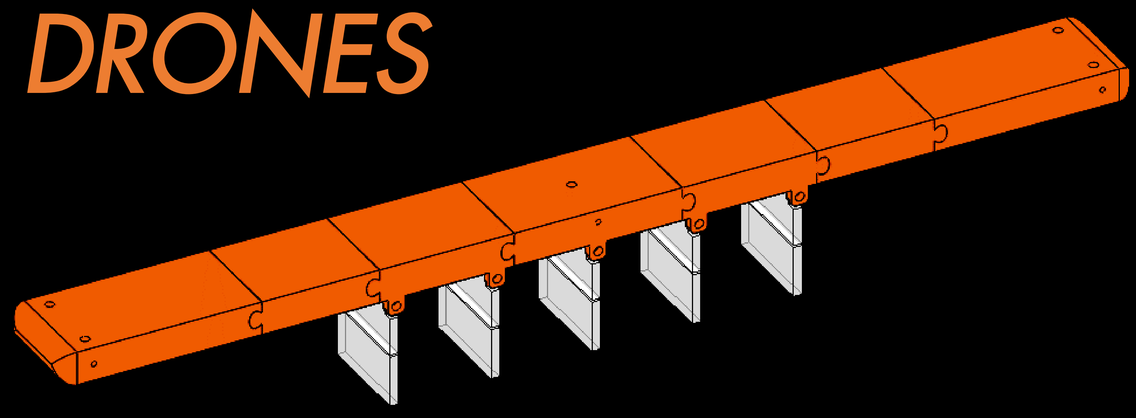
Krill: Kils U, *BIOMASS Sci. Ser.* 3, 1981 Stomatopod: Patek SN & Caldwell RL, *J. Exp. Biol*. 208, 2005

BIO-INSPIRED DESIGN of UNDERWATER DRONES



Metachronal, Synchronous, and Hybrid Stroke Kinematics in Paddling-Based Swimming at Low Reynolds Numbers

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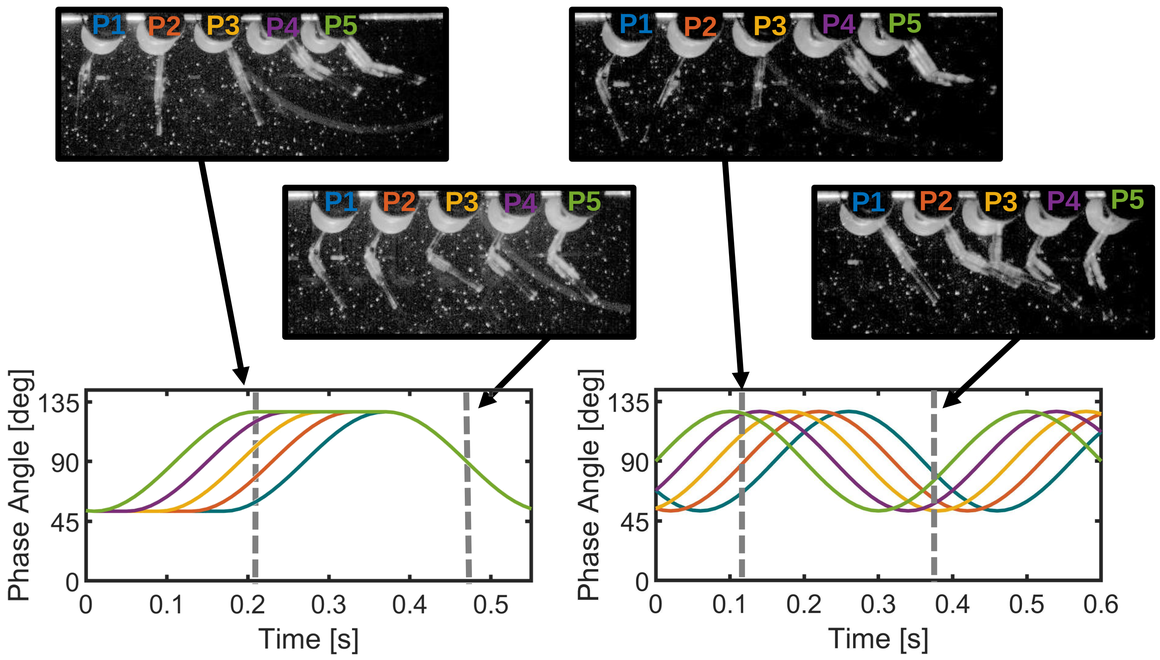
BACKGROUND

- Many aquatic crustaceans such as krill, mantis shrimp, and mysids use oscillatory paddling of closely-spaced pairs of swimming limbs for propulsion.
- Time delay (phase lag) between the motion of neighboring limbs results in the generation of a **metachronal wave** that travels along the body length.
- Mantis shrimp use hybrid stroke kinematics for escape swimming, consisting of a metachronal power stroke (PS) followed by a synchronous recovery stroke (RS).

SELF-PROPELLING ROBOT KINEMATICS

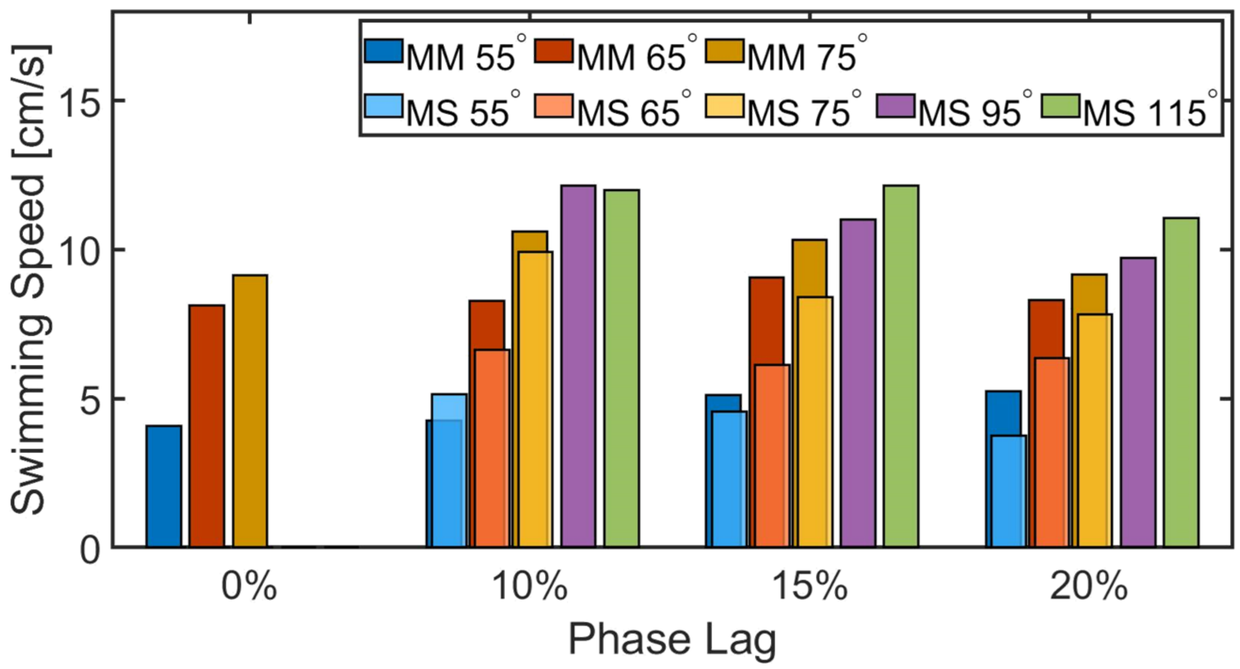
Metachronal PS + Synchronous RS (MS)

Metachronal PS + Metachronal RS (MM)

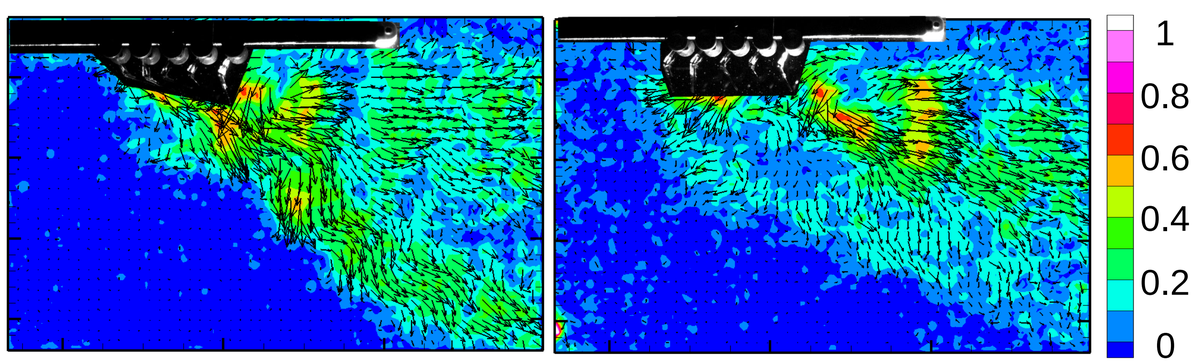


MM = metachronal PS + metachronal RS; **MS** = metachronal PS + synchronous RS;
PS = power stroke; **RS** = recovery stroke; **PL** = phase lag; **SA** = stroke amplitude

RESULTS



MM wake flow field MS wake flow field Speed [m/s]



FINDINGS

- For constant SA, MM generally exhibits faster swimming speed than MS, regardless of PL.
- SA has a greater effect on swimming speed than PL.
- Compared to MM, MS kinematics allow for larger SA while avoiding paddle collisions between neighboring limbs, thus enabling faster swimming.

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