Training of Robotic Pectoral Fin Maneuvers Based on the CMAES Algorithm (Fin Orientation Selection)

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Problem

Vegetation and sediment buildup in irrigation canals reduces flow rates and reduces water volume in shallow channels. In this project, we focus on the locomotion of a fish-inspired robot which has been designed and built in order to maneuver inside the narrow lateral canals, and clean the canals by removing vegetation and sediment.

Approach

The current design of bio-inspired robotic fish features two pectoral fin inspired spherical mechanisms to enhance the robot's turning capability in narrow spaces. The two-degree-of-freedom mechanism utilizes two underwater servos for controlling the orientation of the attached fin. In order to control the rotation, servos of each fin are commanded by a sinusoidal angle described as:

$$\theta_1 = \beta_1 + \alpha_1 \sin 2\Pi f_1 t$$

$$\theta_2 = \beta_2 + \alpha_2 \sin(2\Pi f_1 t + \phi)$$

where, θ_i, β_i, α_i, f_i and ϕ are servo rotation angle, rotation offset, rotation amplitude, rotation frequency and servo angle phase shift, respectively.

To span this 7 dimensional space, the ``covariance matrix adaptation evolution strategy'' (CMA-ES) is used to find the best achievable servo rotation parameters for desired goals. In this part of study, the ability of the pectoral fin to provide rotation torque in still water is studied.

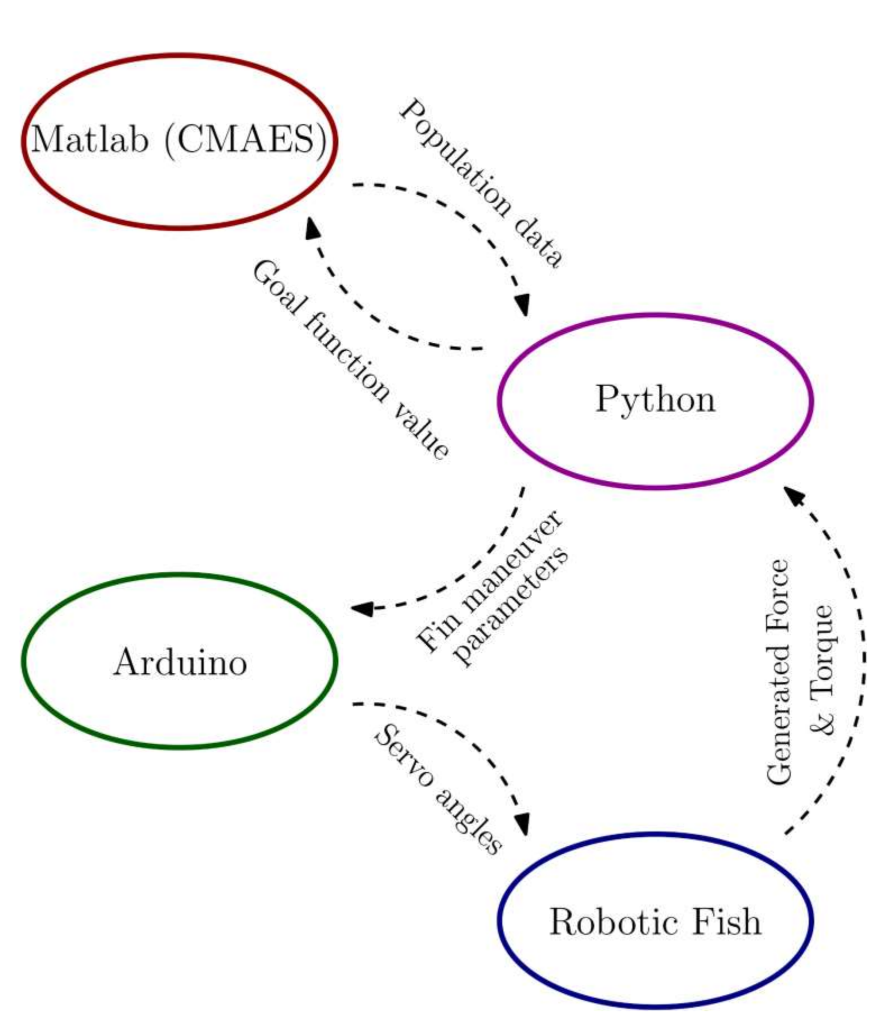
Objective

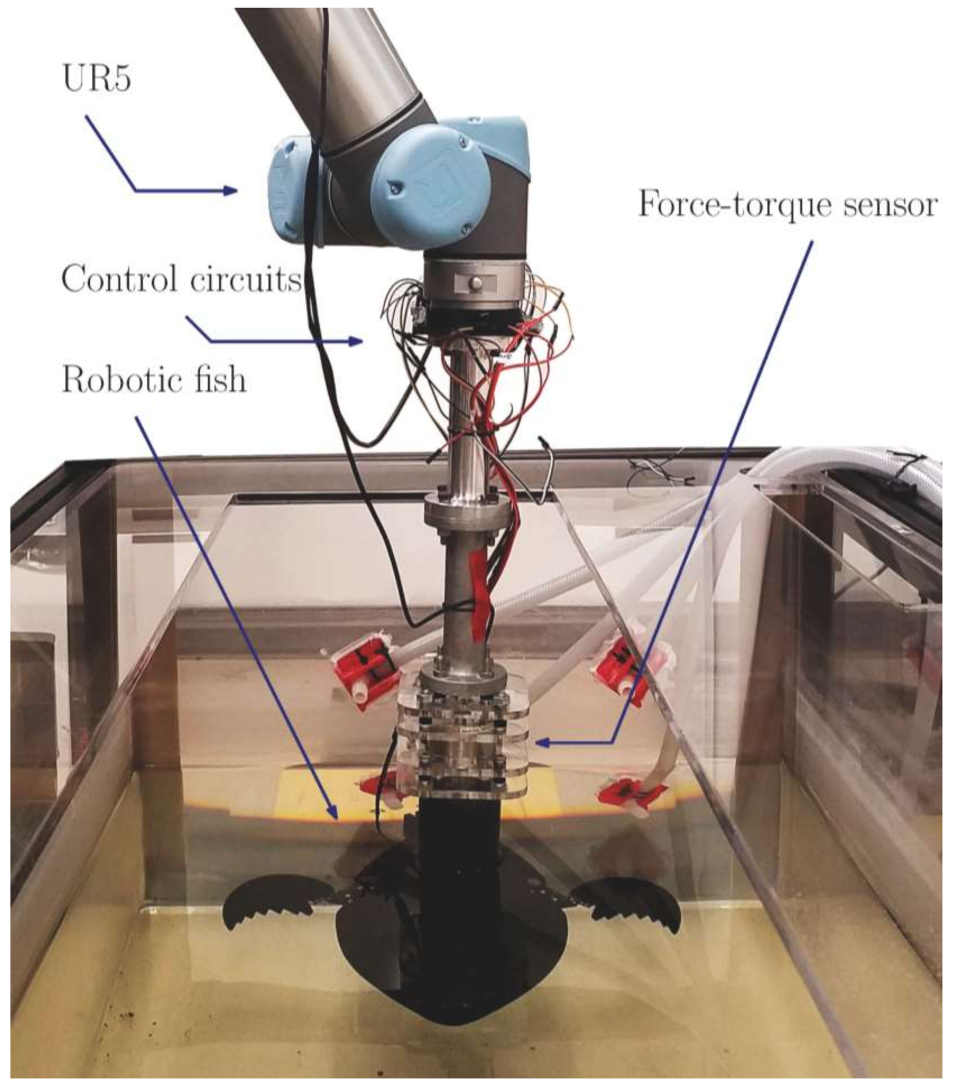
The mechanisms fins have two degrees of freedom. Hence, the effect of rotation of the fin in the third rotation axis must be studied by a different approach. To this end, three different attachments for the spherical mechanism have been designed, built, and tested with the fin. In addition, another two-bodied fin design has been investigated as well. CMA-ES is used to train each fin for maximizing rotational torque and the best fin is selected based on the result obtained.

CMA-ES novel evolutionary optimization strategy based on the derandomized evolution strategy with covariance matrix adaptation. This approach is intended to reduce the number of generations required for convergence to the optimum [1].

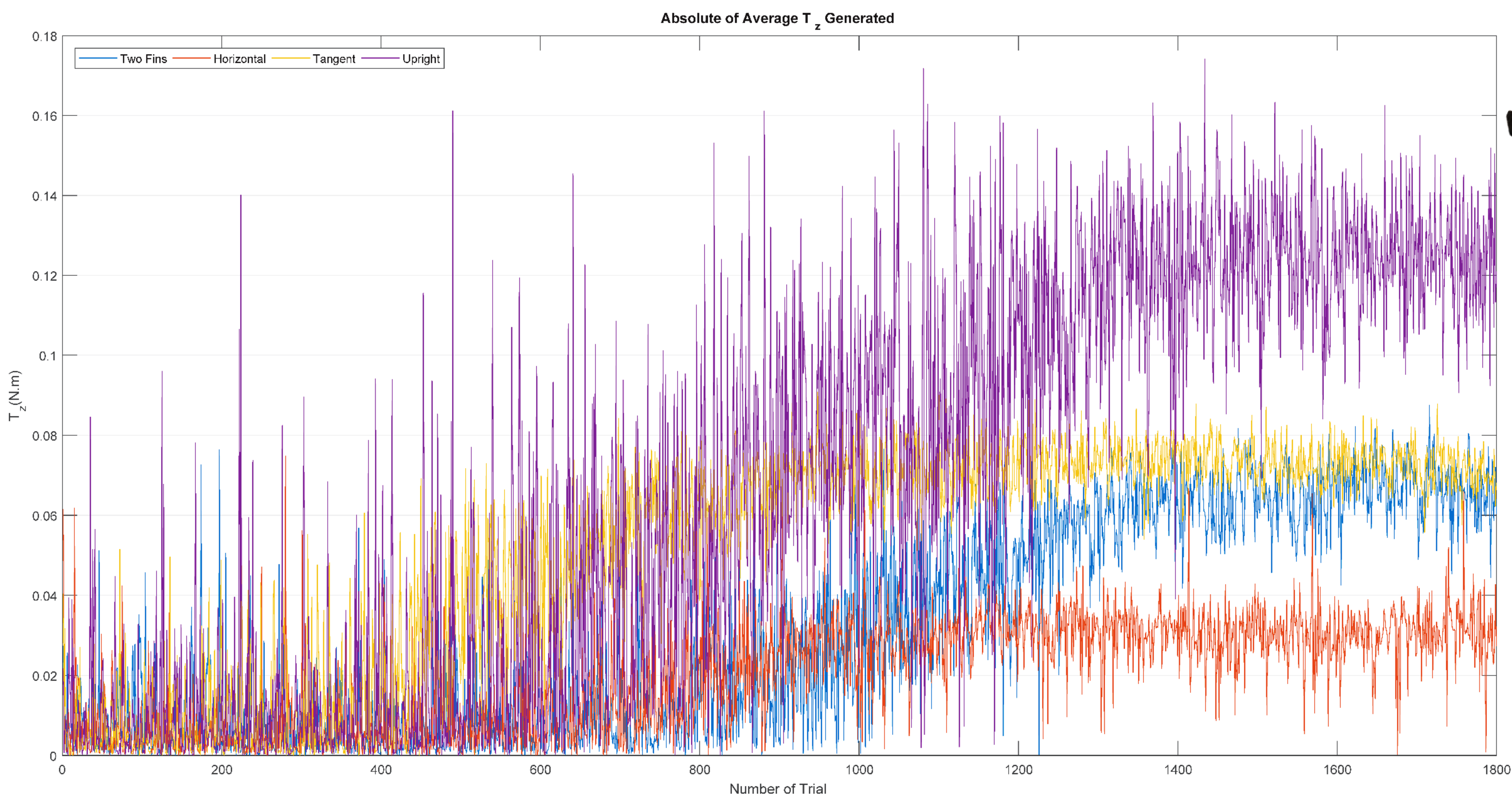
[1] Hansen, Nikolaus, Sibylle D. Müller, and Petros Koumoutsakos. "Reducing the time complexity of the derandomized evolution strategy with covariance matrix adaptation (CMA-ES)." Evolutionary computation 11.1 (2003): 1-18.

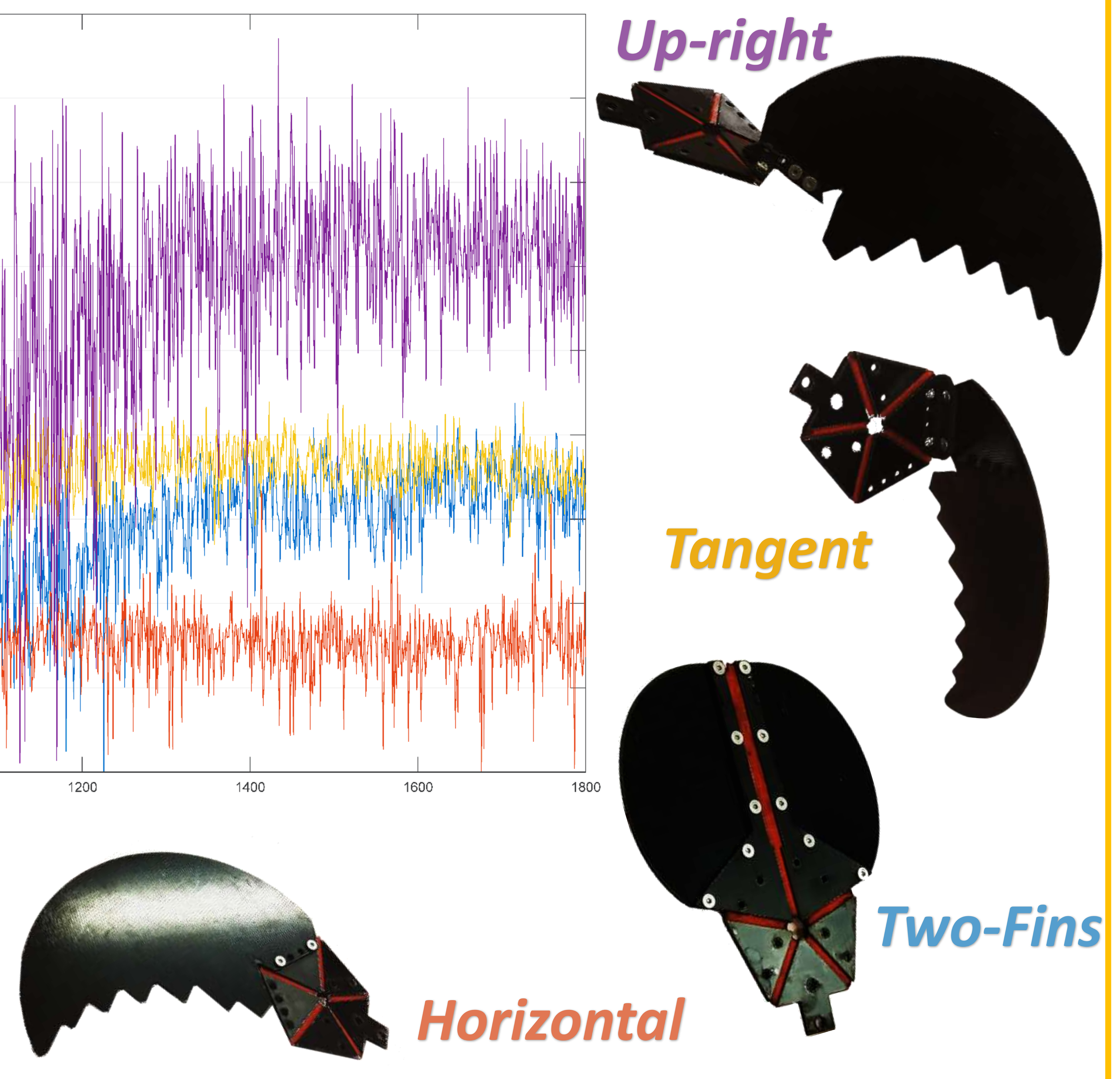
Data Flow & Experimental setup





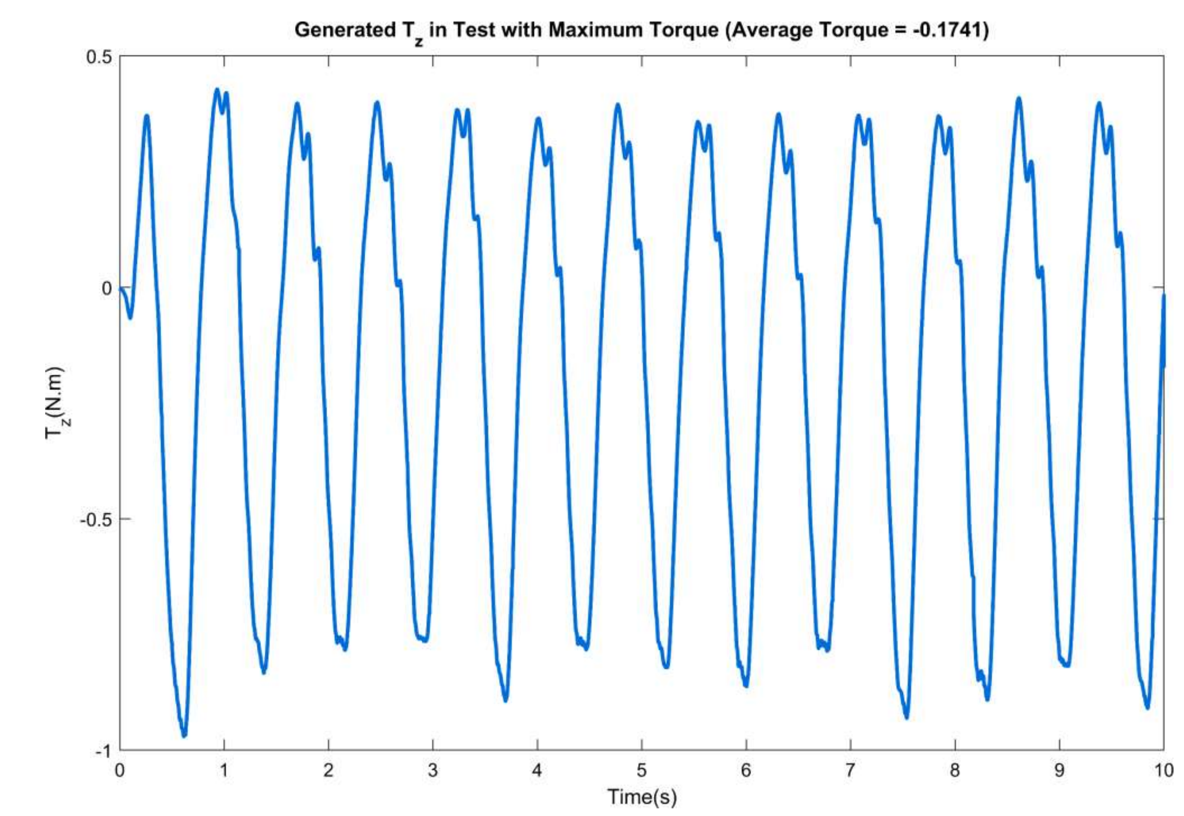
CMA-ES results





Generated Torque

Selected fin is able to produce close to 0.18 Nm of torque, turning the robotic fish under water. This torque is generated by propulsion of 1 fin. Higher torques would be reachable by actuating both fins.



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