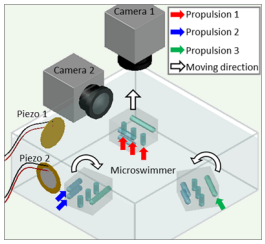
3-D Maneuverable Feedback-Controlled Micro Swimming Drone for Biomedical Applications

PI: Sung Kwon Cho
Dept. of Mechanical Engineering/Materials Science, University of Pittsburgh
Co-PI: Nitin Sharma [a] and Kang Kim [b]
[a]: Dept. of Joint Biomedical Engineering, North Carolina State University
[b]: Dept. of Medicine. University of Pittsburgh

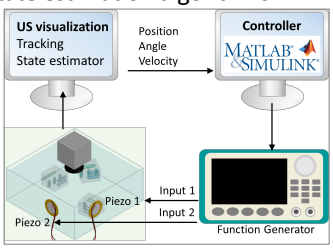
I. Objective

The project aims to develop a wireless 3D-maneuverable microdrone to perform *in vivo* drug delivery:

1. maneuverable microdrone propelled by acoustically-activated bubble oscillation
2. remote drug release with desired profile
3. real-time ultrasound imaging system for *in* vivo tracking
4. feedback control and state estimation algorithms



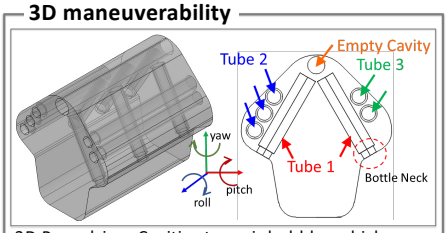
3D Micro drone



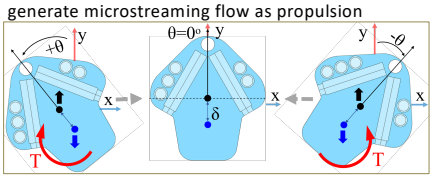
Project overview

II. Methods

3D maneuverability

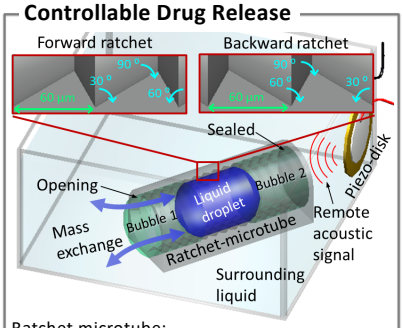


3D Propulsion: Cavities trap air bubbles which generate microstreaming flow as propulsion



Stability: By manipulating the mass distribution, microdrone can always return to up-right position

Controllable Drug Release



Ratchet microtube:

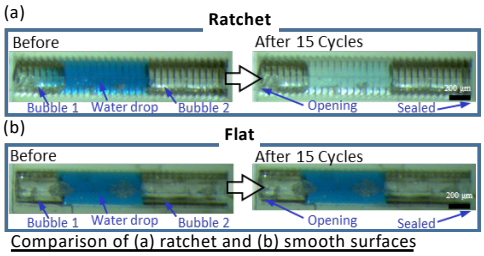
Microtube dimension
Length: 2000 μm; Average diameter: 400 μm

Forward / Backward ratchet
Base: 60 μm; Preceding : 30° / 60°; Receding: 60° / 30°

Groove
Width: 5 μm, six in total

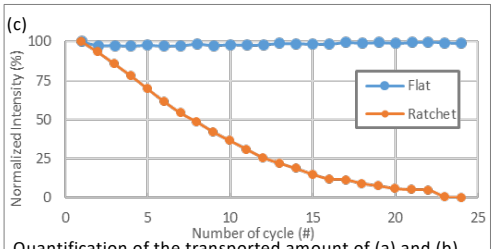
III. Results

1. Mass Transport in Ratchet Microtube



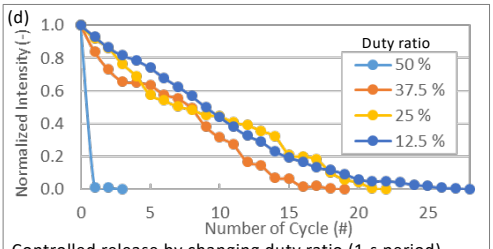
Comparison of (a) ratchet and (b) smooth surfaces

- The droplet is DI water with 2.4 % blue dye
- Excitation signal is 2.4 kHz, 5.5 V, duty ratio 50 %



Quantification of the transported amount of (a) and (b)

- Measurement by intensity change of droplet
- Ratchet significantly promotes the mass transport



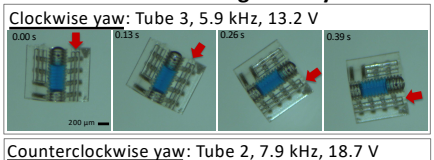
Controlled release by changing duty ratio (1-s period)

- 50 % duty ratio has a burst release profile
- 12.5 % has a steady, continuous releasing manner

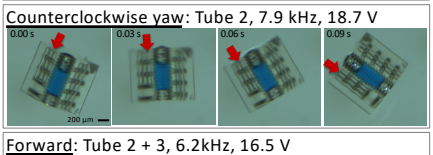
III. Results (Cont'd)

2. 3D Microdrone of Drug Delivery

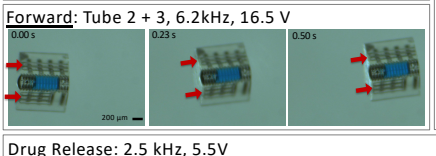
Clockwise yaw: Tube 3, 5.9 kHz, 13.2 V



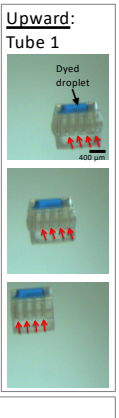
Counterclockwise yaw: Tube 2, 7.9 kHz, 18.7 V



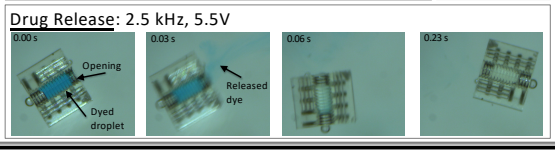
Forward: Tube 2 + 3, 6.2kHz, 16.5 V



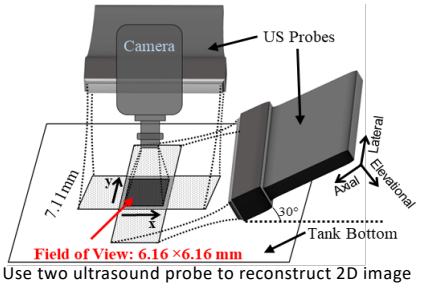
Upward: Tube 1



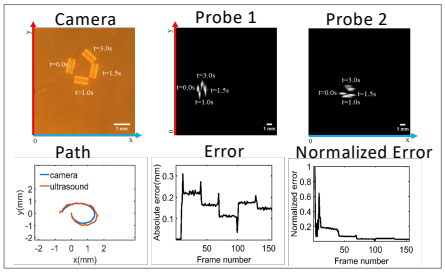
Drug Release: 2.5 kHz, 5.5V



3. 2D Ultrasound Visualization

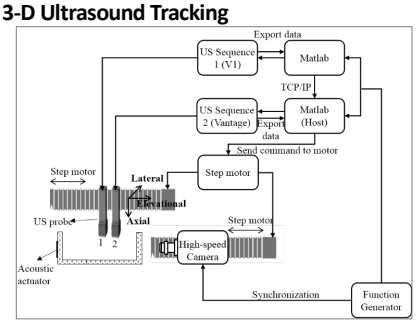


Use two ultrasound probe to reconstruct 2D image



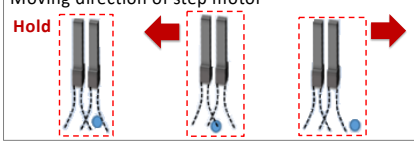
VI. Future Plan

3-D Ultrasound Tracking



- Two ultrasound probe and 1 step motor
- Probe 1: elevational motion
- Probe 2: axial and lateral motion

Moving direction of step motor



2020 National Robotics Initiative (NRI) Principal Investigators' Meeting
FEBRUARY 27 - 28, 2020 | ARLINGTON, VIRGINIA

Award ID#: ECCS-1637815