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A biomimetic robot crawling bidirectionally with load inspired by rock-climbing fish

Key words:

Fish kinematics; Adhesive locomotion mechanism; Fin rays motion; Climbing model; Bio-inspired robot

Related research by same authors:

Wang J, Ji C, Wang W, et al., 2019. An adhesive locomotion model for the rock-climbing fish, Beaufortia kweichowensis Sci Rep-Uk 9(1). https://doi.org/10.1038/s41598-019-53027-2

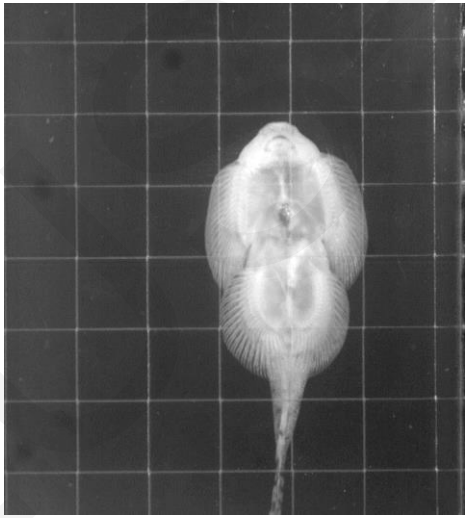
Zou J, Wang J, Ji C, 2016. The Adhesive System and Anisotropic Shear Force of Guizhou Gastromyzontidae Sci Rep-Uk 6(1). https://doi.org/10.1038/srep37221

❖ Rock climbing fish

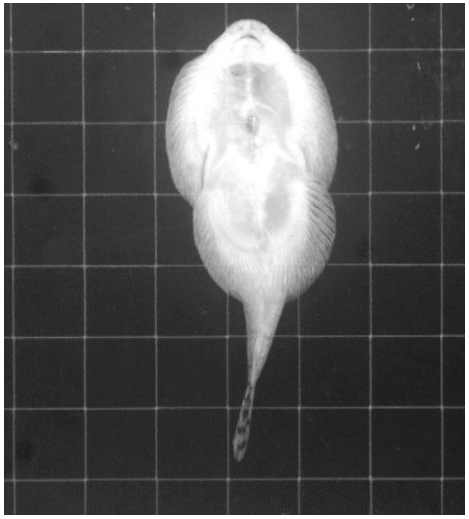
Beaufortia kweichowensis

Live fish climbing on vertical surface

forward



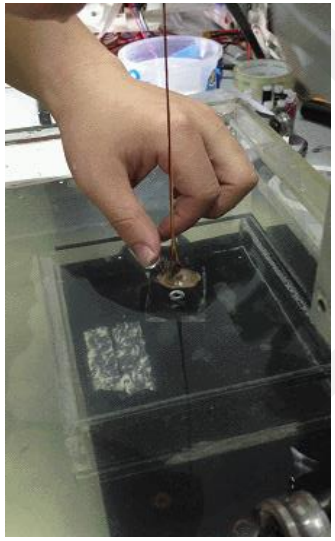
backward



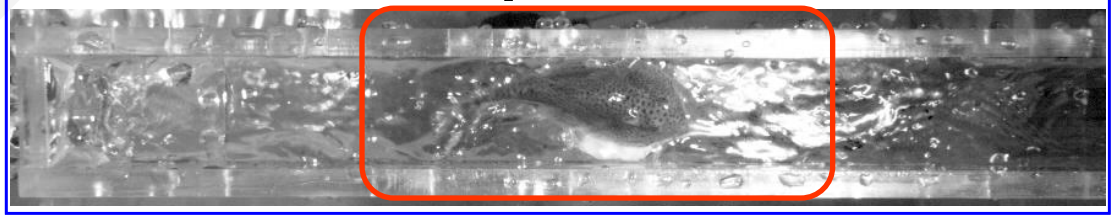
Dead fish

Wet surface

Submerged surface

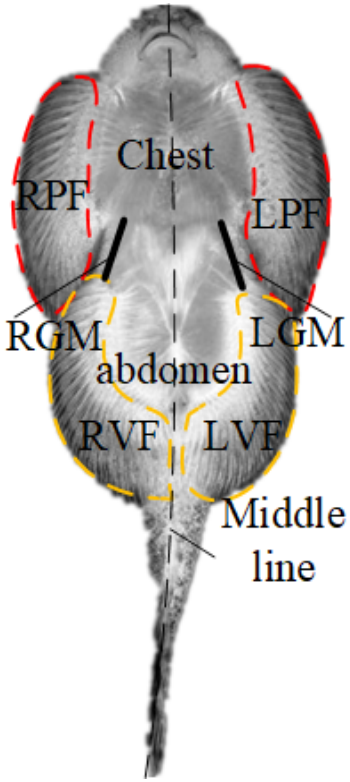


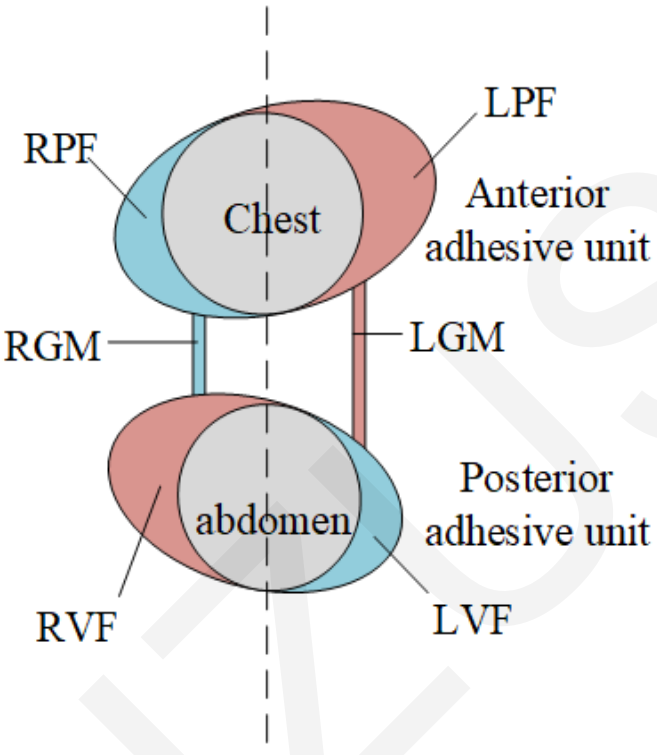
upstream

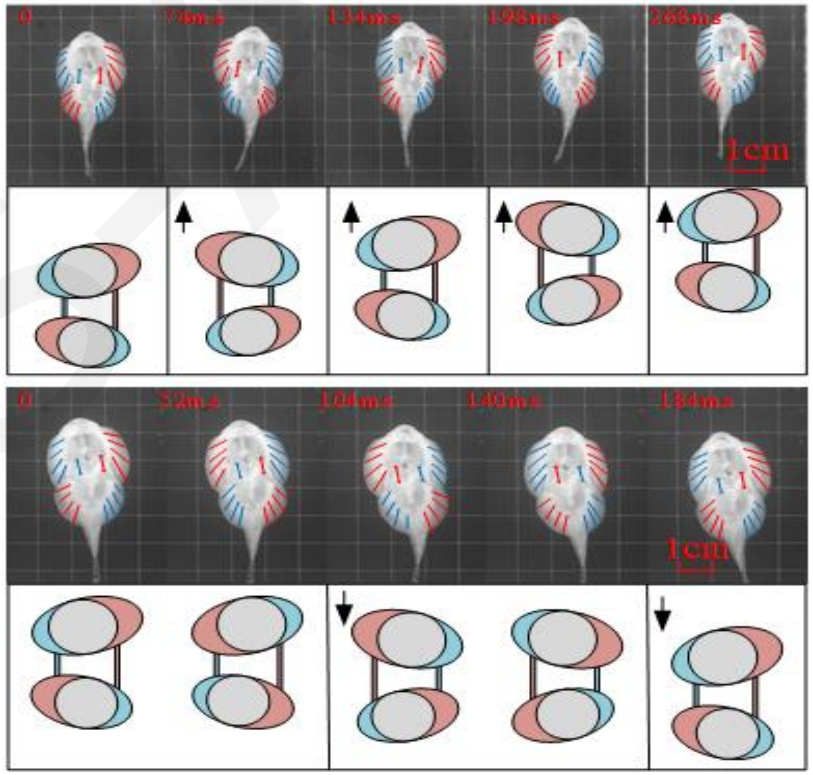


Rock climbing fish own adhesion and locomotion properties

❖ Crawling locomotion modeling

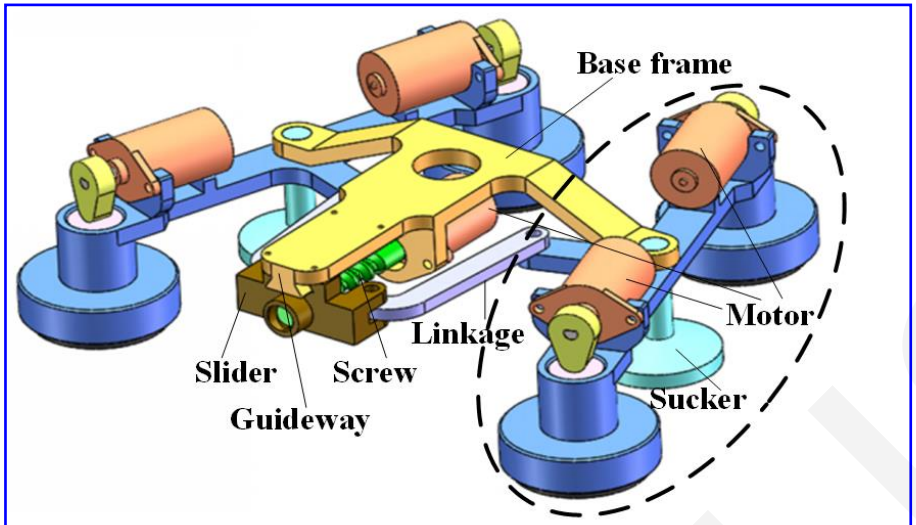


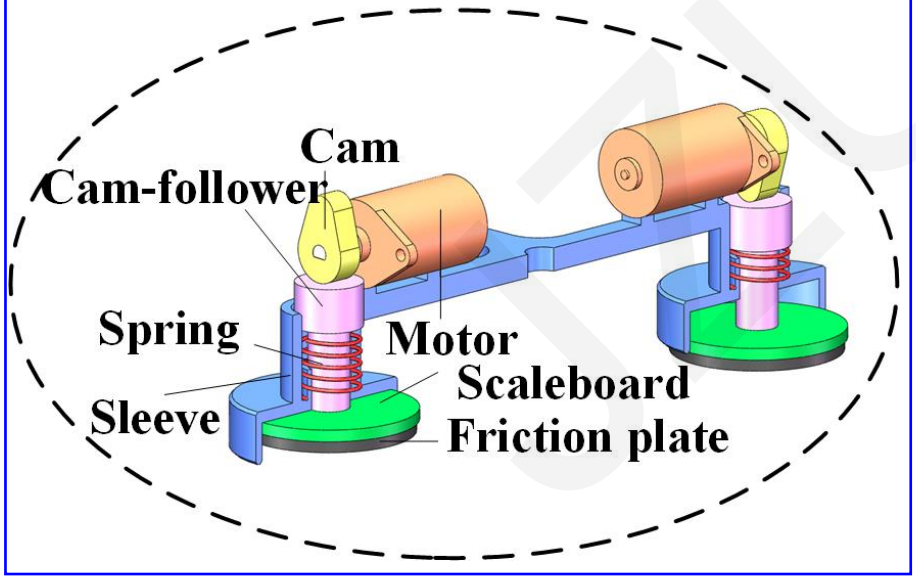


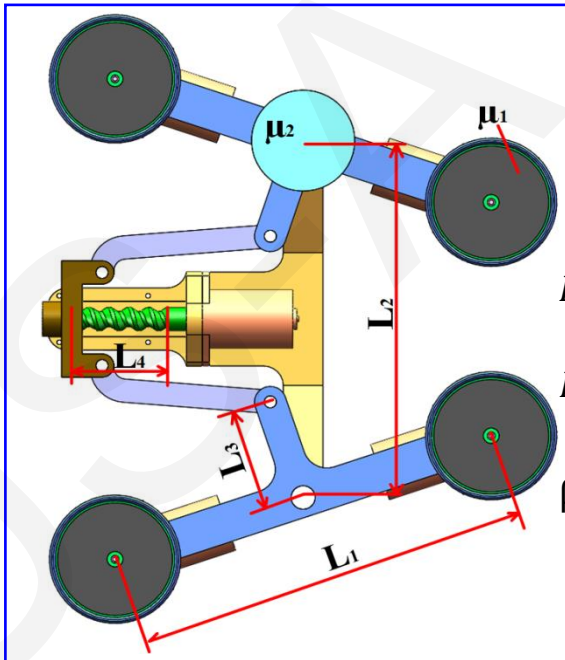


1. Anterior adhesive unit: bilateral pectoral fins (PF) and chest
2. Posterior adhesive unit: bilateral ventral fins (VF) and abdomen
3. Extensible cylinders: girdle muscles (GM)
4. Red area: Unfolded fin
5. Blue area: folded fin

❖ Robot design





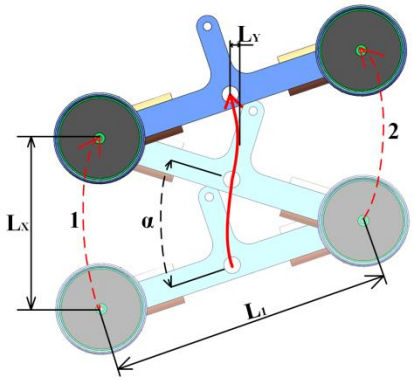


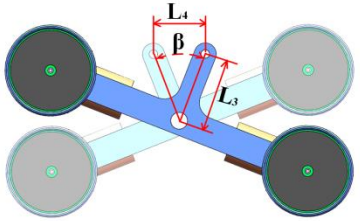
$$L_X = 2 \times L_1 \sin\frac{\alpha}{2}$$

$$L_Y = \frac{L_1}{2} - \frac{L_1}{2} \times \cos\frac{\alpha}{2}$$

$$\beta = 2 \times \sin^{-1}\frac{L_4}{2 \times L_3}$$

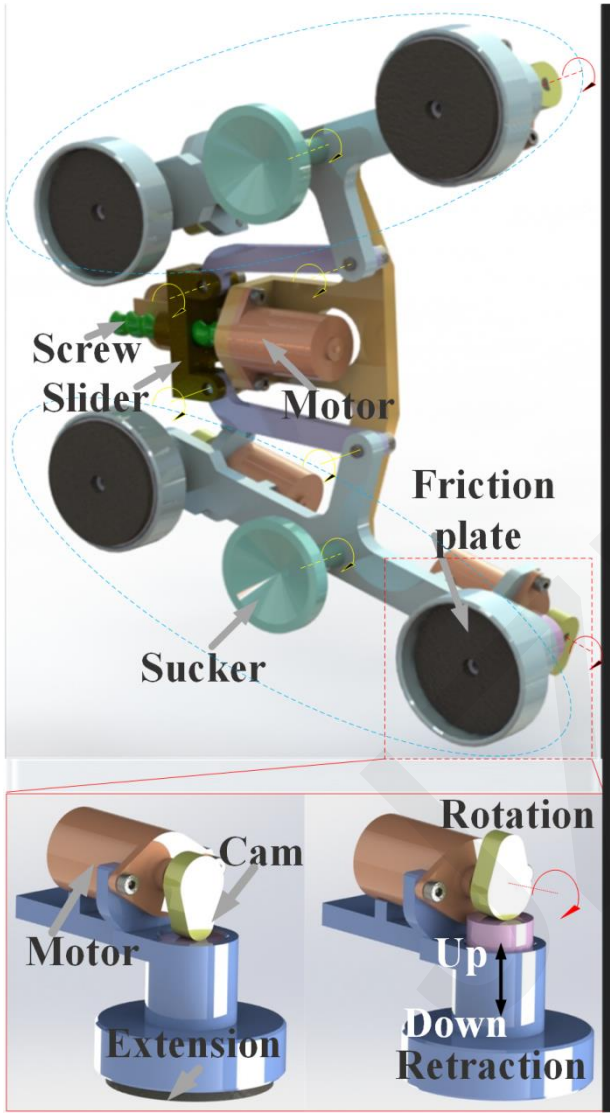
$$L_X = \frac{L_1 \times L_4}{L_3}$$

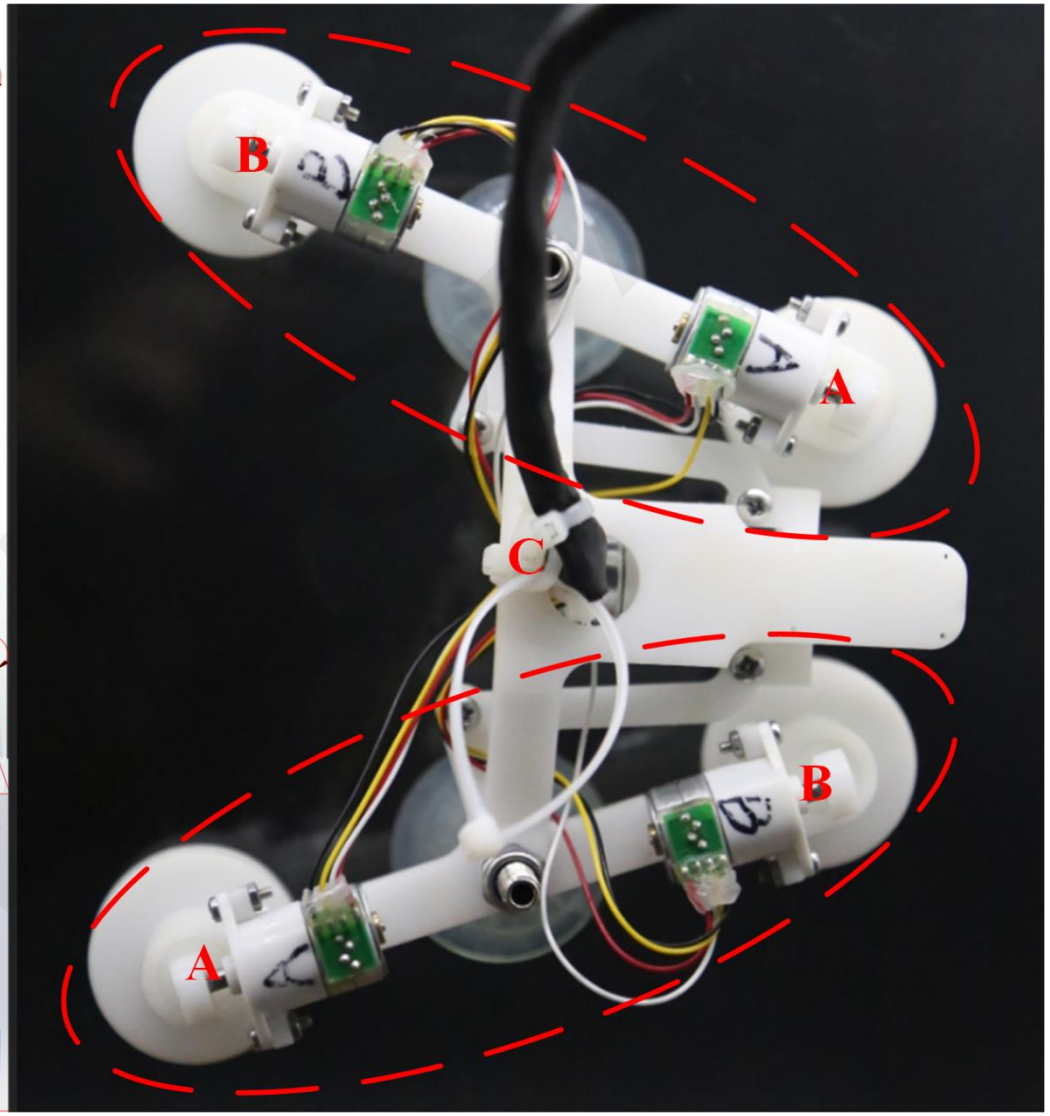




L_X means axial displacement, L_Y means radial displacement of the robot.

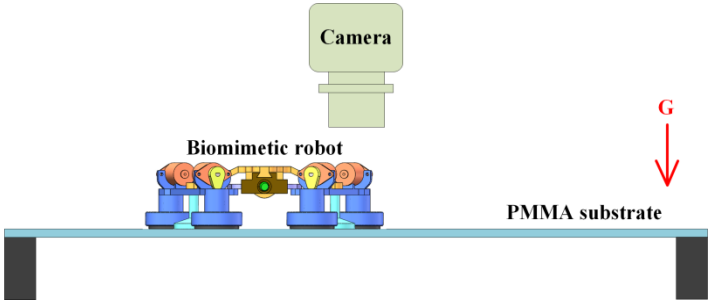
❖ Real robot

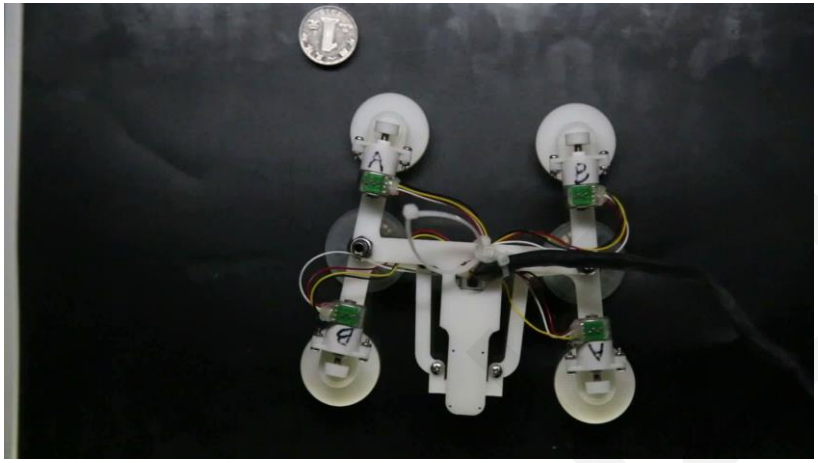


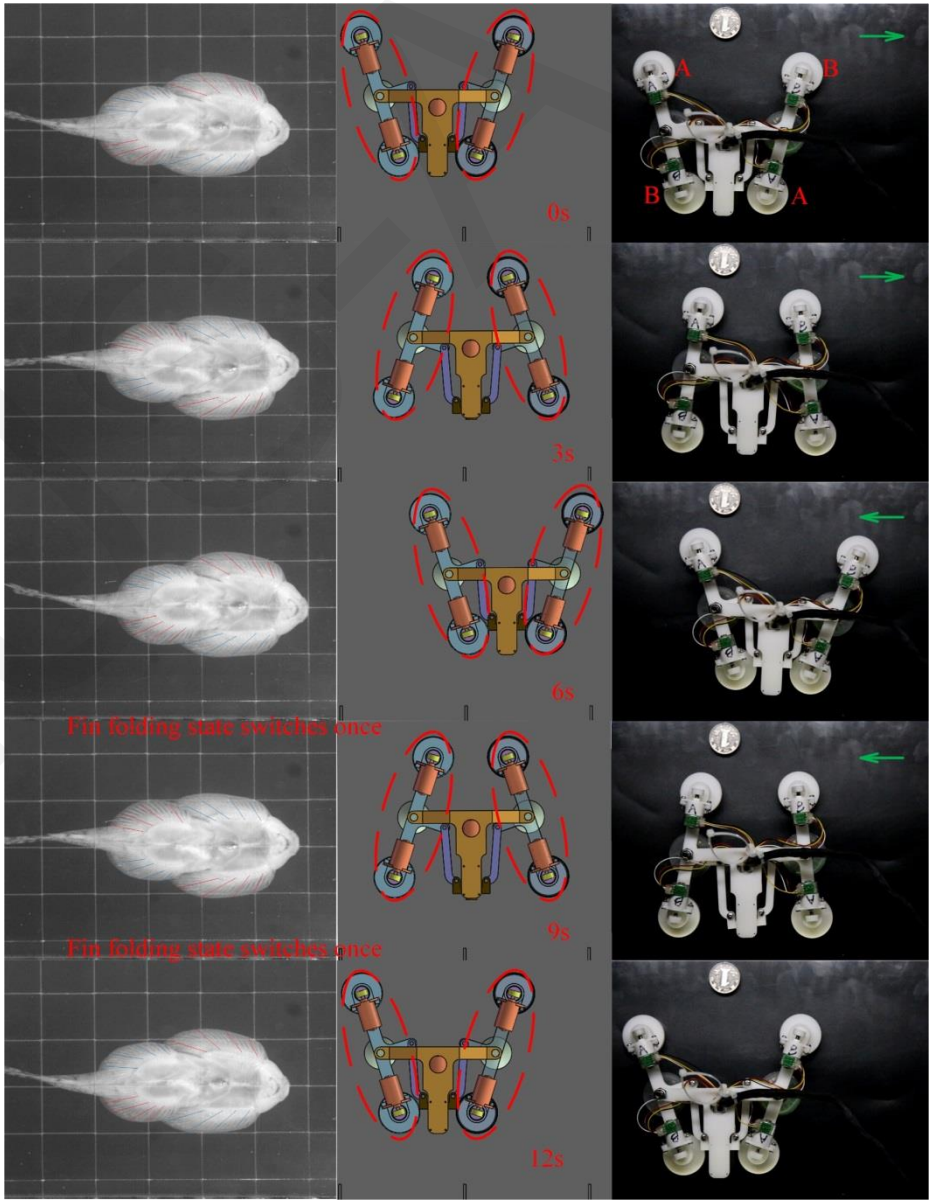


One motor drives body swing through screw and four motors drive adhesive units through cam

❖ Robot test on horizontal surface

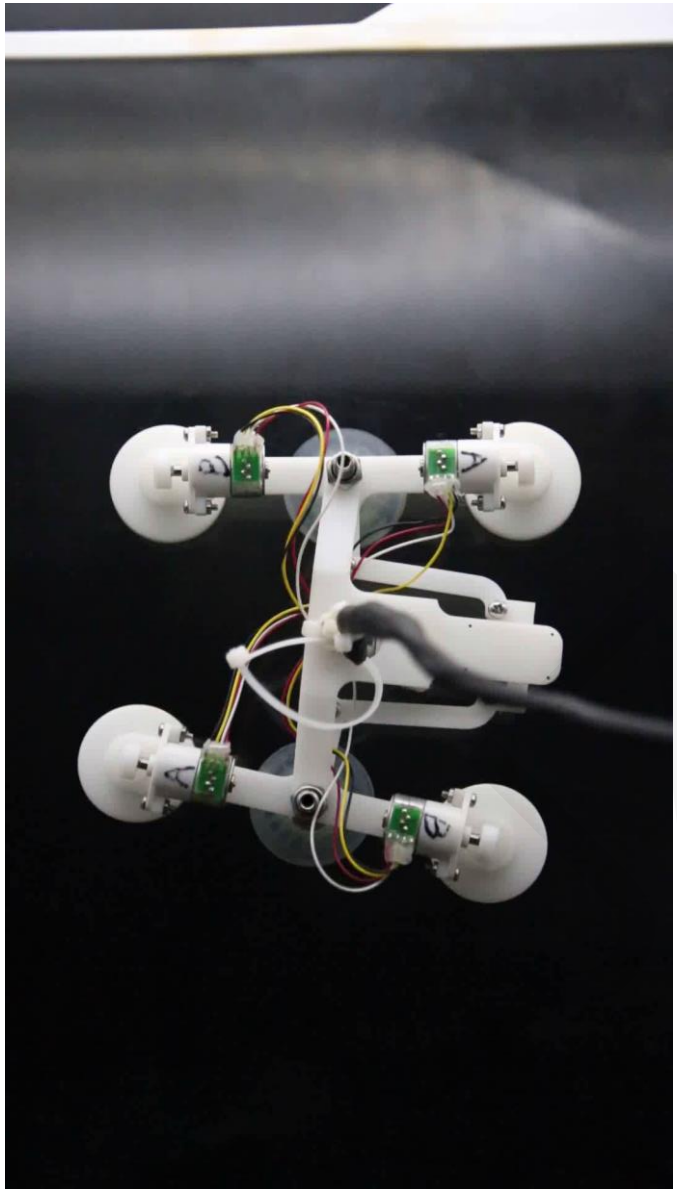


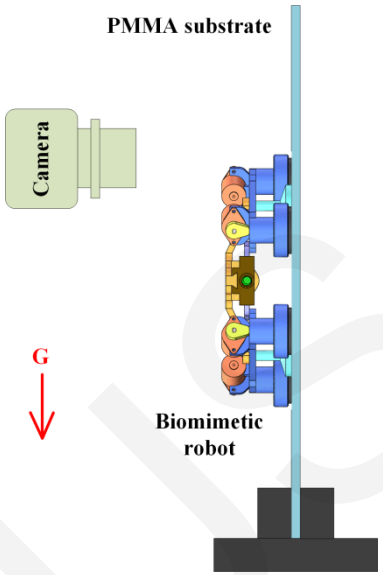




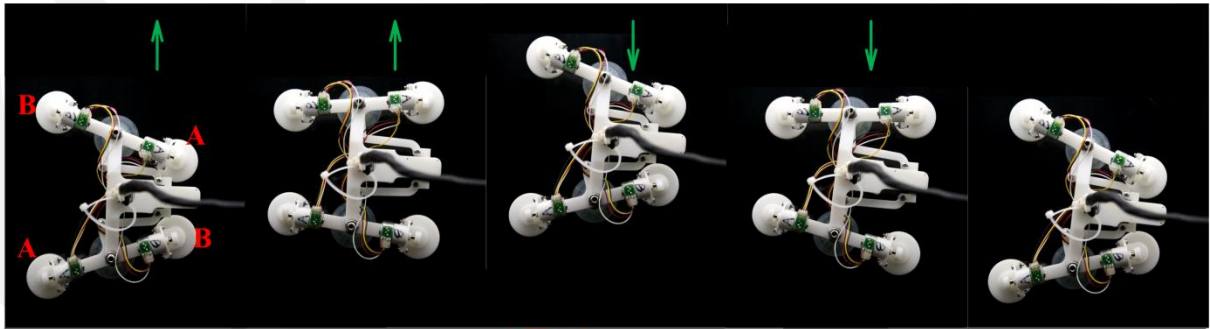
(1) Forward state (0-3s)
(2) Forward state (3-6s)
(3) Backward state (6-9s)
(4) Backward state (9-12s)

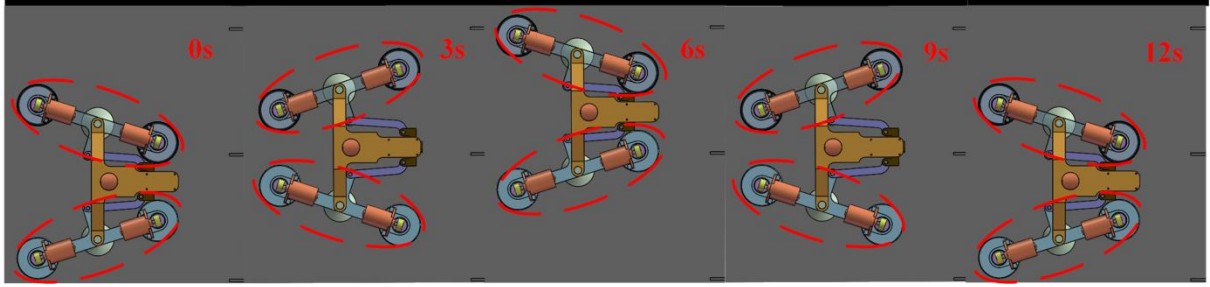
❖ Robot test on vertical surface



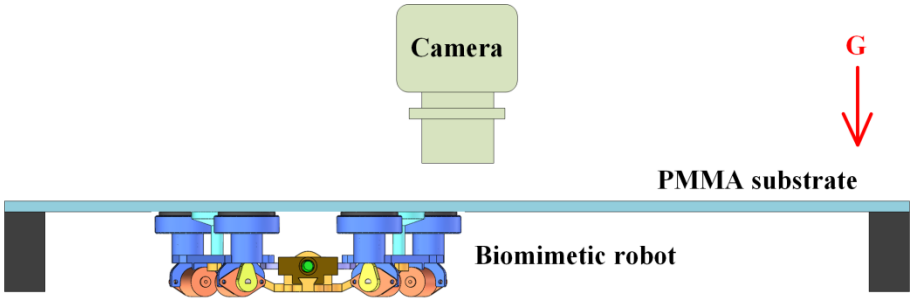


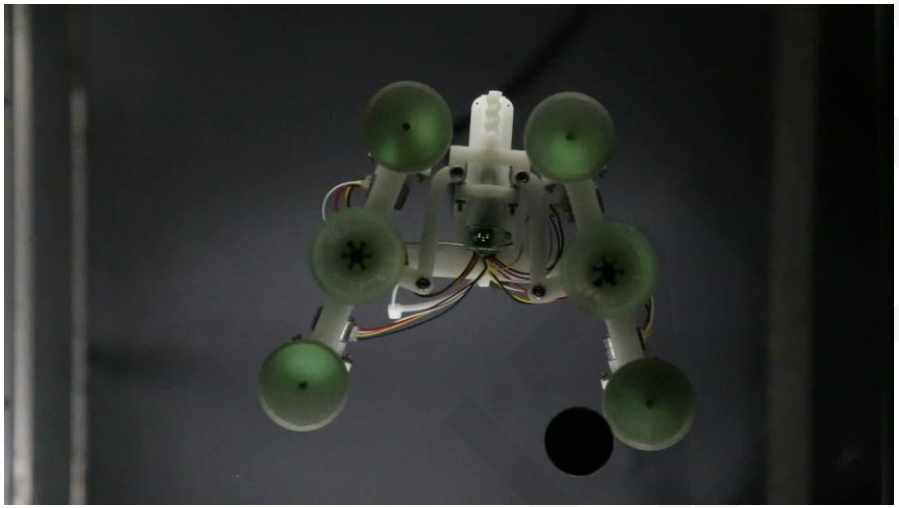
(1) Forward state (0-3s)
(2) Forward state (3-6s)
(3) Backward state (6-9s)
(4) Backward state (9-12s)



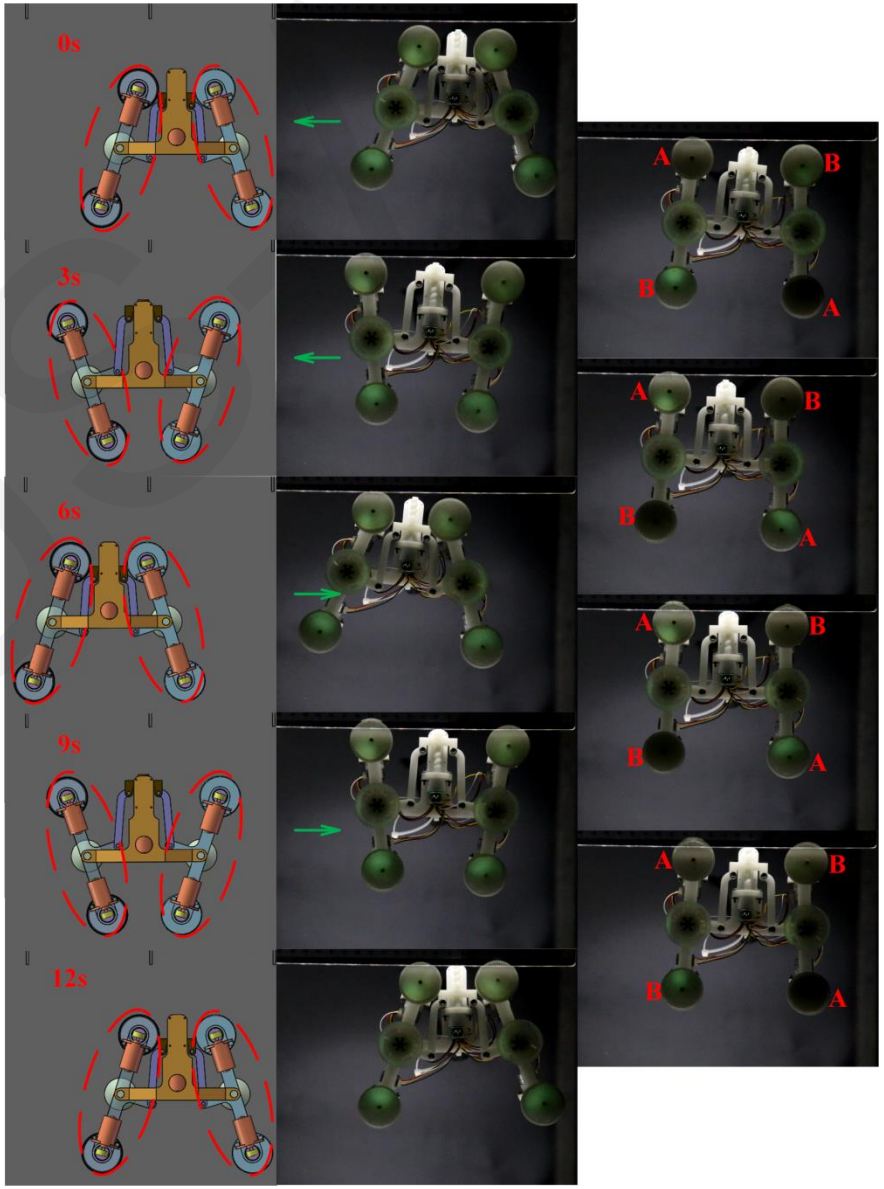


❖ Robot test on inverted surface

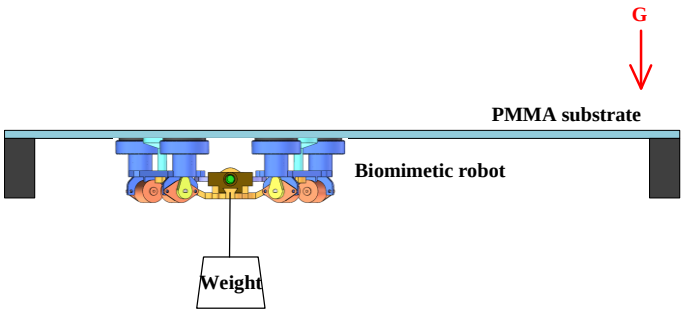


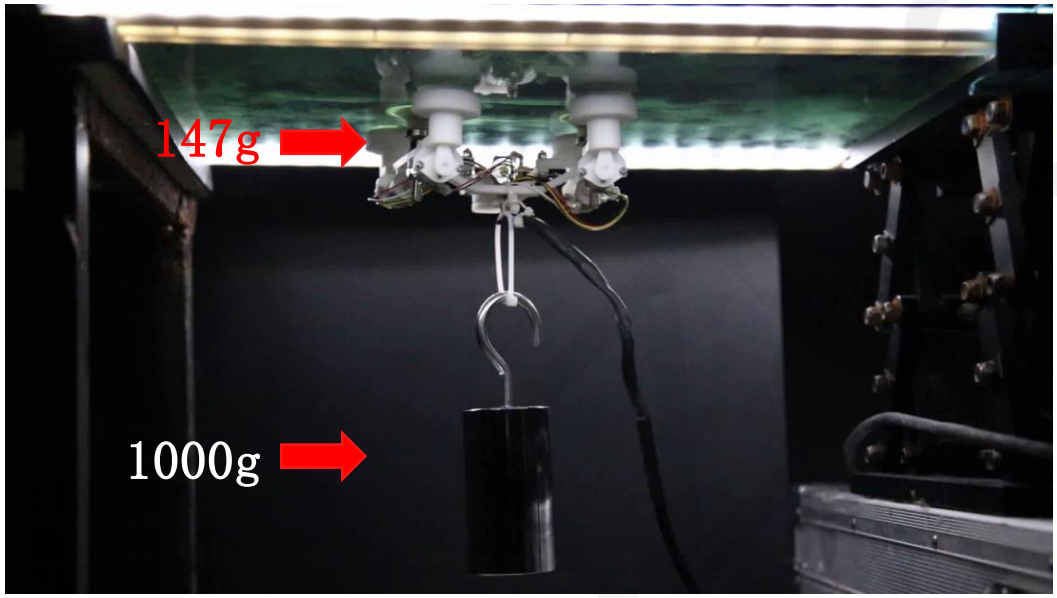


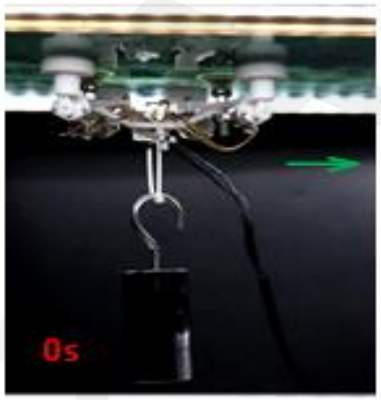
(1) Forward state (0-3s)
(2) Forward state (3-6s)
(3) Backward state (6-9s)
(4) Backward state (9-12s)

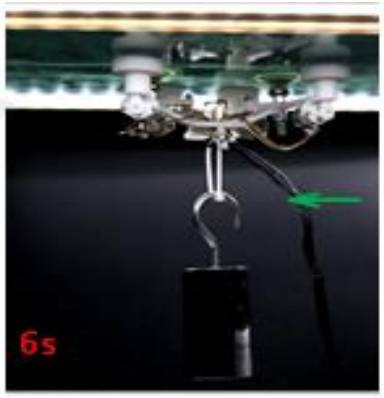


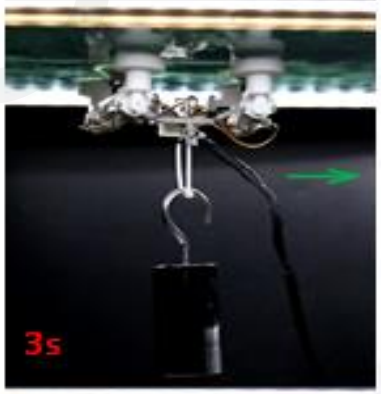
❖ Robot test on inverted surface with load

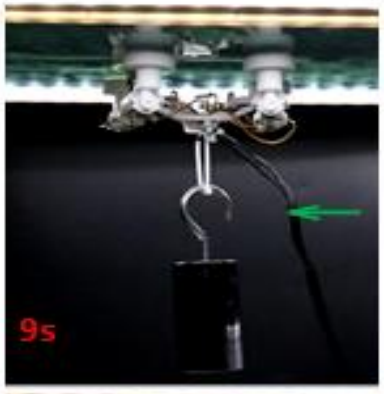


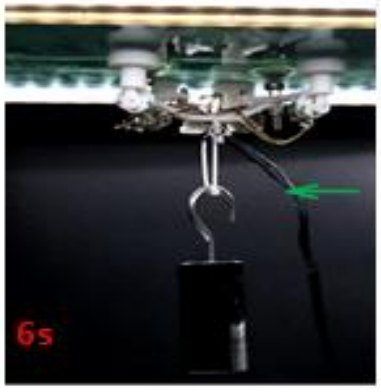


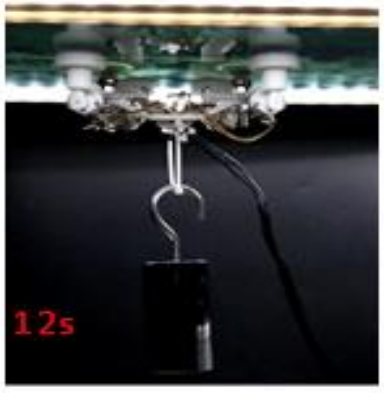












(1) Forward state (0-3s)
(2) Forward state (3-6s)
(3) Backward state (6-9s)
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