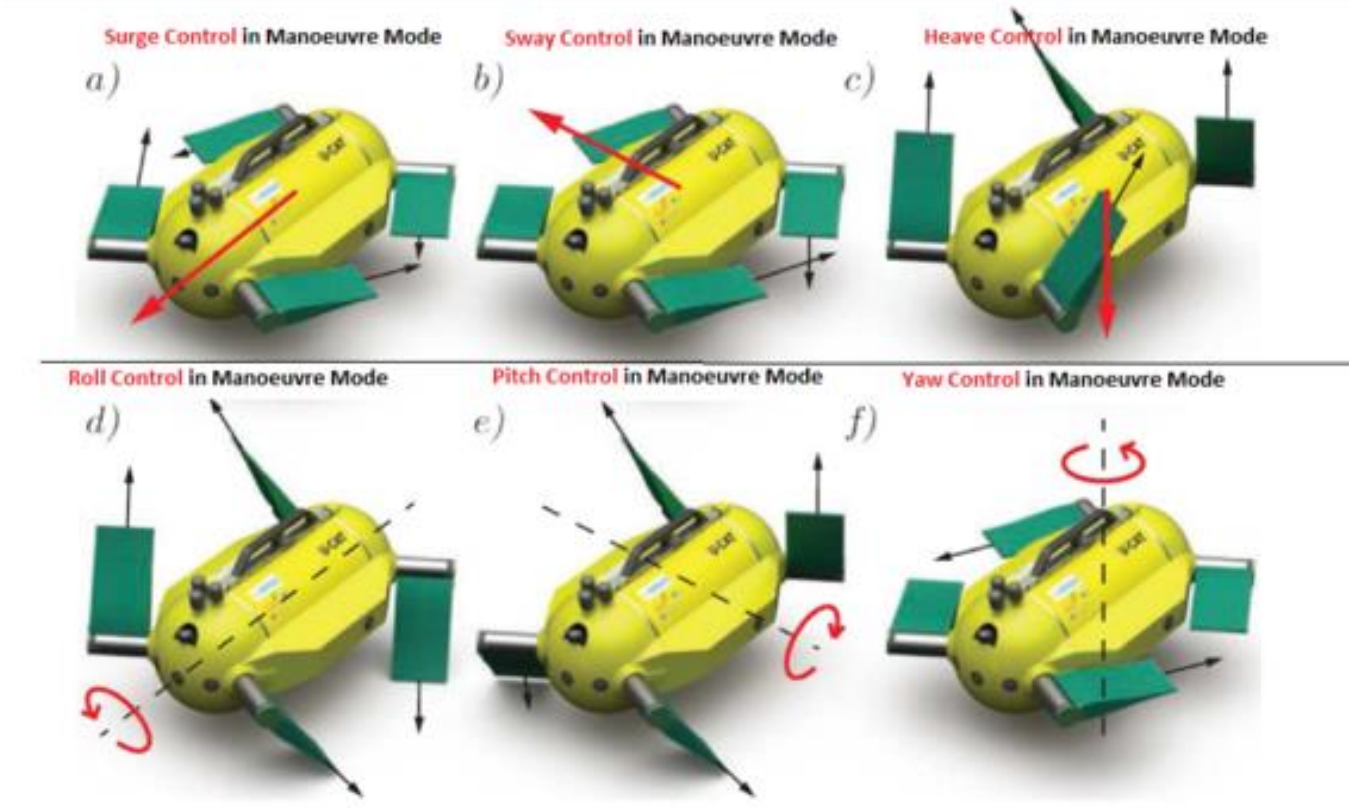
Design paradox for shallow water robotics:

- Going shallow means going small
- Small means less mass and less inertia
- Less mass and inertia means more sensitive to disturbances
- Disturbance rejection means more controllability
- Controllability means more controllable DOFs
- Which means higher mechanical complexity
- Which means larger vehicles

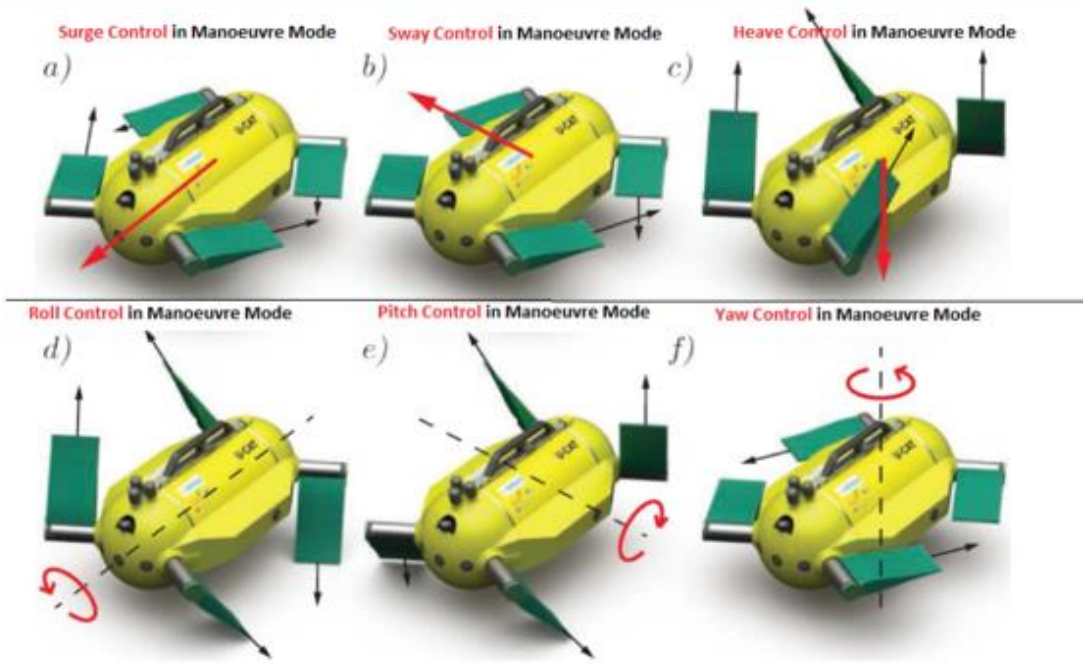
Design and control a small agile AUV: why fins?

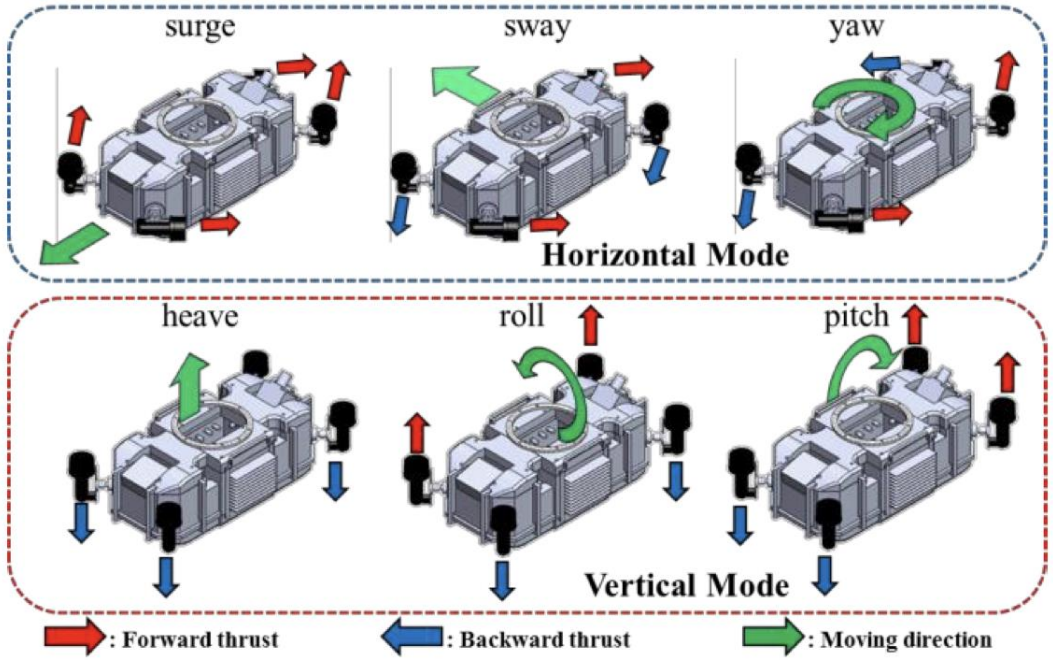
Salumäe, T. et al. "Motion control of a hovering biomimetic four-fin underwater robot."
IEEE Journal of Oceanic Engineering 44.1 (2017): 54-71.

Control challenges: 6 DOF control with 4 actuators



Control challenges: 6 DOF control with 4 actuators

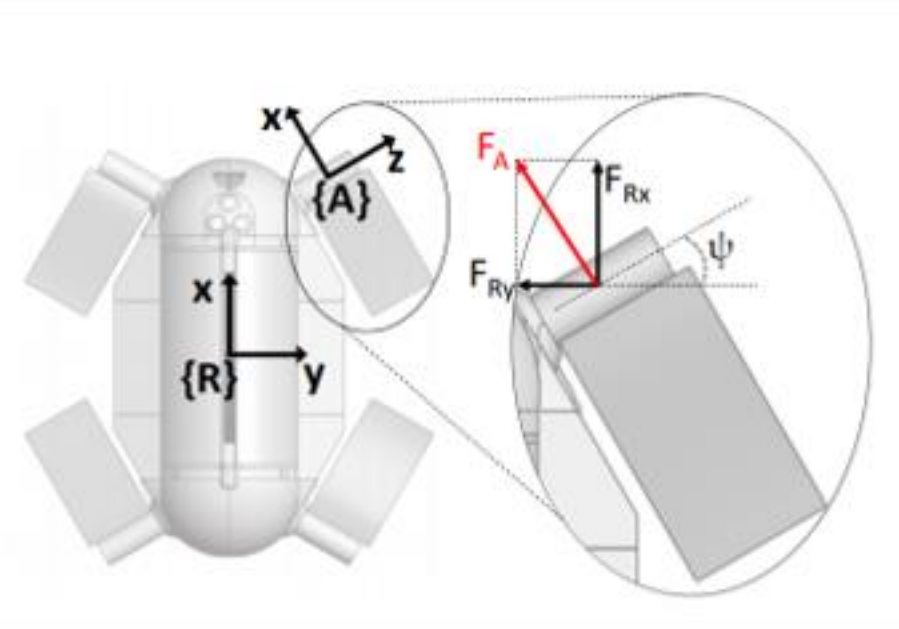




Jin, Sangrok, et al. "Hovering underwater robotic platform with four tilting thrusters." *2014 IEEE/ASME*.

Challengies of fin modelling

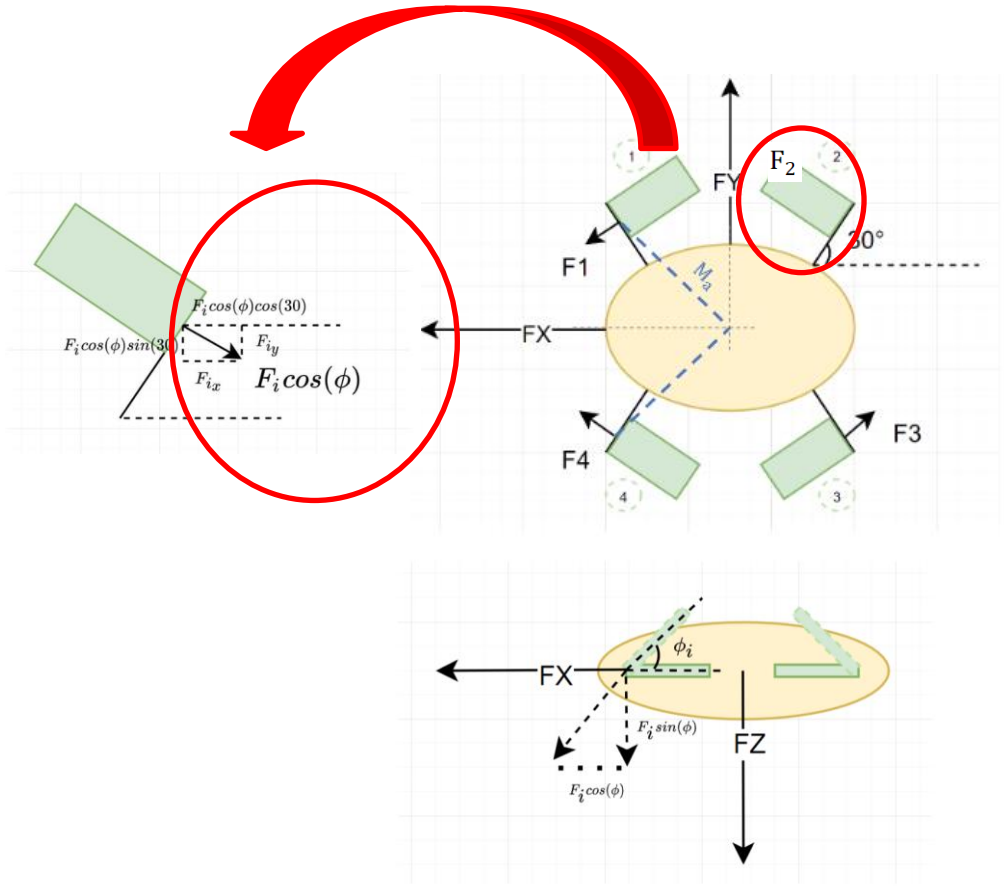
Multiple parameters, oscillatory thrust profile



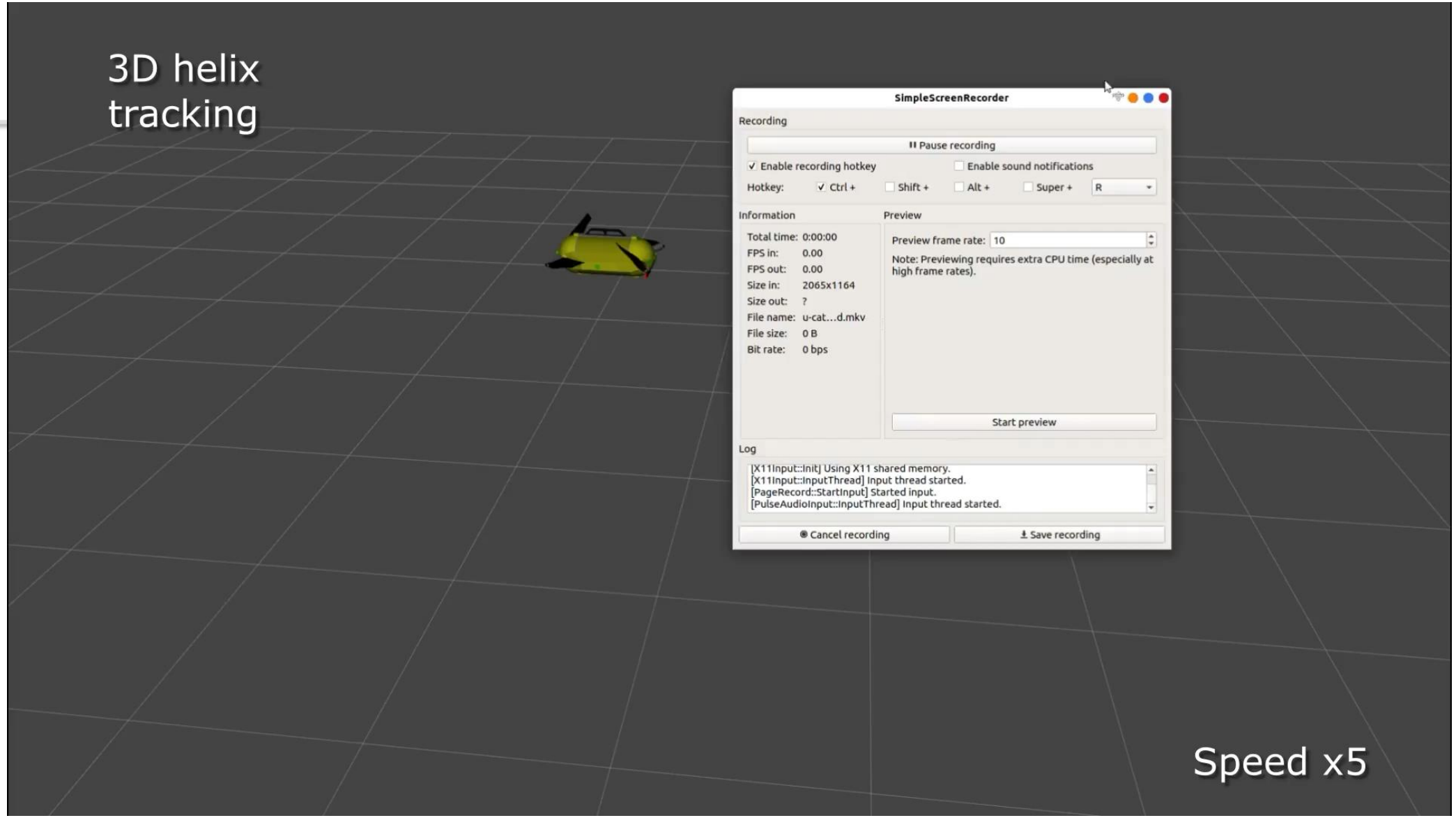
W. Remmas et al. “Inverse-model intelligent control of fin-actuated underwater robots based on drag force propulsion”, Ocean Engineering, to appear.

Modelling of the vehicle

$$\begin{bmatrix} 1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 \\ -1 & -1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1 \\ 0 & 0 & 0 & 0 & -1 & 1 & 1 & -1 \\ -1 & 1 & -1 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} (C(\phi_1)F_1 \\ (C(\phi_2)F_2 \\ (C(\phi_3)F_3 \\ (C(\phi_4)F_4 \\ (S(\phi_1)F_1 \\ (S(\phi_2)F_2 \\ (S(\phi_3)F_3 \\ (S(\phi_4)F_4 \end{bmatrix} = \begin{bmatrix} \frac{\tau_x}{C(30)} \\ \frac{\tau_y}{S(30)} \\ \tau_z \\ \frac{\tau_\Phi}{M_a} \\ \frac{\tau_\Theta}{M_a} \\ \frac{\tau_\Psi}{M_a} \end{bmatrix}$$

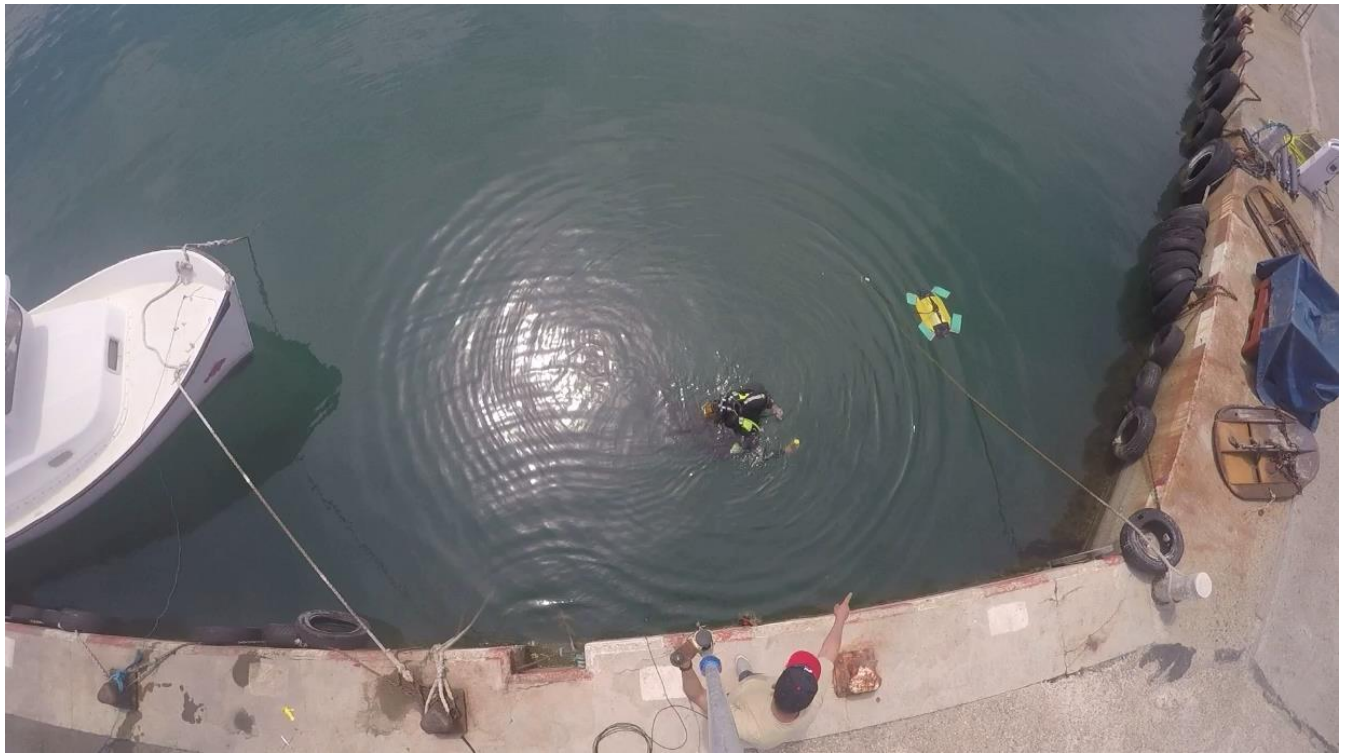


3D helix tracking



New applications for shallow and close

- Environmental monitoring
- Benthic surveys
- Underwater infrastructure inspection
- Wildlife monitoring
- Ship hull inspection
- SAR
- ……



Remmas, Walid, et al."Diver tracking in open waters: A low-cost approach based on visual and acoustic sensor fusion." *Journal of Field Robotics 2021*

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Kruusmaa, M., et al. "Salmon behavioural response to robots in an aquaculture sea cage." *Royal Society open science* 7.3 (2020): 191220.

Questions ?