NRI: 3-D Maneuverable Feedback-Controlled Micro Swimming Drone for Biomedical Applications

(ECCS-1627815)
University of Pittsburgh

I. Team Members

PI: Sung Kwon Cho
Dept. of Mechanical Engineering/Materials Science
University of Pittsburgh

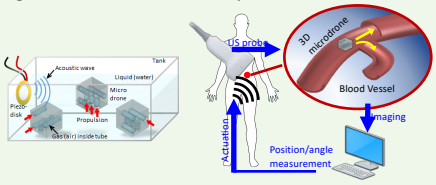
Co-PI: Nitin Sharma
Dept. of Mechanical Engineering/Materials Science
University of Pittsburgh

Co-PI: Kang Kim
Dept. of Medicine/Bioengineering
University of Pittsburgh

II. Objective

The project aims to develop a remotely controlled microdrone as an *in vivo* cargo to conduct biomedical investigations or operations such as bio-sensing, drug delivery, microsurgery, bio-imaging, etc.

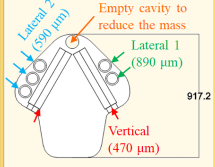
The strategy consists of three parts: (1) 3-D self-propelled microdrone powered by microstreaming flow from acoustically oscillating bubbles with orientation restoration (2) real-time ultrasound (US) imaging system (3) feedback control algorithms and state estimation algorithms for maneuverability.



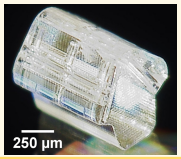
III. Materials and Methods

1. 3-D Microdrone

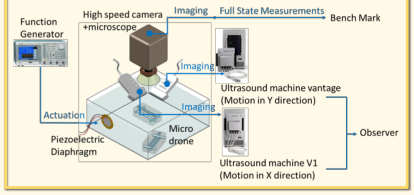
CAD design



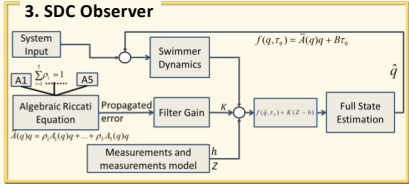
3D Microscope Image



2. US Tracking System on 2D plane



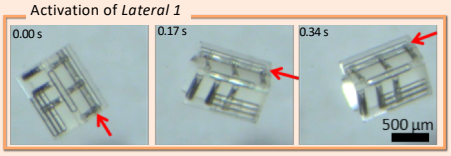
3. SDC Observer



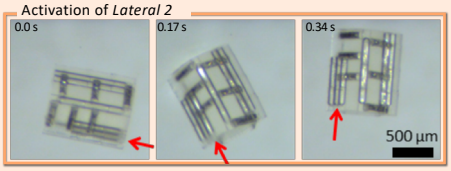
IV. Results

1. Single Propulsion (3-D)

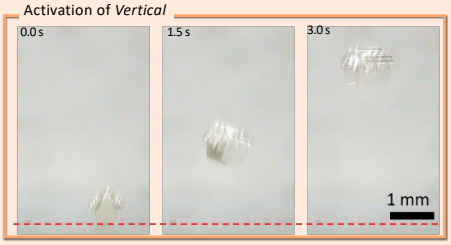
Activation of *Lateral 1*



Activation of *Lateral 2*

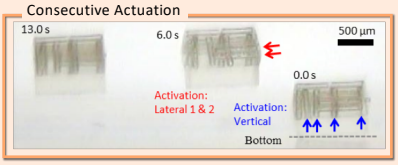


Activation of *Vertical*

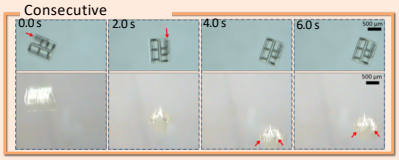


2. Multiple Propulsion (3-D)

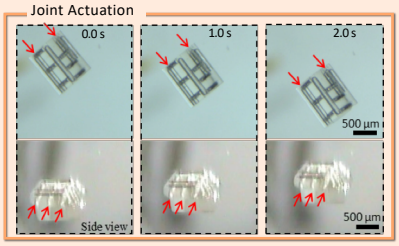
Consecutive Actuation



Consecutive

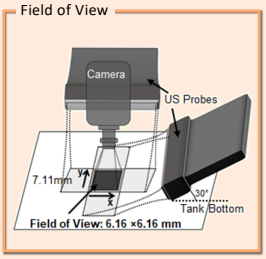


Joint Actuation

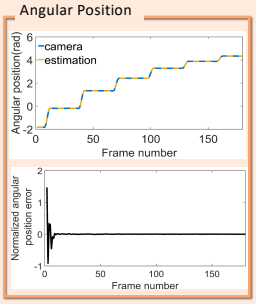


3. Reconstruction of Microdrone Trajectory on 2D plane

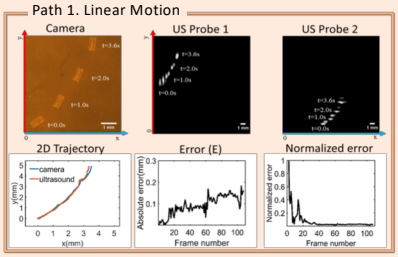
Field of View



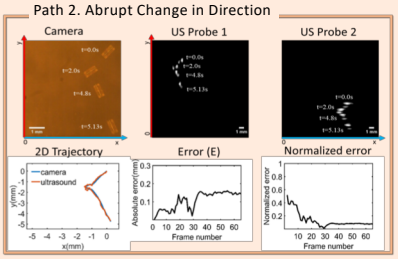
Angular Position



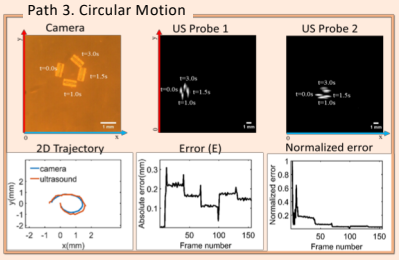
Path 1. Linear Motion



Path 2. Abrupt Change in Direction



Path 3. Circular Motion



V. Conclusion

- 3-D maneuverable propulsion is achieved using multiple bubbles.
- Yawing (clockwise/counterclockwise), moving forward and elevating upward/downward can be achieved by activating each *Lateral* microtubes, both *Lateral 1&2*, *Vertical* tubes and gravity, respectively.
- The state-dependent coefficient estimator improves the accuracy of measurement in US images and predicts the immeasurable angular position of it
- The error remains within ultrasound lateral resolution (~0.3 mm)
- The error between ultrasound and camera does not accumulate as the microswimmer travels

NSF NRI PI Meeting , Oct. 29-30, 2018, Arlington, VA