Passive Degrees of Freedom in Fish Like Robots

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Biography

I received my undergraduate degree in mechanical engineering from Clemson University May of 2015. While working on my bachelors I had multiple internships but nothing that I learned there can be directly applied to my research now. I am currently a TA in the mechanical engineering lab teaching ME 4440. I am a member of the American Physical Society. My research interests are in robotics, programming, nonlinear dynamics and fluid mechanics.

Overview:

In nature it has been shown that natural swimmers and fliers use passive degrees of freedom to perform some interesting maneuvers. For example, a fly's ability to hover is a result of the twisting of the wing along its leading edge, which is a passive degree of freedom. If robots can be designed utilizing passive degrees of freedom similar to natural creatures, then the robot could be designed simpler, lighter, and it could also simplify the robots control algorithm. We plan to study passive degrees of freedom on our robot to see if we can get certain characteristics that are different from a similar model which does not utilize passive degrees of freedom.

Motivation

In the past decade there has been exponential growth in the field of bio-inspired locomotion. The reason for this is because even with today's modern technology we are not even close to matching certain characteristics (i.e. speed, efficiency, maneuverability) of biological creatures. My research is specifically centered around a bio-inspired aquatic robot. Our model is driven by the oscillations of an internal momentum wheel, meaning that there are no external fins or propellers. The major challenge with this is coming up with an accurate model describing the fluid and body interaction that is not too computationally inefficient. We are also investigating how the addition passive degrees of freedom effects the locomotion.

State of the Art

Most other researchers are studying bio-inspired locomotion with robots that have directly actuated tails [1-2]. In [1] they perform some dynamic modeling for their robot but they exclude the vortex shedding, which is the primary means of propulsion, but it brings with it computational inefficiencies. We are trying to come up with a dynamic model which takes into account the interaction with the vortices shed and the body. This model we are working towards will also be used to analyze the future robots which will have passive degrees of freedom.

Intellectual Merit

The main research question I will be investigating is if passive degrees of freedom effect the locomotion of robots. We have already been able to show at least with initial tests that the addition of a passive tail greatly increases the maneuverability of the robot. Passive degrees of freedom on aquatic robots are also predicted to be able to harness the energy of flow fields, which could increase efficiency and also in some cases decrease the complexity of a controller. An example is a group at Harvard placed a robot with a passive fin downstream from a rectangular structure which forced the fluid to flow around it. As the robot approached the structure the passive fin harvested the energy from the wake forming behind the structure and pushed the robot around the structure. This is significant because if we were to design a controller for the robot we may not have to worry about obstacle avoidance if some sort of fin can accomplish that task for us.

Broader Impact

This robot or another robot that used some of the significant finding from this robot could be used in the future for environmental monitoring. If the robot was as efficient as some natural swimmers, then it could spend days or even weeks mapping the ocean floor without needing to be refueled. It could also have significant military uses as a surveillance sub.

Research Approach

The fundamental concept of computational thinking for my research is the geometric modeling of the robot and how it interacts with the fluid. We are investigating multiple methods of first simplifying the vortex wake and then moving on to modeling a robot with multiple segments. We plan to first change the vortex shedding from many discrete point vortices to one vortex wake with a changing value of circulation. This would bring limit the number of equations in the state space of the system to 5 instead of the constantly expanding dimension for the case of individual point vortices. We then want to use a method known as the panel method to try to model the robot with some sort of passive fins.

Findings to Date

To date we have been able to demonstrate that even though the equations describing the motion of this robot are highly nonlinear and complicated there are some linear characteristics in the relation of the heading angular velocity of the body and the angular velocity of the internal rotor. We have also been able to show that the addition of a passive tail on the robot greatly increases the robot’s maneuverability.

Conclusions

We plan to have a full understanding as to why the addition of passive degrees of freedom benefits the locomotion of the robot. This will be accomplished through the detailed computationally efficient modeling of the robot and verifying this model with the physical representation of the robot.

References

[1] Kopman, V., Laut, J., Rizzo, A., and Porfiri, M., 2014. “Dynamic modeling of a robotic fish propelled by a compliant tail.”. IEEE Journal of Oceanic Engineering, pp. 1–13.

[2] Epps, B. P., P. Valdivia Alvarado, K. Y.-T., and Techet, A. H., 2009. “Swimming performance of a biomimetic compliant fish-like robot”. Experiments in Fluids, 47, pp. 927–939.