Implementation and Evaluation of Centre Pattern Generator Locomotion for Robofish Prototype

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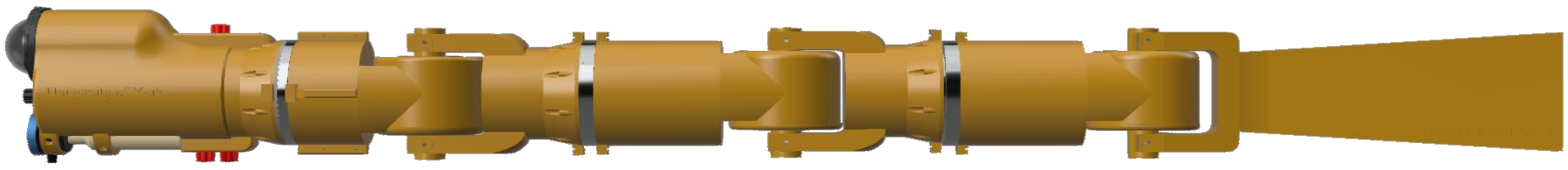
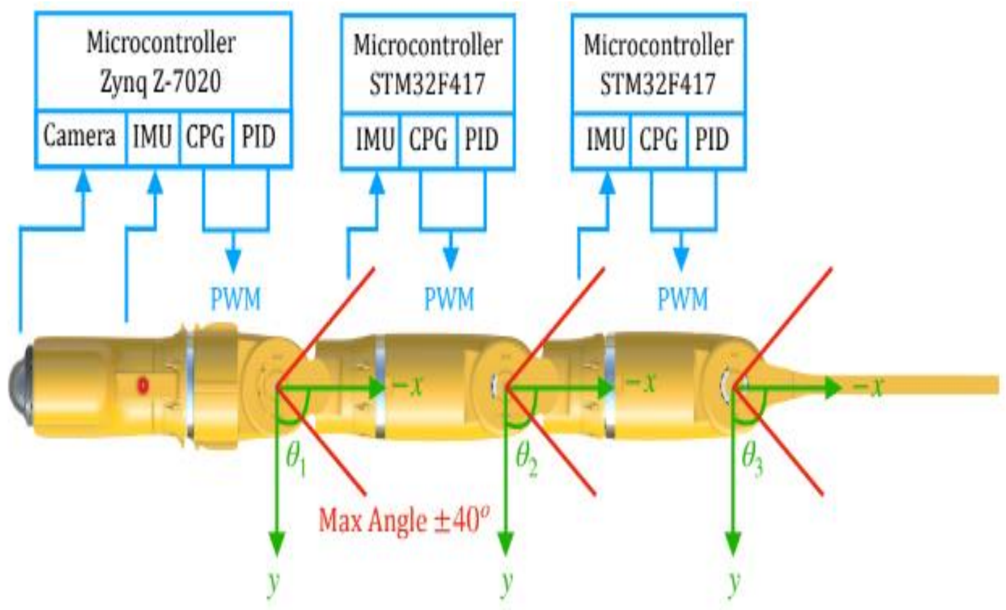


Introduction

The RoboFish prototype, an Autonomous Underwater Vehicle (AUV) developed by the EPSRC Hub, mimics the agile and energy-efficient movement of an eel, ideal for inspecting offshore wind turbine foundations. While the first-generation RoboFish captures the propulsion of fish, it remains underexplored due to the COVID-19 pandemic. This project aims to evaluate and enhance its performance using Central Pattern Generator technology for better reliability and efficiency.



Research outline

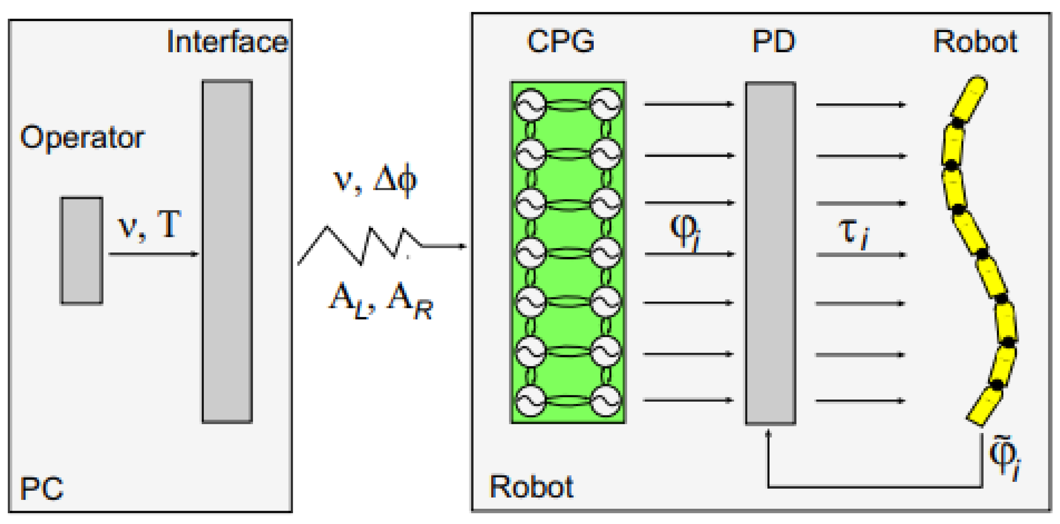
Over the course of my summer internship, I delved into devising a comprehensive Central Pattern Generator (CPG) control strategy. This initiative encompassed an in-depth exploration of CPG modeling, coupled with rigorous analysis and precise modulation of the patterns. A pivotal component of this endeavor was the assessment of the RoboFish's performance using the CPG-based control mechanism. This analysis was contrasted with results from the pure Sinusoid-based control, allowing a comparative study of the efficiencies of both methodologies. Additionally, field tests were undertaken to understand the practical differences between CPG and Sinusoid controls when exposed to real-world aquatic conditions

Implementation

- **Brief Definition of CPG**

A Central Pattern Generator (CPG) is a neural network within the central nervous system that produces rhythmic motor patterns, such as those required for walking, swimming, or breathing, in the absence of rhythmic sensory or central inputs. It autonomously produces rhythmic outputs and plays a crucial role in controlling repetitive motions in many animals.

- **Modelling**



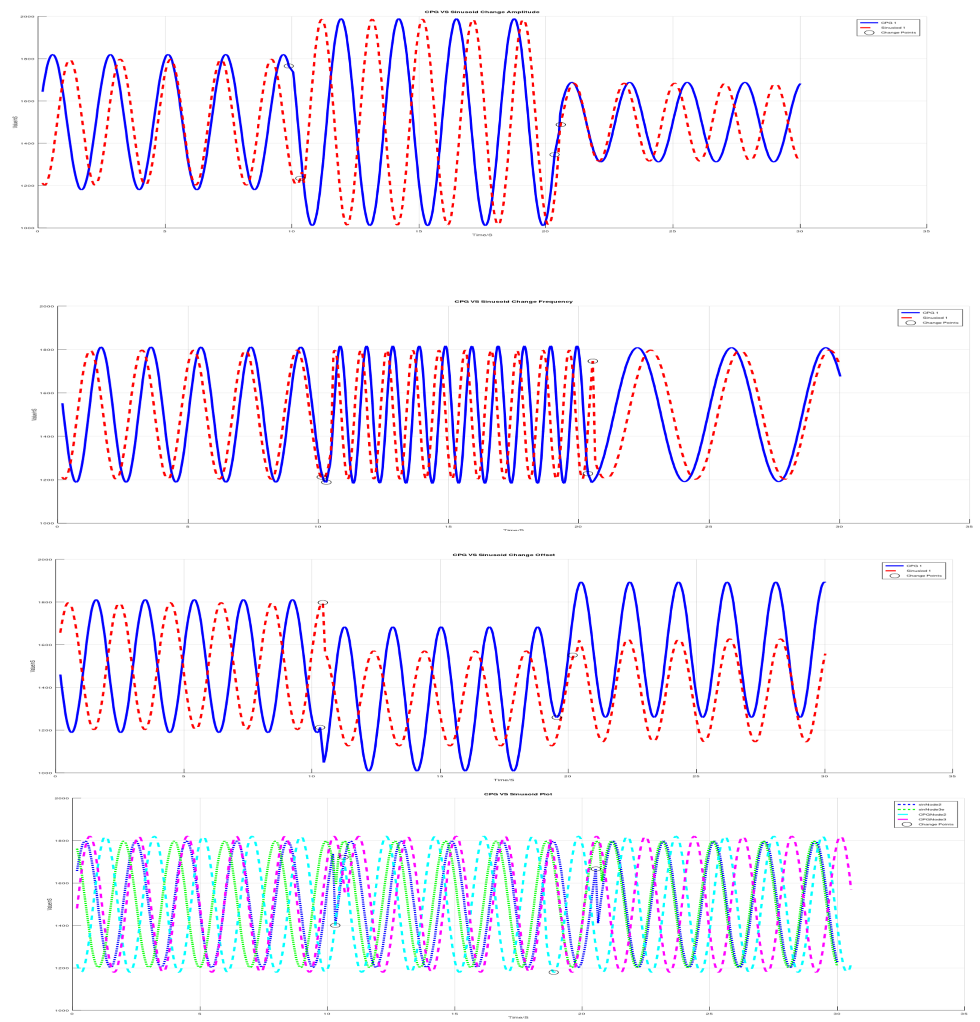
The RoboFish employs a CPG model built on amplitude-controlled phase oscillators. This CPG architecture features a dual-chain design, with coupling between immediate

$$\begin{cases} \dot{\theta}_i &= 2\pi\nu_i + \sum_j w_{ij}\sin\left(\theta_j - \theta_i - \phi_{ij}\right) \\ \ddot{r}_i &= a_i\left(\frac{a_i}{4}(R_i - r_i) - \dot{r}_i\right) \\ x_i &= r_i\left(1 + \cos(\theta_i)\right) \end{cases}$$

The Central Pattern Generator (CPG) is designed as a system of interconnected oscillators. The behavior of each oscillator is defined by the equations presented above, ensuring coordinated motion patterns.

Conclusion

The four plots presented below offer a comprehensive visual comparison of the RoboFish's behavior and performance in response to sudden modifications in key parameters—namely amplitude, frequency, offset, and phase—of both the Central Pattern Generator (CPG) and sinusoid controls. This side-by-side illustration aims to elucidate the distinct effects and potential advantages of each control method under varying conditions



In conclusion, Central Pattern Generators (CPGs) in biomimetic robotics offer advanced rhythmic control. Their adaptability, stability after disturbances, and modular design highlight their pivotal role in both current research and future robotic advancements.
While CPGs offer dynamic control, their complexity can pose challenges in fine-tuning, leading to suboptimal performance in some scenarios

Future work

1. Future work will explore using RoboFish swarms for tasks like seafloor mapping and marine archaeology, posing challenges in underwater protocols for acoustic localization, navigation, and real-time data collection
2. In upcoming iterations, we envision a more compact RoboFish model emphasizing modularity in body design, complemented by easy-to-use magnetic joints for swift assembly and disassembly. This design refinement will pave the way for enhanced data validation and facilitate experimental studies in hydrodynamic laboratory settings

Reference: A. J. Ijspeert and A. Crespi, "Online trajectory generation in an amphibious snake robot using a lamprey-like central pattern generator model," in Proceedings 2007 IEEE International Conference on Robotics and Automation, Roma, Italy, 2007, p. 3.