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BoxyBot II

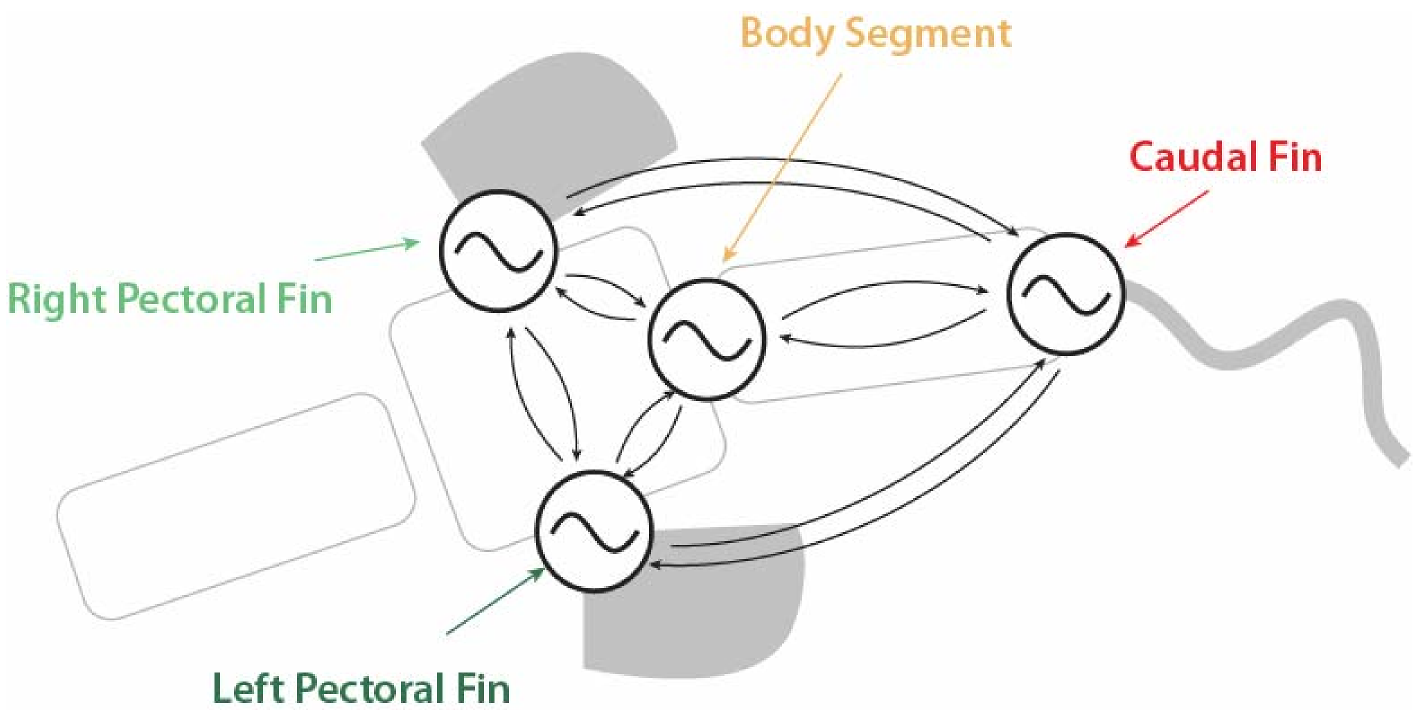
Intermediate Presentation

Fin Design, Programmation, Simulation & Testing

Content Overview

- General Design
- Programmation using a CPG
- Localization and Control
- Fin Design & Testing
  - Resonance frequency
  - Efficiency Estimation
- Simulation

Programmation using a CPG



Programmation using a CPG

$$\dot{\phi}_i = \omega_i + \sum_j (\omega_{ij} \cdot r_j \cdot \sin(\phi_j - \phi_i - \varphi_{ij})) \qquad [1]$$

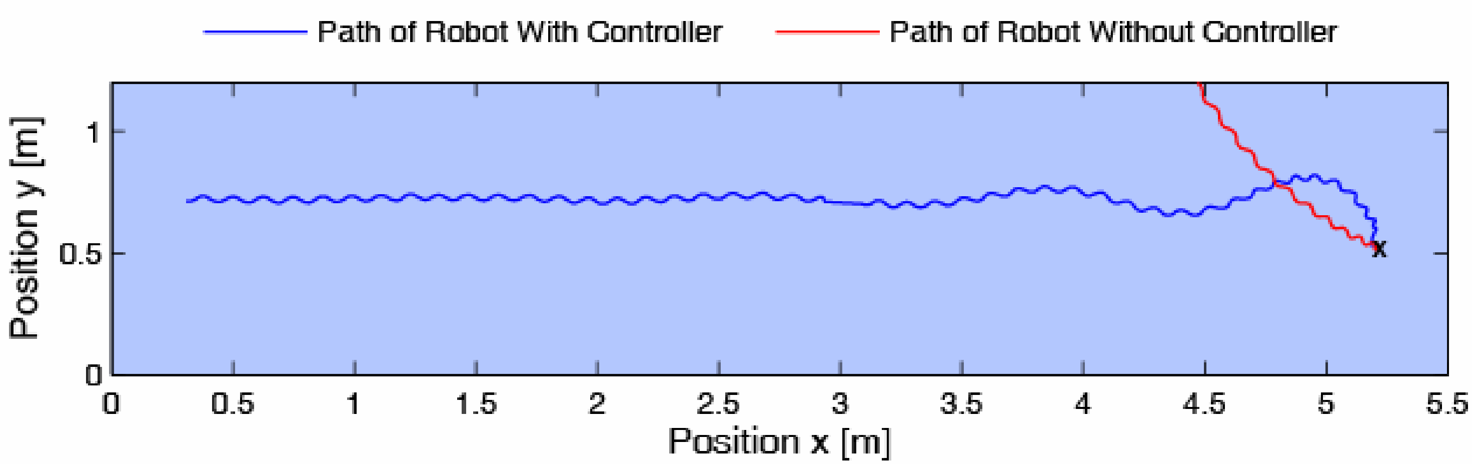
$$\ddot{r}_i = a_r \left(\frac{a_r}{4}(R_i - r_i) - \dot{r}_i \right)$$

$$\ddot{x}_i = a_x \left(\frac{a_x}{4}(X_i - x_i) - \dot{x}_i \right)$$

$$\theta_i = x_i + \cos(\phi_i)$$

$$\lim_{t\to\infty} \theta_i(t) = X_i + R_i \cdot \cos(\omega_i t + \phi_{0,i}) \qquad [2]$$

Localisation and Control



Videos

http://birg.epfl.ch/webdav/site/birg/users/196786/public/BoxyBotII%20-%20with%20Controller%20(5%20MB).avi

http://birg.epfl.ch/webdav/site/birg/users/196786/public/BoxyBotII%20-%20without%20Controller%20(3%20MB).avi

Fin Design - Resonance Frequency

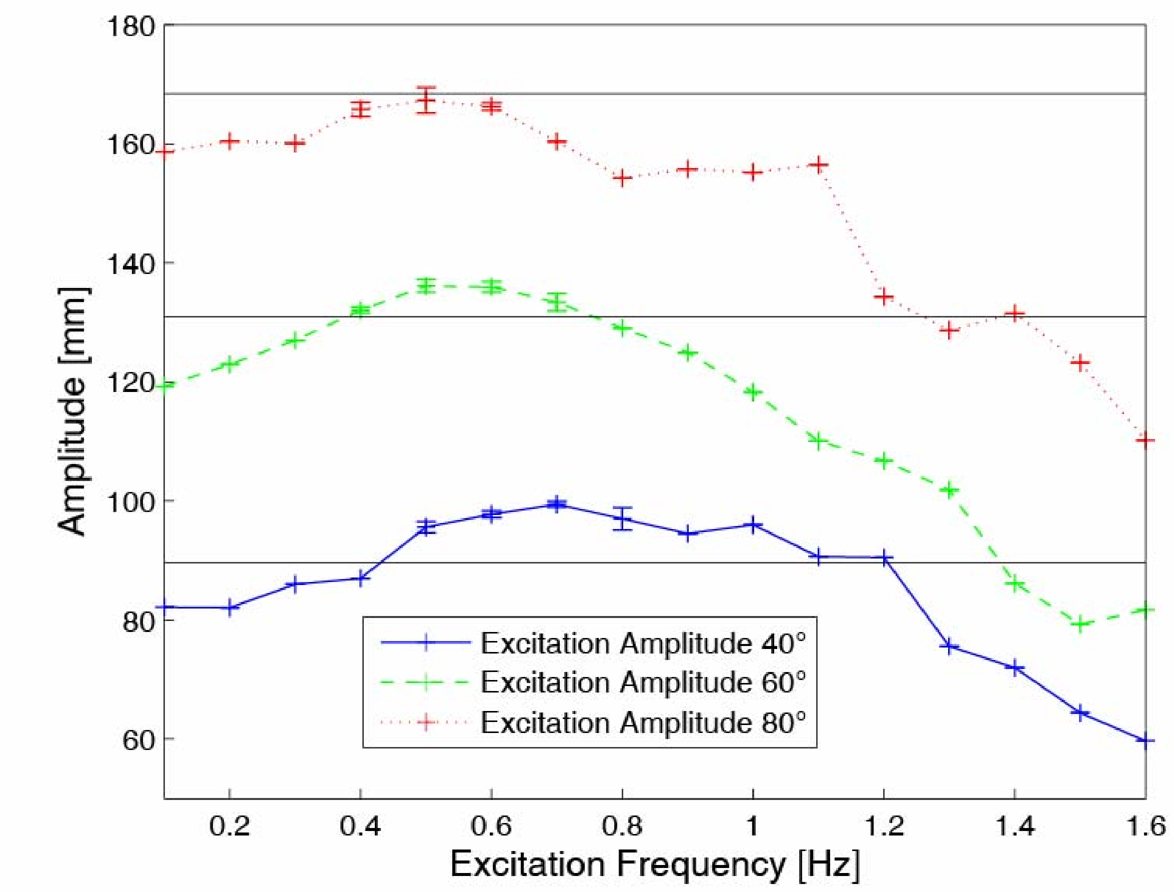
$$f_r = \frac{1}{2\pi} \cdot \sqrt{\frac{k}{m_f + m_a}}$$

Spring Constant:

$$k = \frac{E \cdot I}{l^3} = \frac{E \cdot w \cdot t^3}{4 \cdot l^3}$$

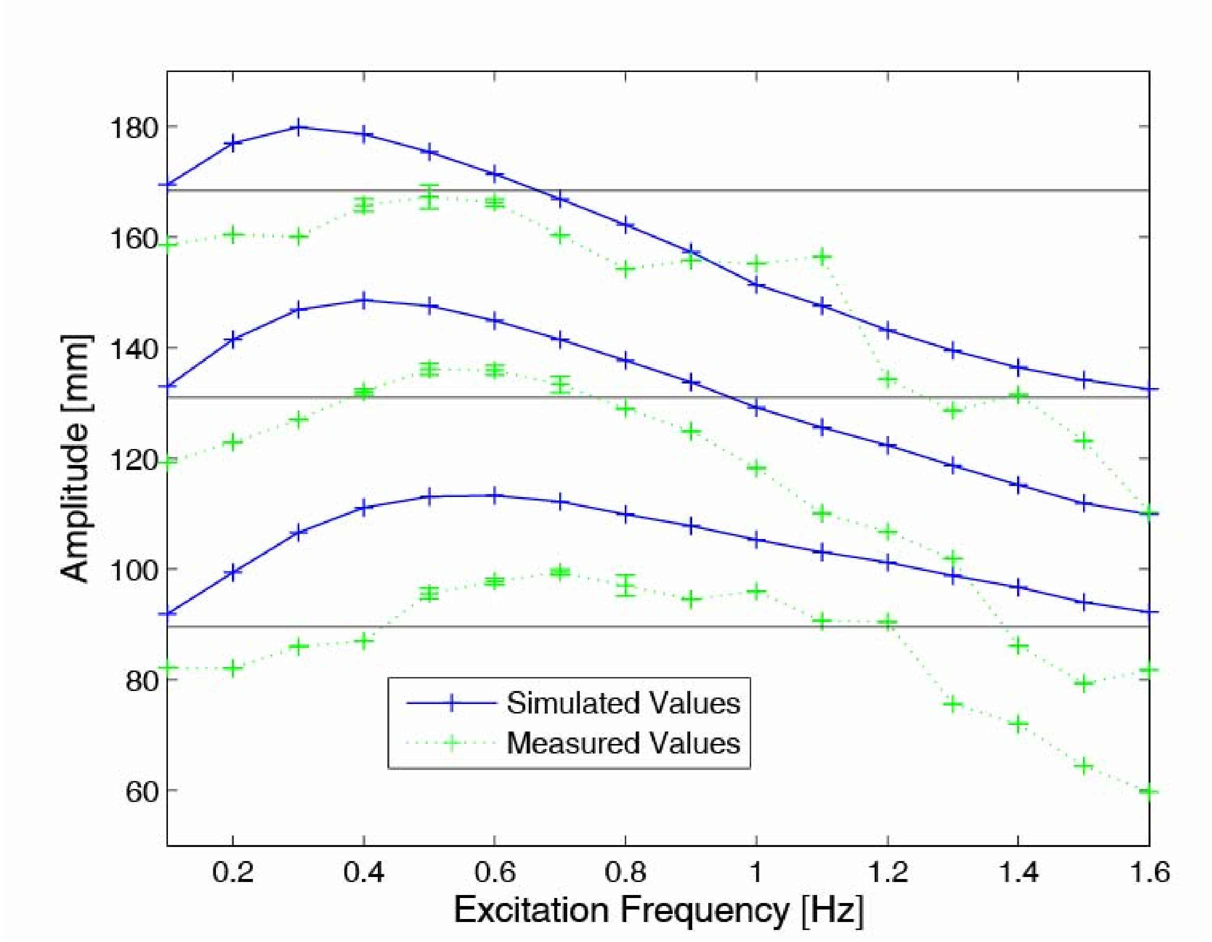
Results – Fin Amplitude

Fin 1 : 95x40 mm F_{R1}=0.7±0.1 Hz   Fin 2 : 95x60 mm F_{R2}=0.6±0.1 Hz



Amplitude vs. Frequency for fin 2

Simulation – Fin Amplitude



Simulated and Real Amplitude vs. Frequency for fin 2 (F_{R2}=0.6±0.1 Hz), Excitation Amplitude 40°, 60° and 80°

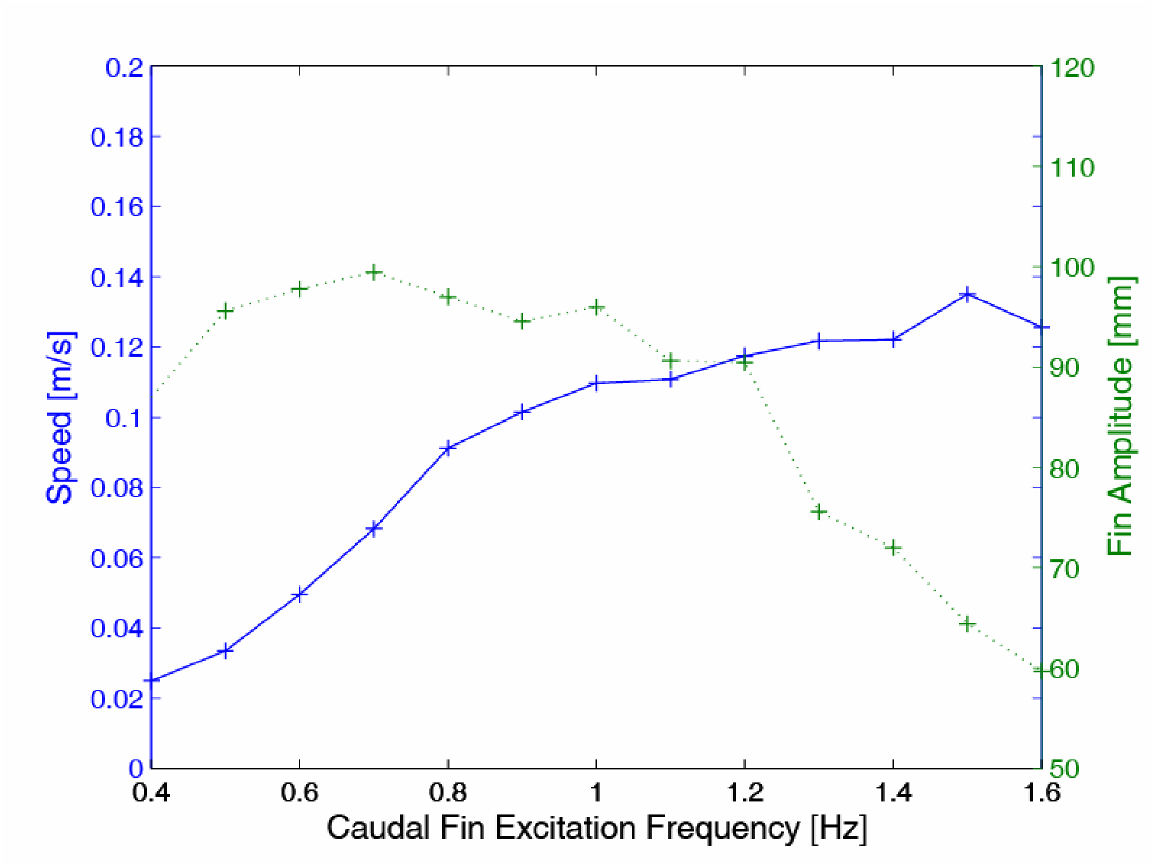
Videos

http://birg.epfl.ch/webdav/site/birg/users/196786/public/Simulation%20-%20Freq%200.6%20-%20Resonance%20(1%20MB).avi

http://birg.epfl.ch/webdav/site/birg/users/196786/public/Simulation%20-%20Freq%201.2%20(1%20MB).avi

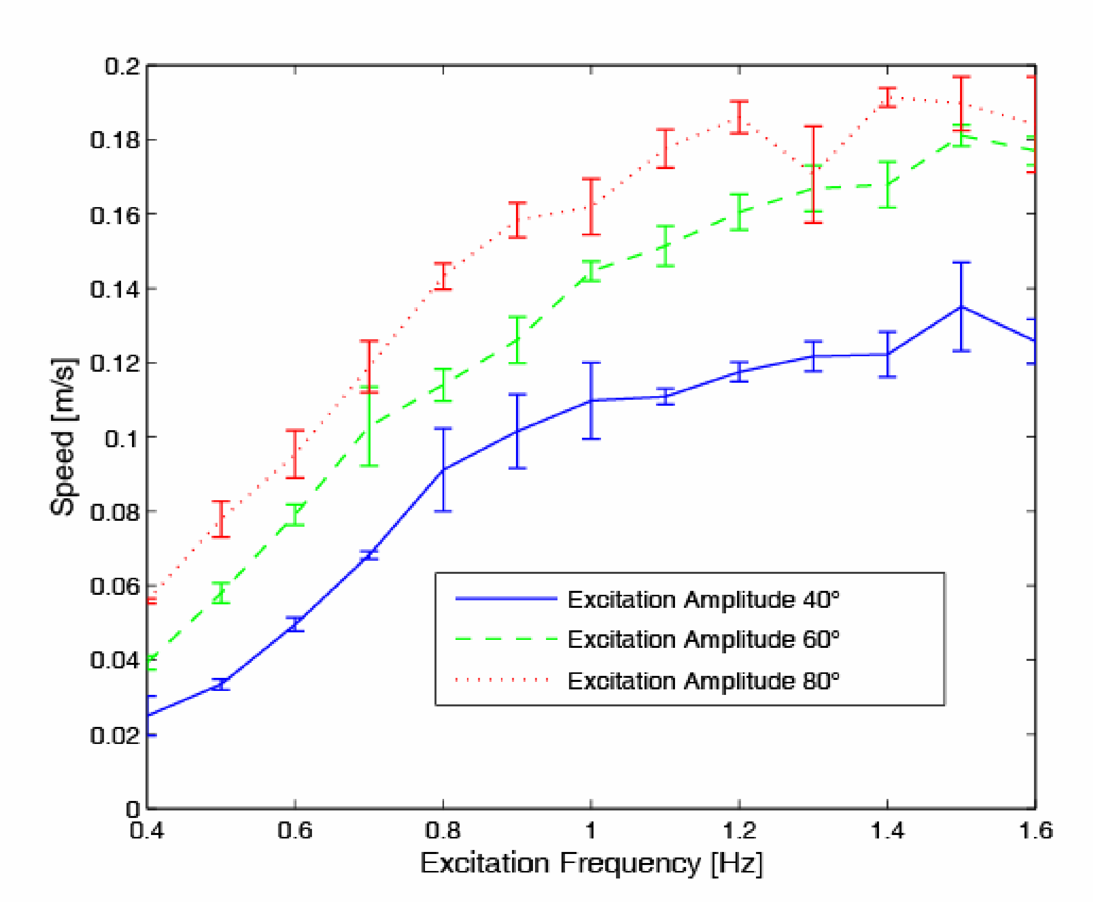
http://birg.epfl.ch/webdav/site/birg/users/196786/public/Simulation%20-%20Freq%201.8%20(1%20MB).avi

Results – Speed and Resonance Frequency



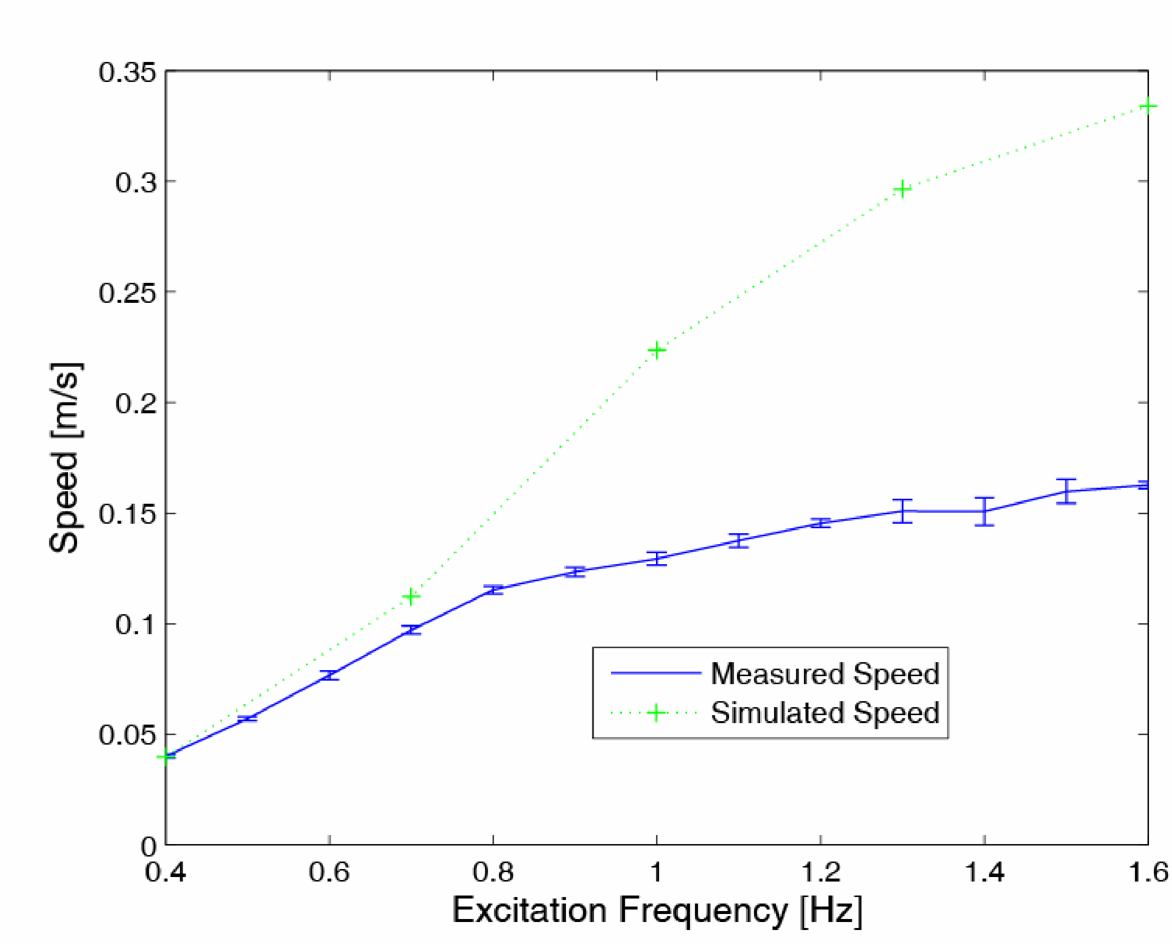
Speed and Amplitude vs. Frequency for fin 2 (F_{R2}=0.6±0.1 Hz), Excitation Amplitude 40°

Results – Speed and Excitation Amplitude



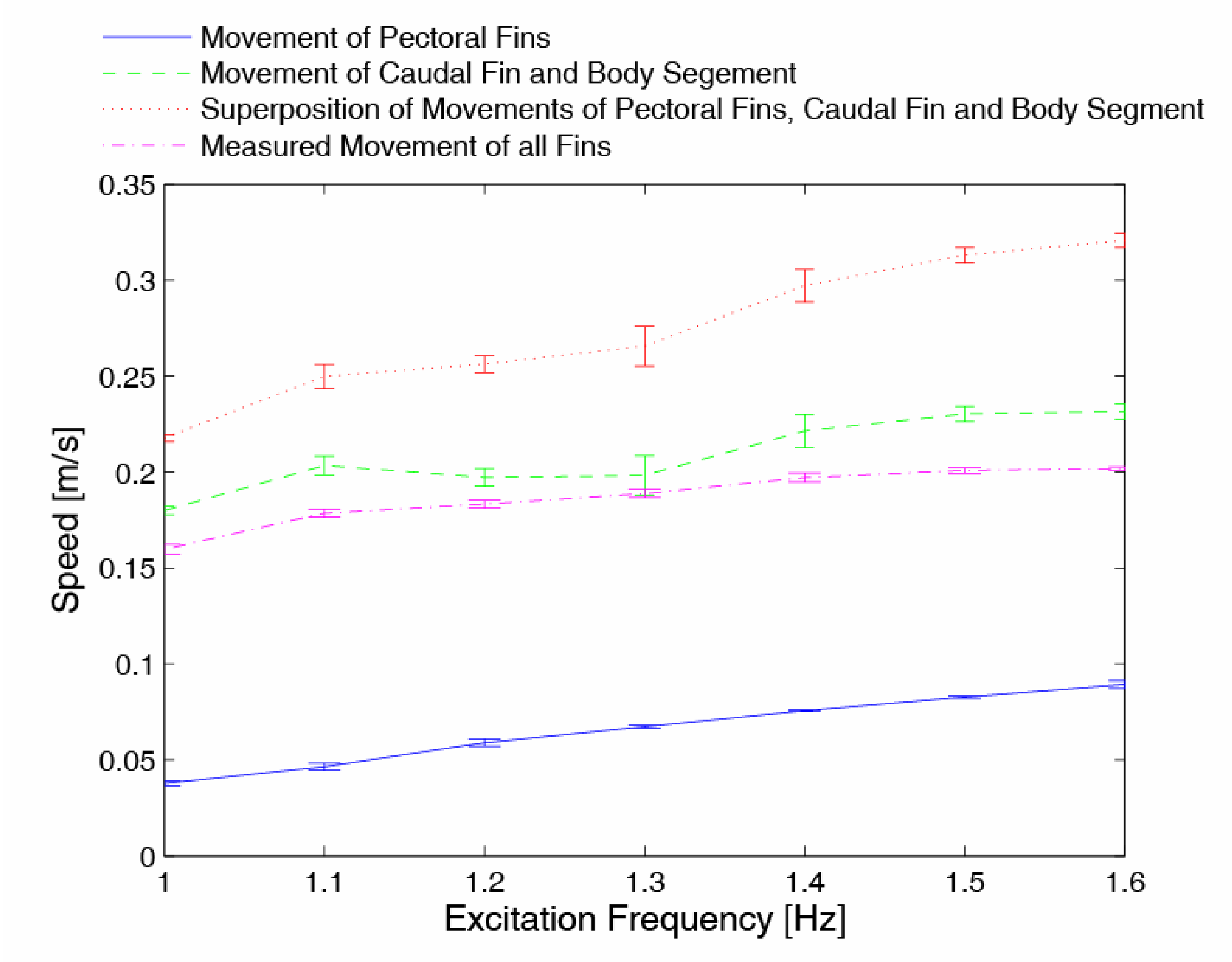
Speed vs. Frequency for fin 2 (FR2=0.6±0.1 Hz)

Simulation and Reality - Speed



Simulated and Real Speed vs. Frequency for fin 2, Excitation Amplitude 60°

BoxyBot Swimming Behaviour



Videos

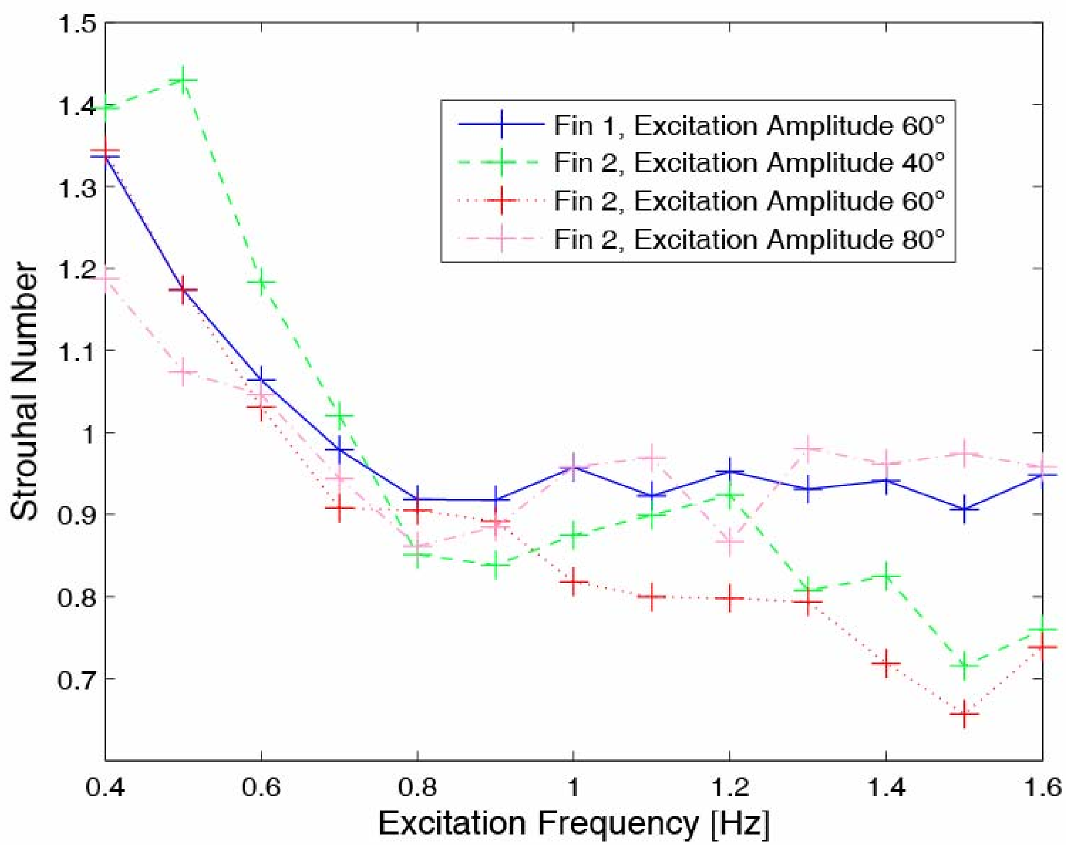
http://birg.epfl.ch/webdav/site/birg/users/196786/public/BoxyBotII%20-%20CaudalFin%20BodySegment%20(3%20MB).avi

http://birg.epfl.ch/webdav/site/birg/users/196786/public/BoxyBotII%20-%20Pectoral%20Fins%20(2%20MB).avi

http://birg.epfl.ch/webdav/site/birg/users/196786/public/BoxyBotII%20-%20All%20Fins%20(3%20MB).avi

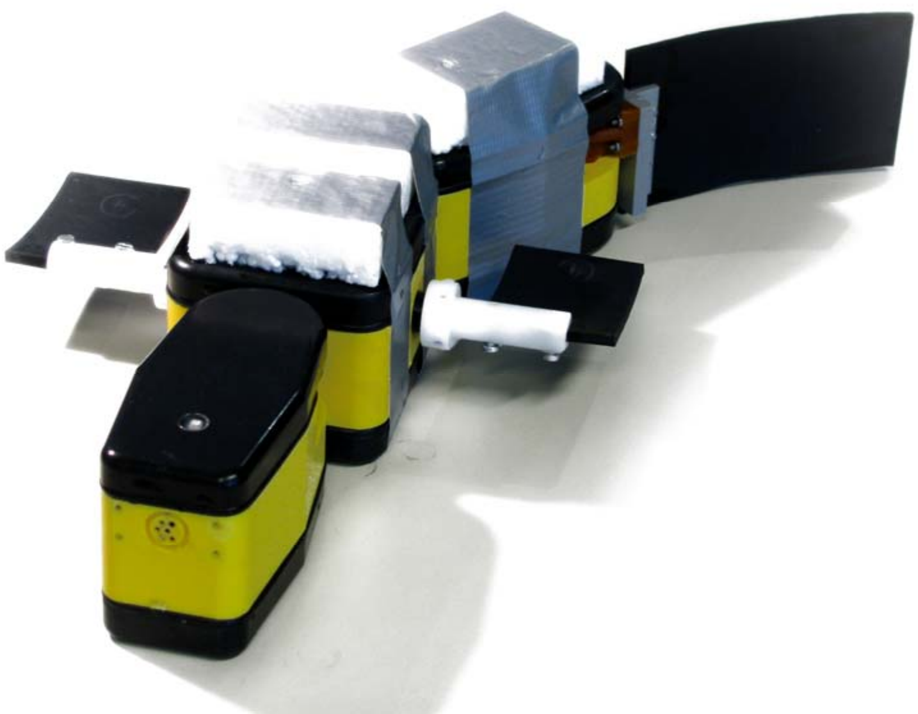
Efficiency Estimation

Strouhal Number: $St = \frac{A \cdot f}{v}$ [3] [4]



Conclusion

- BoxyBotII swims in a controlled manner
- Fin Design
  - Resonance Frequency F_R
  - Good Efficiency around F_R
  - Use only Caudal Fins for Propulsion
- Simulation
  - Comparable Amplitude Plot
  - Model needs Optimizing



Bibliography

1. A.Crespi, D.Lachat, A.Pasquier, A.J.Ijspeert: „Controlling swimming and crawling in a sh robot using a central pattern generator“, BIRG, School of Computer and Communication Science, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, 2005
2. A. Crespi and A.J. Ijspeert. AmphiBot II: „An amphibious snake robot that crawls and swims using a central pattern generator“, in: *Proceedings of the 9th International Conference on Climbing and Walking Robots (CLAWAR 2006),* 2006.
3. S.Heo, T.Wiguna, H.Ch.Park, N.S.Goo: "Effect of an Artificial Caudal Fin on the Performance of a Biomimetic Fish Robot Propelled by Piezoelectric Actuators", *Journal of Bionic Engineering* 4, 151-158, 2007
4. J.J.Rohr, F.E.Fish: "Strouhal numbers and optimization of swimming by odontocete cetaceans", *The Journal of Experimental Biology 207*, 1633-1642, 2004