

UNIVERSITA' DEGLI STUDI DI PADOVA
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE



Laurea specialistica in Ingegneria dell'Automazione

ANALISI TEORICA E SPERIMENTALE DI UN SISTEMA DI CONTROLLO PER UN VEICOLO BIOMIMETICO “BOXFISH”

RELATORE: Ch.mo Prof. Luca Schenato

CORRELATORE: Ch.ma Prof.ssa Xinyan Deng (University of Delaware)

LAUREANDO: Giovanni Barbera

19 Ottobre 2009



Progetto di ricerca



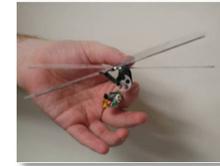
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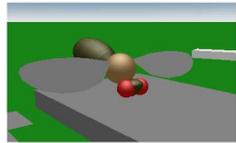
Aerodinamica
dell'ala flessibile



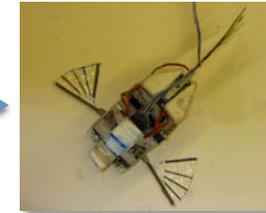
Prof. Xinyan Deng
Bio-robotics Laboratory
University of Delaware



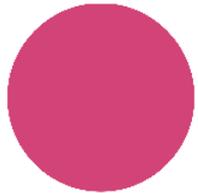
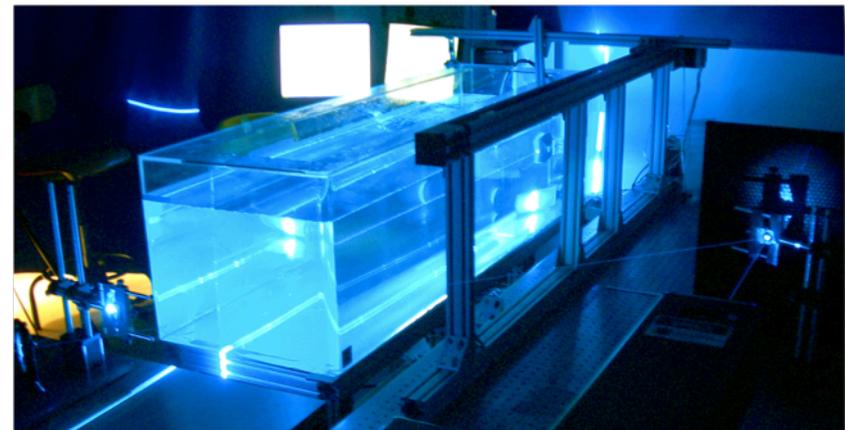
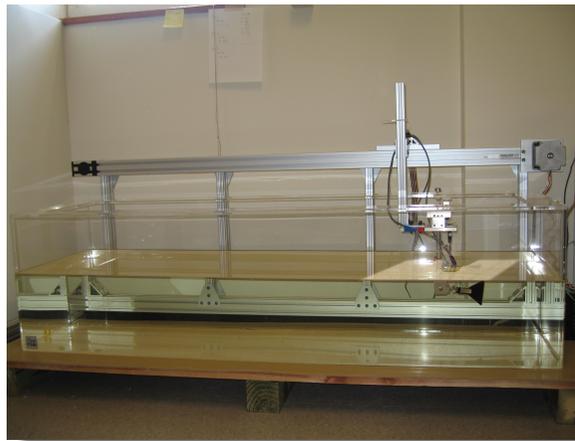
Libellula robotica

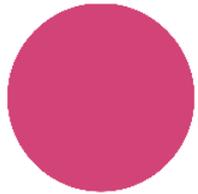


Micro veicoli aerei



Boxfish





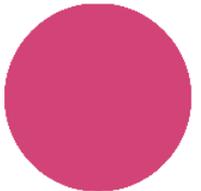
Applicazioni

- Esplorazione di ambienti ostili
- Monitoraggio di aree marine
- Manutenzione apparecchiature subacquee
- Studi biologici





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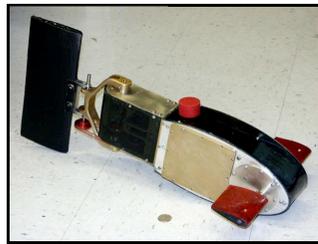


Stato dell'arte

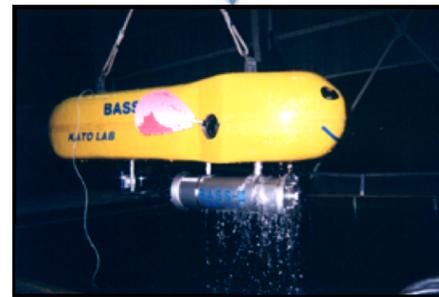
Anguilliforme (Lampreybot)



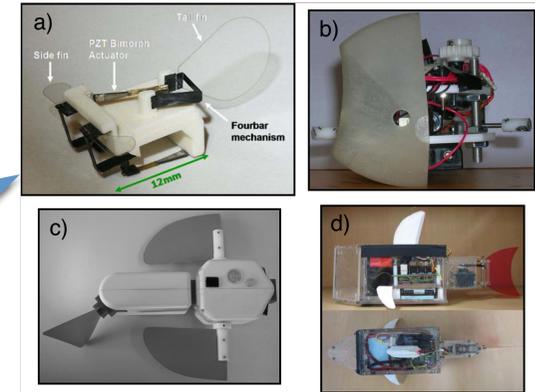
Tonniforme (Robotuna,
MIT 1996)



Carangiforme
(Morgansen, University
of Washington)



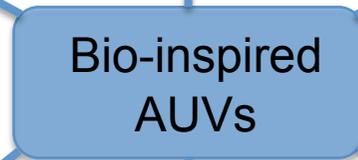
Paired fin (Bass III, Kato)



Ostraciforme



Esapodo (AQUA)

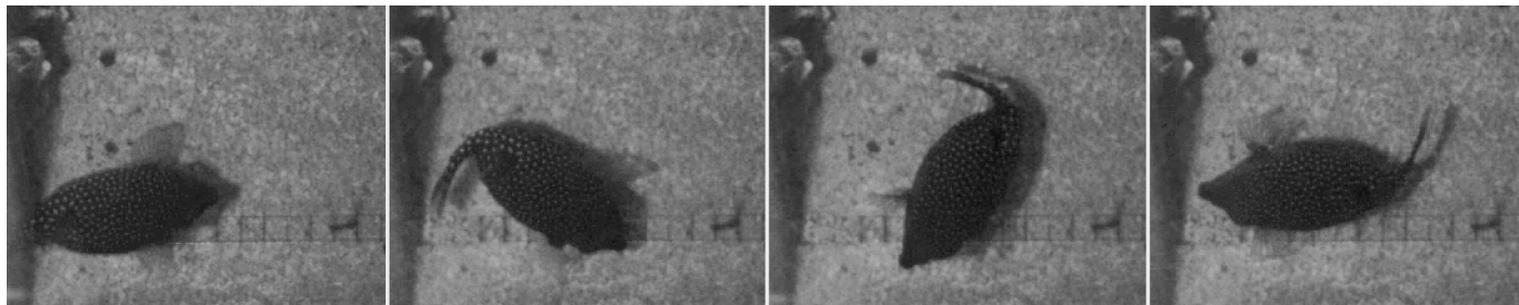
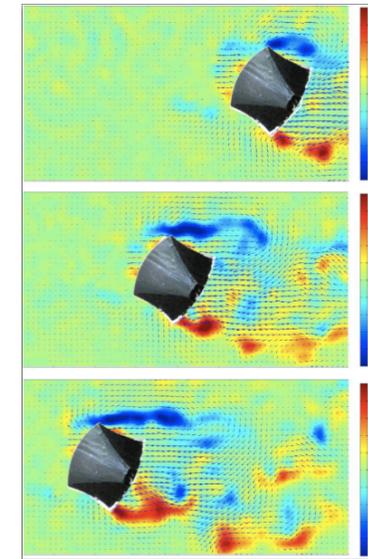
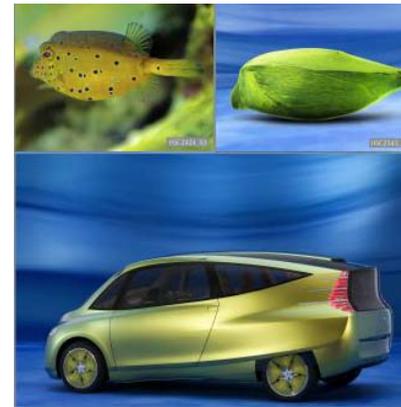




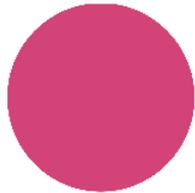
Boxfish

Perché il boxfish?

- Manovrabilità [1]
- Efficienza
- Stabilità

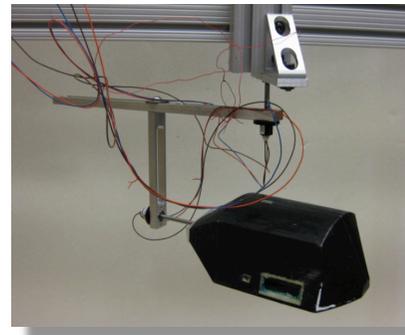
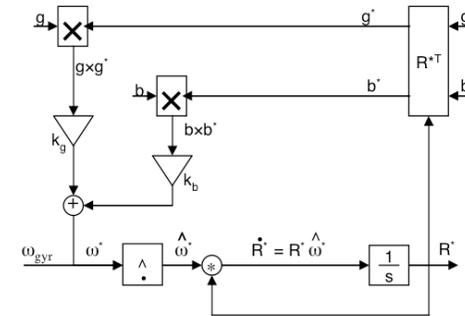
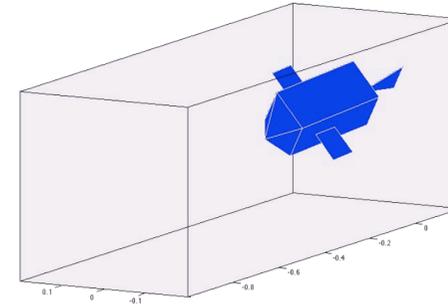


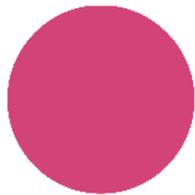
[1] M. S. Gordon, J. R. Hove, P. Webb, and D. Weish. Boxfishes as unusually well-controlled autonomous underwater vehicles. *Physiological and Biochemical Zoology*, 73(6):663–671, 2000.



Contributo della tesi

- Modellizzazione e simulazione
- Filtri di assetto: simulazione e prove sperimentali
- Risultati sperimentali: controllo di rollio e imbardata





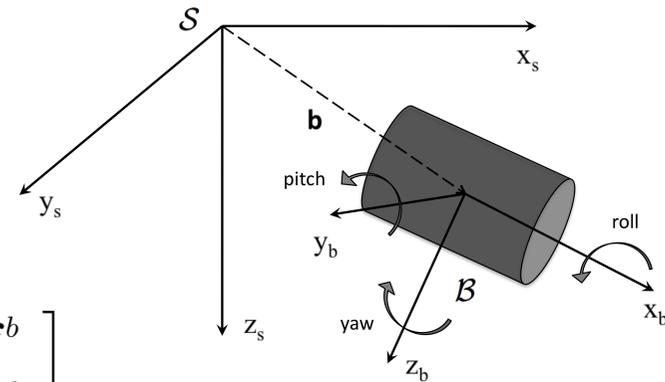
Il Modello

Sistemi di coordinate: S e \mathcal{B}

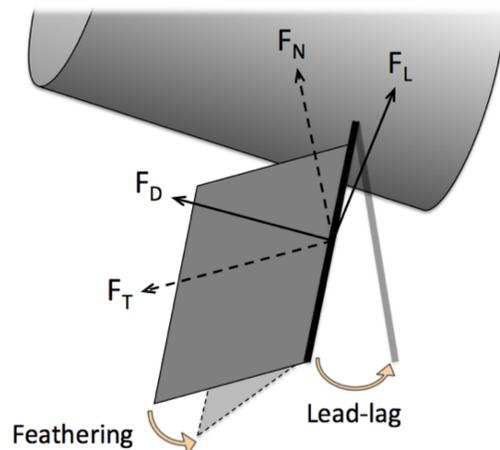
Rappresentazione di stato in $SE(3)$:

$$SE(3) = \{(\mathbf{b}, R) : \mathbf{b} \in \mathbb{R}^3, R \in SO(3)\}$$

$$\begin{cases} \begin{bmatrix} mI & 0 \\ 0 & I \end{bmatrix} \begin{bmatrix} \dot{\mathbf{v}}^b \\ \dot{\boldsymbol{\omega}}^b \end{bmatrix} + \begin{bmatrix} \boldsymbol{\omega}^b \times m\mathbf{v}^b \\ \boldsymbol{\omega}^b \times I\boldsymbol{\omega}^b \end{bmatrix} = \begin{bmatrix} \mathbf{f}^b \\ \boldsymbol{\tau}^b \end{bmatrix} \\ \dot{R} = R\hat{\boldsymbol{\omega}}^b \\ \dot{\mathbf{b}} = R\mathbf{v}^b \end{cases}$$



Forze esterne:
gravità, galleggiamento,
interazione pinne/fluido



Modello delle pinne

$$\begin{cases} F_L = \frac{1}{2}\rho AU_t^2 C_{Lmax} \sin 2\alpha \\ F_D = \frac{1}{2}\rho AU_t^2 C_{Dmax} (1 - \cos 2\alpha) \end{cases}$$



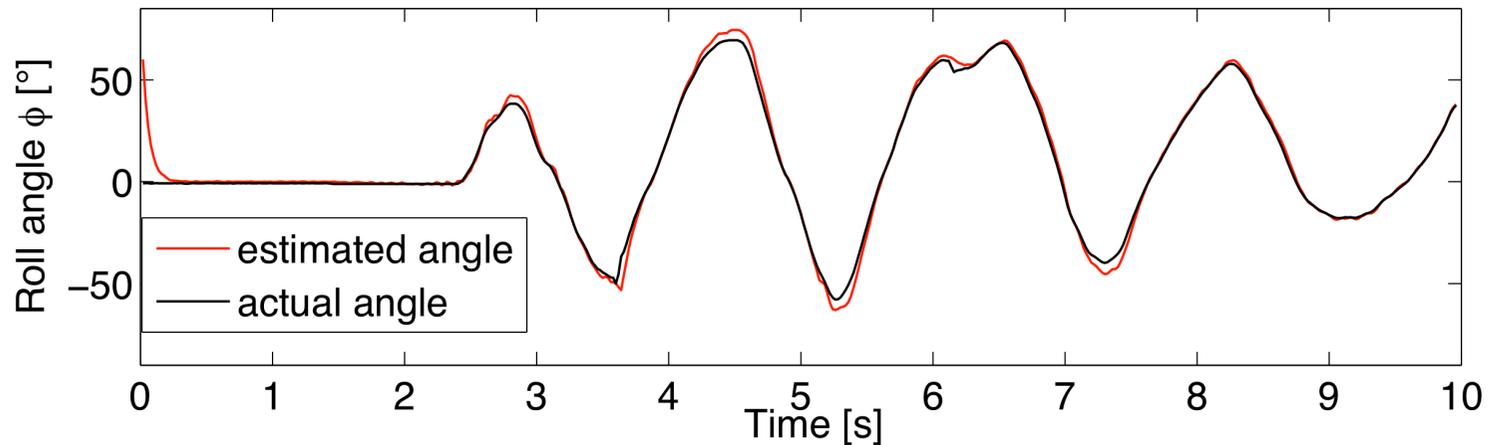
Filtro d'assetto

Stima di $R \in SO(3)$: approccio geometrico [2]

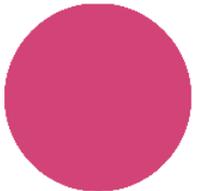
- Robustezza
- Semplicità
- Precisione

$$\begin{cases} \dot{R}^* &= R^* \hat{\omega}^* \\ \omega^* &= \omega_{gyr} + \sum_{i=1}^N k_i (\mathbf{v}_i \times \mathbf{v}_i^*) \\ \mathbf{v}_i^* &= R^{*T} \mathbf{v}_{0i} \end{cases}$$

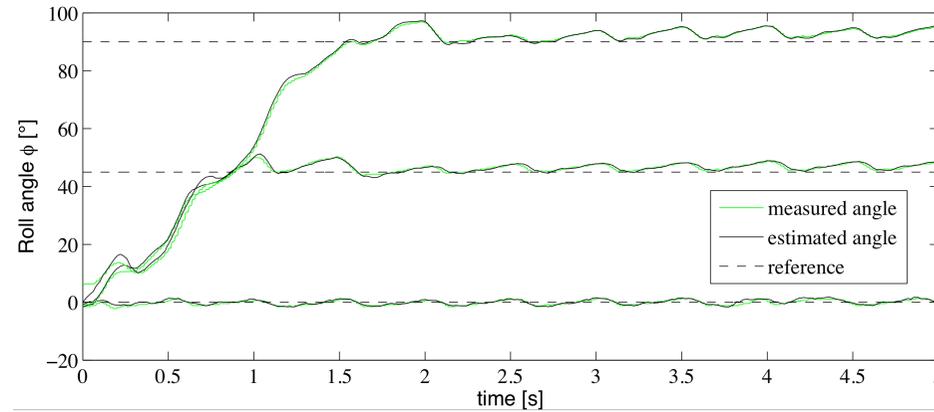
giroscopio
accelerometro, magnetometro, ecc...
vettore riferimento



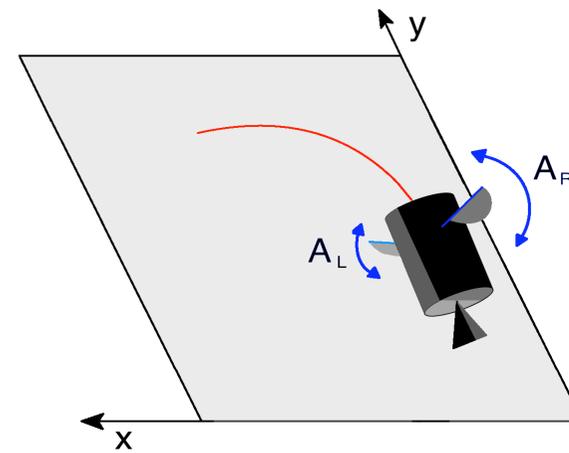
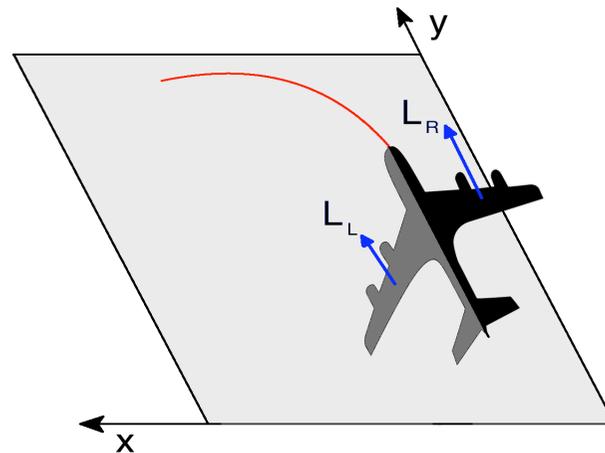
[2] D. Campolo, G. Barbera, L. Schenato, L. Pi, X. Deng and E. Guglielmelli. Attitude stabilization of a biologically inspired robotic housefly via dynamic multimodal attitude estimation, to appear on Advanced Robotics Journal, 2009.



Controllo di rollio e imbardata



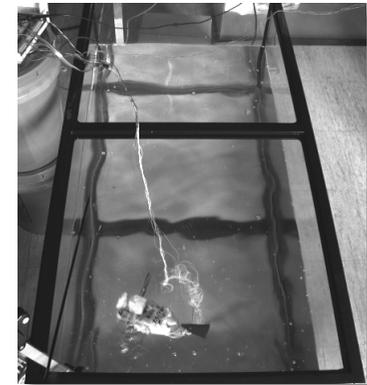
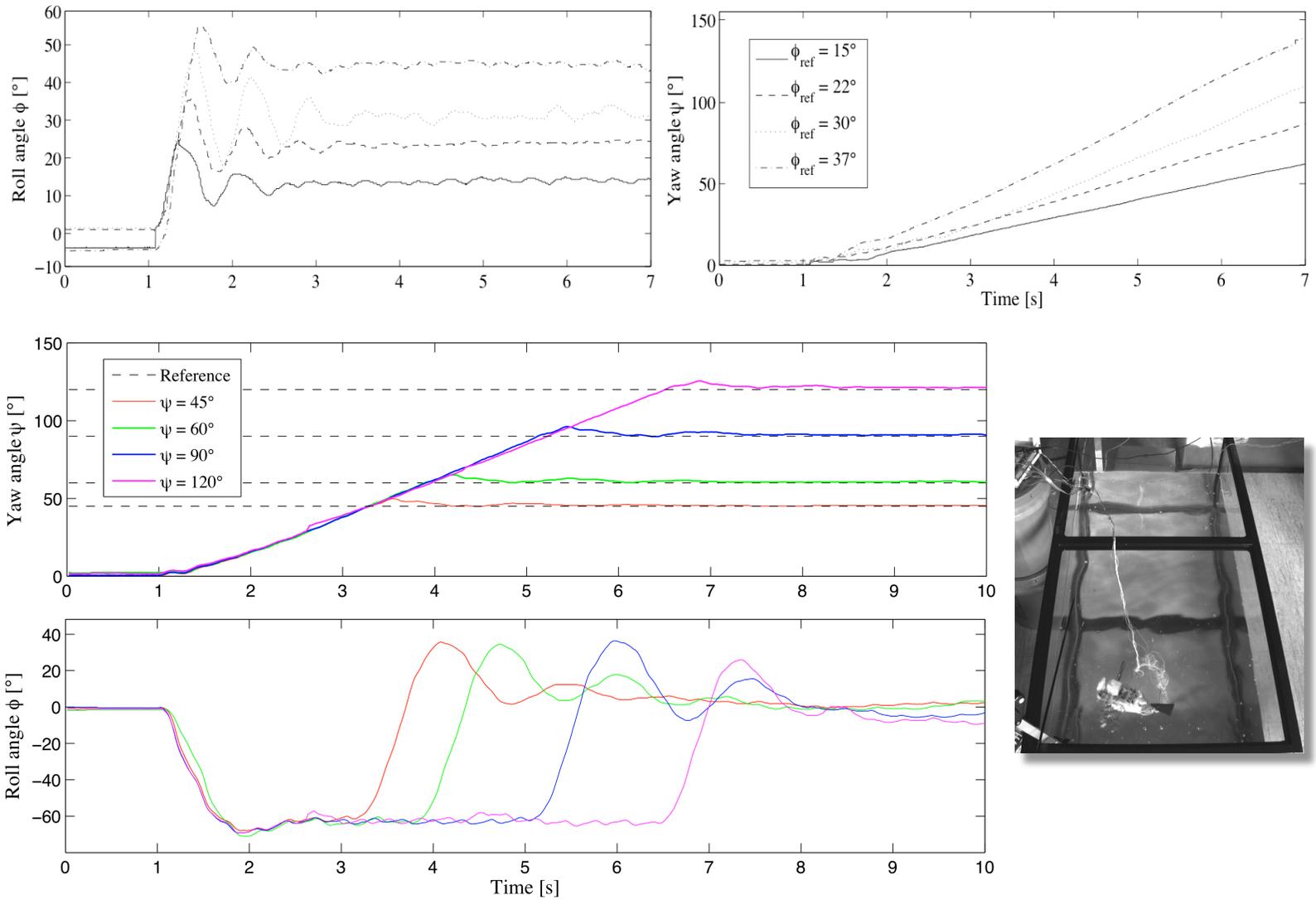
Rollio indotto $\begin{cases} \beta_l(t) = A(0.5 - u(t)) \sin(\omega t) \\ \beta_r(t) = A(0.5 + u(t)) \sin(\omega t) \end{cases} \quad u(t) \in [-0.5, 0.5]$

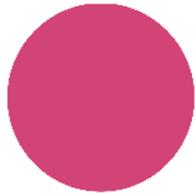




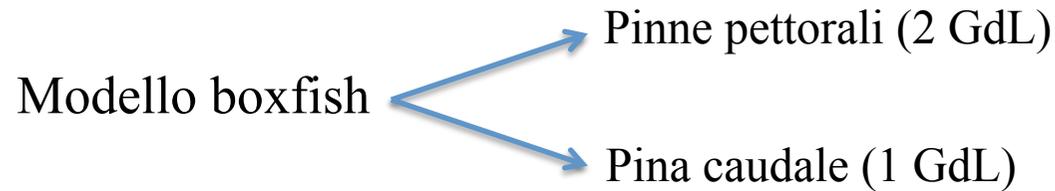
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Risultati sperimentali





Conclusioni



Filtro di assetto e controllo in retroazione

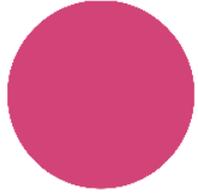
Risultati sperimentali: controllo di rollio e imbardata

Sviluppi futuri:

- Controllo geometrico
- *Trajectory tracking*
- Pinna caudale
- Pinne a più gradi di libertà o flessibili



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Grazie per l'attenzione