Box Jellyfish-Inspired Water Exploration - A Soft Robotic Approach

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Abstract—This paper takes inspiration from a jellyfish bell in order to create a bio-inspired soft robot. A jellyfish was chosen due to its combination of speed and efficiency. This is due to the natural aerodynamics of the jellyfish as well as their use of a toroidal vortex. In addition to the swimming characteristics of a jellyfish, the animal is also naturally soft and flexible allowing for an easy translation of the jellyfish kinematics to soft robot. A soft robot was chosen because the final intention of this robot is to aid marine researchers in their studies of fragile ecosystems such as coral reefs.

Key Terms:

Biomimetic- relating to or denoting synthetic methods that mimic biochemical processes

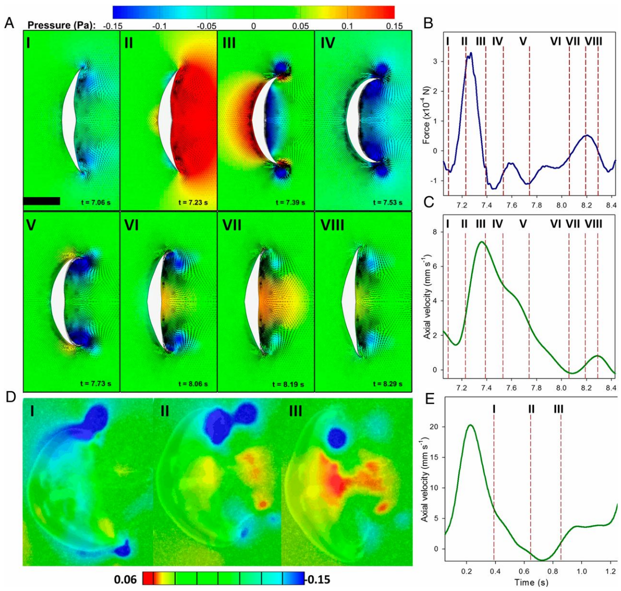
Troidal Vortex- is a region of rotating fluid moving through the same or different fluid where the flow pattern takes on a doughnut shape

1 Introduction

THROUGHOUT the seas, ocean ecosystems are experiencing a rapid decline in health. The coral reef is among those ecosystems that have taken a nose dive in health. As of 2011, over 60% of reefs have already been seriously damaged. And over 25% of the remaining healthy reefs are threatened to follow this unfortunate health trend. The health of coral reefs can be improved by immediate human intervention as soon as the decline begins to occur. In order to maximize the effectiveness of that intervention vital coral reef health indicators need to be constantly monitored. These factors include over fishing, destructive fishing methods, coral harvesting, pollution, sedimentation, sewage, temperature and ocean acidification. Current methods of monitoring these health indicators are proving to be either too invasive, expensive, or don't provide data over a large enough area. Thus, the idea for a small, cheap, and mobile soft robot was inspired. In order to minimize environmental impact the look and feel of the robot ideally will mimic something from nature. When researching animals that fit the criteria of a small, cheap, and mobile noting came close to the jellyfish. Upon further investigation, there was more to learn from the jellyfish than just the look and feel. The jellyfish is one of the best animals on the planet at balancing both efficiency and power while maintaining durability and flex ability. The key to achieving these feats in a robot was to understand the locomotion of the jellyfish bell and design a soft robot around it.

2 Swimming Performance

Jellyfish are widely considered one of the most efficient creatures on the planet. In part this is due to the way in which they are able to harness the energy of a current (current surfing) as well as their innate ability to create Trodial vortexes in order to propel themselves.



2.1 Speed and Power

2.2 Efficiency

Jellyfish are able to move both passively and actively.

2.2.1 Current Surfing

passive movement

2.2.2 Troidal Vortex

Result of active movement

3 Bell Shape and Behavior at Rest

Neutral Buoyant Larger the Bell the More Current Influences Movement

4 Bell Elasticity and Flexibility

No Skeletal Structure How does bell maintain shape? Degrees of freedom for bell?

5 Bell Kinematics

Jellyfish cycle through three different muscle phases in order to accomplish their two different swimming gates.

5.1 Muscle Mechanics

Jellyfish muscle mechanics can be broken down into the separate movements. The contraction phase, recoil phase, and Reduced Amplitude Oscillation Phase (RAO).

5.1.1 Contraction Phase

Initial push

5.1.2 Recoil Phase

Bring bell back up. This is when the Trodial vortex effects take place

5.1.3 Reduced Amplitude Oscillation Phase

Only occurs in transient swimming gate. Much longer bell recoil phase. 43% longer.

5.2 Gates

Jellyfish have 4 gates. Only focus on Transient and Resonant. Hopping and Sink Fishing are used for hunting.

5.2.1 Transient

Pulse at regular intervals

5.2.2 Resonant

Full range of motion of bell

6 Bomimetic Bell Model

7 Bomimetic Bell Simulation

8 Bomimetic Bell Results

Acknowledgements

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