Development of a Biomimetic Punting Unmanned Underwater Vehicle

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Motivation

Current UUV technology has its limitations. While effective in calm waters, conventional torpedo shaped UUVs do not perform well in areas of more dynamic flow, or in near bottom and complex environments. Access to these areas is essential if we hope to use UUV’s in applications of nearshore ocean dynamics, removal of maritime unexploited ordinance and tactical oceanography. This has led to an increase in biomimetics and bio-inspired engineering in order to develop novel ideas for new generations of UUVs. This project investigates the use of a propulsion system inspired by the punting locomotion of the “Little Skate” as an enabling technology for near-bottom UUV operations.

Little Skate (Leucoraja erinacea)

The Little Skate is a benthic batoid that lives at the bottom of the water column near the seafloor. The Little Skate and a few other batoids have been observed to utilize a novel method of locomotion to move along the seabed. The skate will use its pelvic fins to push off the ground and glide forward, “punting” along the bottom. [2]

Design of Body

• NACA 4412 profile acts as a lifting surface at speed
• 3d printed ABS in 8 parts assembled as shown
• Length: 70cm
• Width: 61cm
• Waterproofed with Minwax polyurethane and Rust-oleum gloss protective enamel

Propulsion Mechanism

• Moog C13-L19-W20 DC motor encased in a waterproof housing
• Linkages translate rotational motion of motor to reciprocating motion
• Linkages joined by flexible joint to appendages under the wings
• The appendages propel the UUV by pushing off the floor similar to the pelvic fins of the skate

Variable System Parameters

• Design had to include variability to allow for tuning of vehicle dynamics
  a) Stroke length can be varied through the use of different holes in the drive wheels
  b) Ballast has different mounting locations for movement of the vehicle’s center of gravity
  c) Additional ballast can change the magnitude of negative buoyancy
  d) Under wing appendage mounts can be interchanged for different angles
  e) Motor speed profiles

Modeling

• Vehicle position and velocity over ground are modeled during ‘launch’ and ‘glide’ phases.
• Leg motion is solved analytically from geometric constraints.
• Assumptions for vehicle modeling include
  1. Quasi-static fluid dynamics for body lift and drag
  2. Only forces during launch phase are from legs
  3. When gliding, the vehicle can be treated as a projectile
  4. There is no slip between legs and the ground
  5. The legs will only accelerate the vehicle if the launch conditions are met:
     1. The leg velocity is negative
     2. The leg acceleration is negative
     3. The leg tip is in contact with the ground

Preliminary Testing

Using a previously rough tuned center of gravity and negative buoyancy magnitude and the maximum stroke length experimental testing will include the varying of:
• Leg velocity profile and
• Leg mount angle
With the aim of improving speed over ground and quantifying their effect on vehicle dynamics

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