COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

Announces the Ph.D. Dissertation Defense of

AISHWARYA S. NAIR

for the degree of Doctor of Philosophy (Ph.D.)

"Navigation and Coordination of artificial swimmers using Deep Reinforcement Learning"

March 14, 2024, 10:00 a.m.
Engineering West Building (EG-36), Room 187
777 Glades Road
Boca Raton, FL
Zoom Link

DEPARTMENT:
Ocean and Mechanical Engineering

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ABSTRACT OF DISSERTATION

Aquatic organisms are able to achieve swimming efficiencies that are much higher than any underwater vehicle that has been designed by humans. This is mainly due to the adaptive swimming patterns that they display in response to changes in their environment and their behaviors, i.e., hunting, fleeing, or foraging. In this work, we explore these adaptations from a hydrodynamics standpoint, using numerical simulations to emulate self-propelled artificial swimmers in various flow fields. Apart from still or uniform flow, the most likely flow field encountered by swimmers are those formed by the wakes of solid objects, such as roots of aquatic vegetation, or underwater structures. Therefore, a simplified bio-inspired design of porous structures consisting of nine cylinders was considered to identify arrangements that could produce wakes of varying velocities and enstrophy, which in turn might provide beneficial environments for underwater swimmers. These structures were analyzed using a combination of numerical simulations and experiments, and the underlying flow physics was examined using a variety of data-analysis techniques.

Subsequently, in order to recreate the adaptations of natural swimmers in different flow regimes, artificial swimmers were positioned in each of these different types of flow fields and then trained to optimize their movements to maximize swimming efficiency using deep reinforcement learning. These artificial swimmers utilize a sensory input system that allows them to detect the velocity field and pressure on the surface of their body, which is similar to the lateral line sensing system in biological fish. The results demonstrate that the information gleaned from the simplified lateral line system was sufficient for the swimmer to replicate naturally found behaviors such as Karman gaiting. The phenomenon of schooling in underwater organisms is similarly thought to provide opportunities for swimmers to increase their energy efficiency, along with the other associated benefits. Thus, multiple swimmers were trained using multi-agent reinforcement learning to discover optimal swimming patterns at the group level as well as the individual level. Here, each swimmer was trained using the combined experience of all agents, while they were allowed to act independently according to the respective inputs from their lateral line sensors. Their behavior was also analyzed by varying the optimization parameters for each swimmer to be the individual efficiency versus the group average efficiency. The swimmers that optimized individual efficiency did not show a significant inclination towards grouping with each other, while the swimmers that optimized their collective efficiencies were found to have a clear preference for following each other. The results from these studies can be useful in distinguishing various swimming patterns and their role in achieving higher efficiency, and the physical mechanisms revealed can be helpful in developing optimal strategies for efficient and autonomous collective navigation of underwater vehicles.

BIOGRAPHICAL SKETCH
Born in North Paravur, Kerala, India
B.S., Birla Institute of Technology and Science, Hyderabad, India, 2017
M.S., Purdue University, West Lafayette, IN, USA, 2018
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CONCERNING PERIOD OF PREPARATION
& QUALIFYING EXAMINATION

Time in Preparation: 2019 - 2024

Qualifying Examination Passed: Fall 2019

Published Papers:

Nair A, Kazemi A, Curet O, Verma S., “Porous cylinder arrays for optimal wake and drag characteristics”. *Journal of Fluid Mechanics*. 2023;961:A18. doi:10.1017/jfm.2023.255

Nair A., Alvaro A., Verma S., “Autonomous navigation of simulated swimmers using deep reinforcement learning”, Bulletin of the American Physical Society, Volume 68, Indianapolis, 2022

Nair A., Verma S., “Navigation of interacting swimmers using Multi-agent Reinforcement Learning”, Bulletin of the American Physical Society, Volume 69, Washington D.C., 2023