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Hydrophone Sensor Integrated with APL Snake Robot

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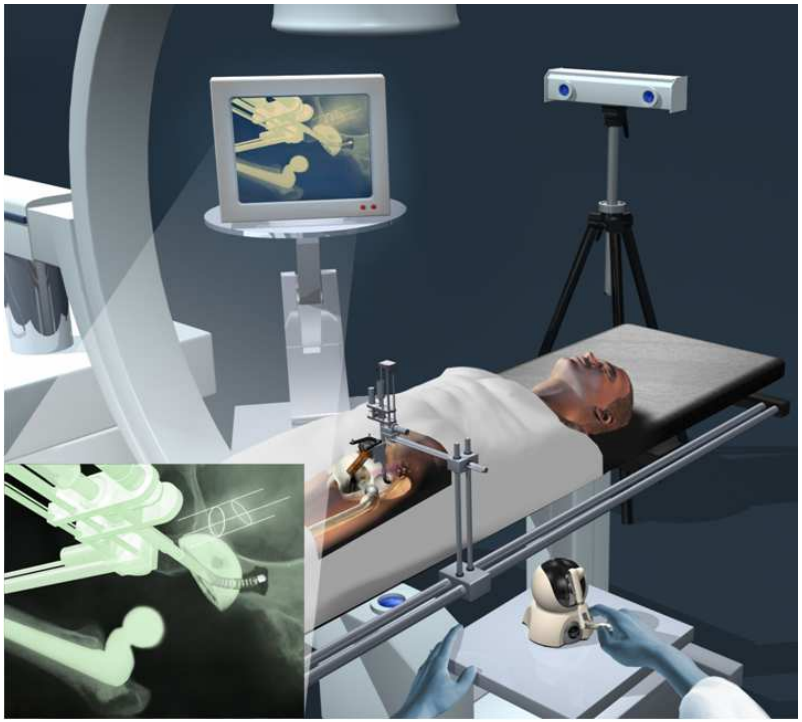
Goals

1. Integrate one or more optical hydrophones into the current APL snake robot manipulator to allow accurate ultrasound readings of tip position.
2. Develop software framework to allow communication between ultrasound machine, EM tracker, robot control system, and optical hydrophone.
3. Visualize position data in useful and visually pleasing way (similar to Robodoc)

Motivation



Kutzer et al.

Current method

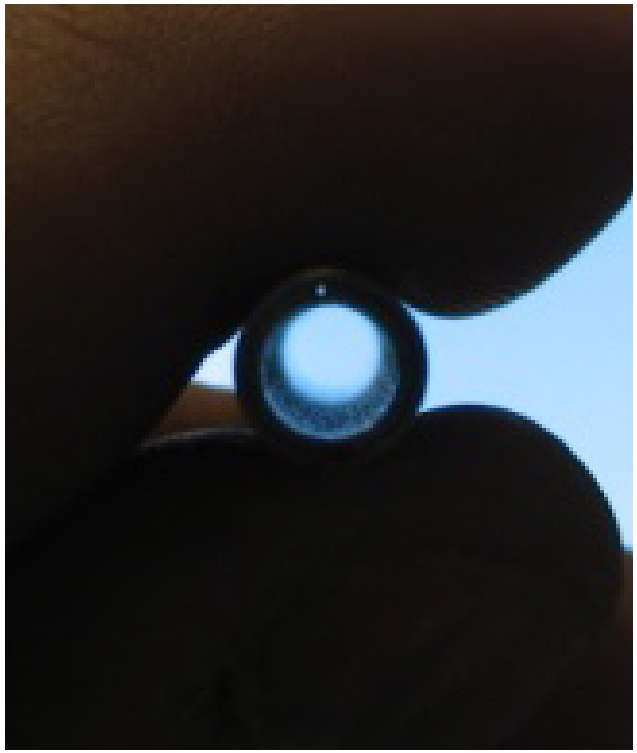
- Inaccurate
- Limited mobility
- Insufficient

Improvements

- Direct measurement
- Accuracy (≤ 1.3 mm)
- Improved visualization

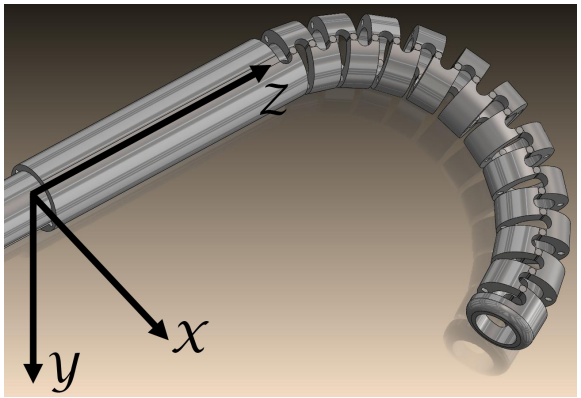
Implementation plan

- Optical hydrophone in end-manipulator
- Measure ultrasound at tip
- Calculate US time of flight
- Triangulate from multiple sources
- Display data back to operator

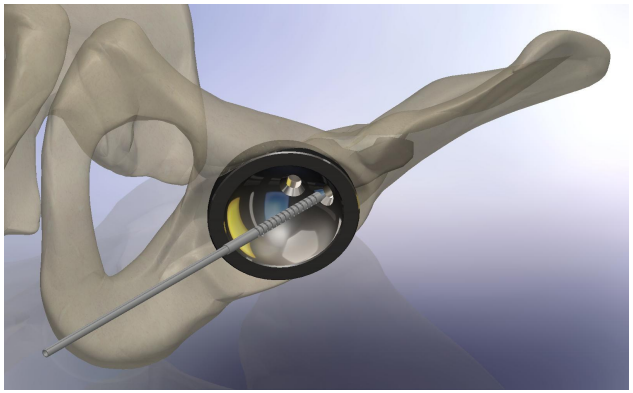


Courtesy of Emad Boctor

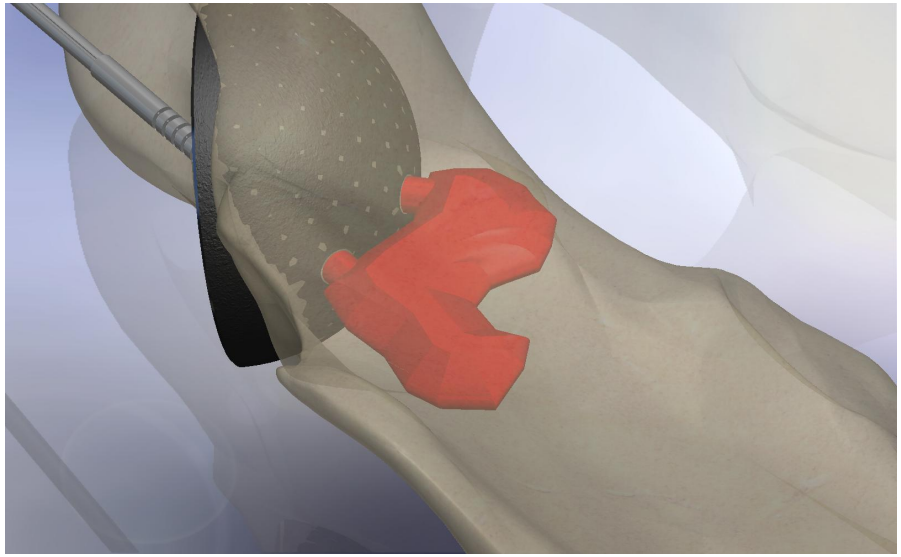
Snake Robot



Liu et al.

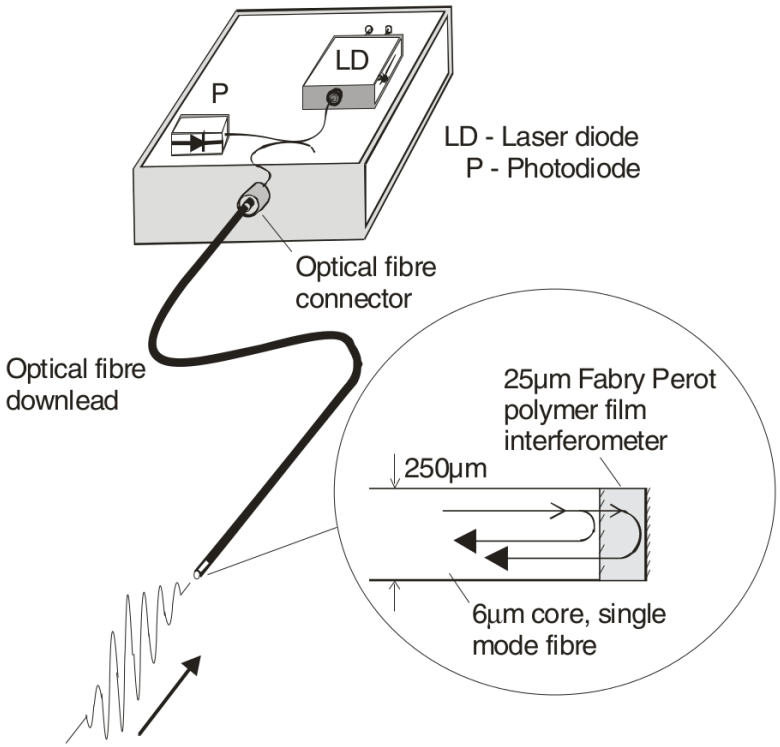


Liu et al.



Liu et al.

Optical Hydrophones



B T Cox et al.

Advantages

- Angle invariant
- Small ($\leq$ 100 microns)
- Flexible
- Sensitive (same as standard hydrophones)

Limitations

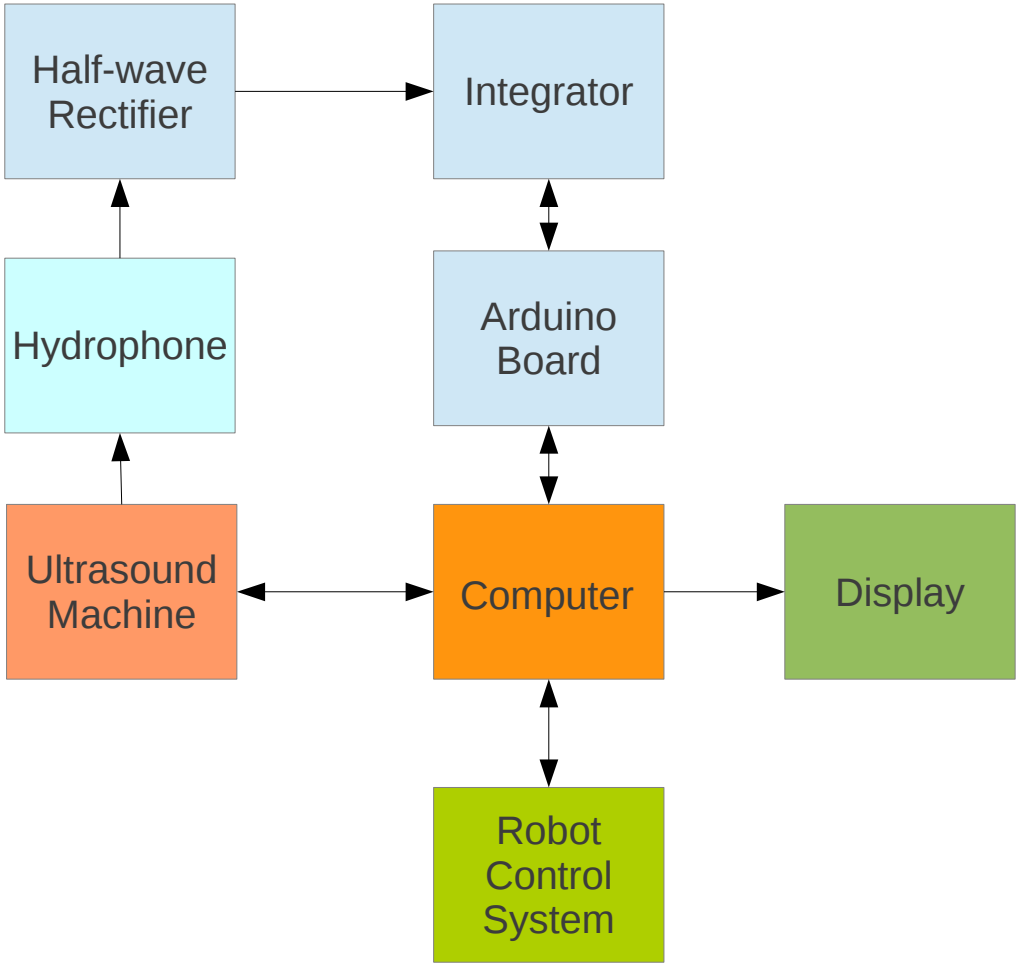
- Loses effectiveness at high curvature

Ultrasound background

Sonosite (sonosite.com)

- MHz frequencies
- Different configurations
- Individual piezoelectric elements
- 1540 m/s propagation in tissue

Implementation plan



Deliverables

Minimum

1. Software and circuitry to measure time of flight
2. Able to determine manipulator position within 5 mm

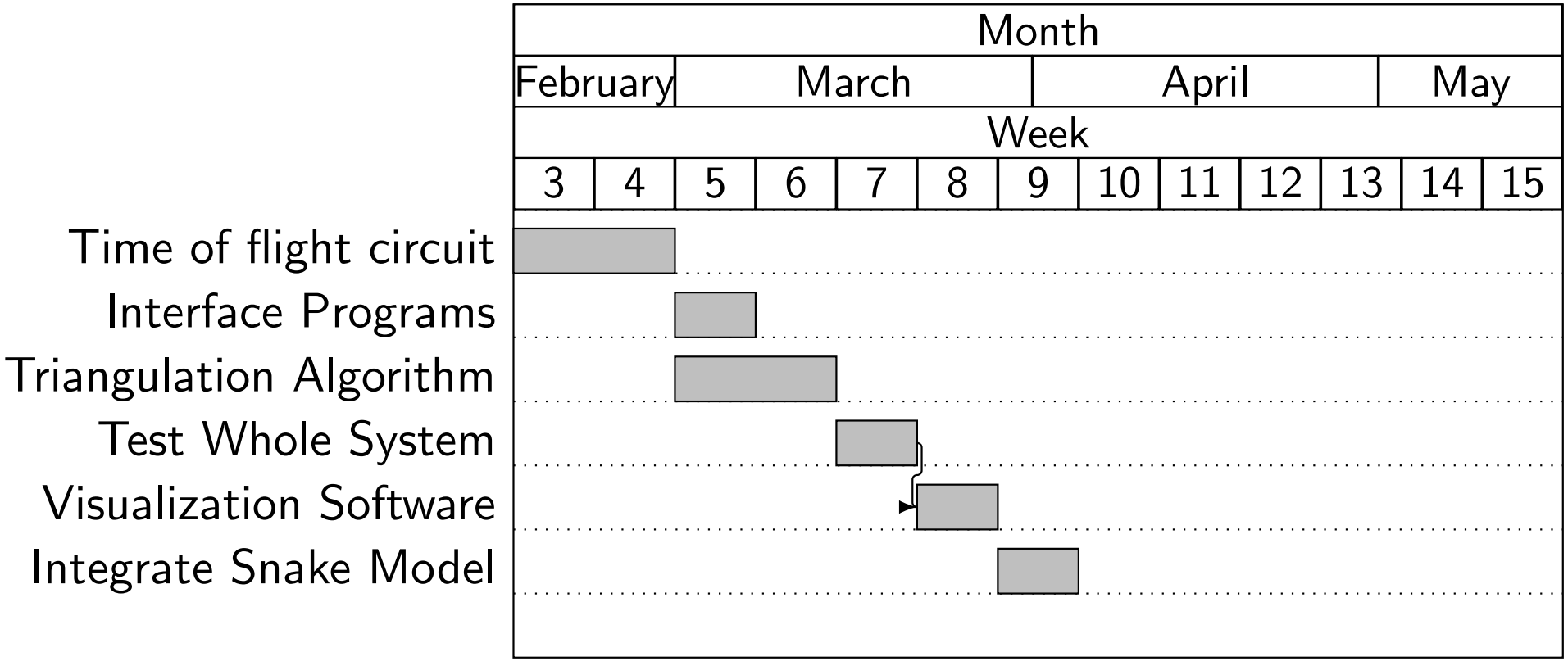
Expected

1. Software and circuitry to measure time of flight
2. Able to determine manipulator position within 1 mm
3. Rudimentary visualization, shows position

Maximum

1. Software and circuitry to measure time of flight
2. Able to determine manipulator position within 1 mm
3. Able to determine manipulator orientation within 5 degrees
4. Clean visualization, shows progress, material to remove

Gantt Chart


Month
February
March
April
May
Week
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Time of flight circuit
Interface Programs
Triangulation Algorithm
Test Whole System
Visualization Software
Integrate Snake Model

Checkpoints

1. March 4: Complete circuit on Arduino board to time ultrasound travel time.
2. March 11: Complete program to interface with EM tracker, ultrasound machine, and Arduino driver programs
3. March 18: Complete triangulation algorithm.
4. March 25: Test all components together (circuit, interface, triangulation)
5. April 1: Complete rudimentary visualization program
6. April 7: Interface previous software to snake control program; use existing software model or create new model for snake robot kinematics

Dependencies

Dependency	**Resolution Plan**	**Action on failure**	**Required date**	Alternative
Ultrasound machine	Acquired	NA	NA	NA
Fibre-optic hydrophone	Acquired	NA	NA	NA
Pelvis model	Animal bone from butcher	Do without	April	Buy/borrow model
EM tracker	Acquired	NA	NA	NA
Arduino board	Acquired	NA	NA	NA
Learn to operate equipment	Ask Xiaoyu	Unacceptable	March 4	Ask Emad
Access to full snake-robot	Schedule with Mehran	Actuate by hand	Late April	NA

Potentials problems

1. Radius of curvature
2. Lensing anatomy
3. Snake self-blocking

Bibliography

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Thanks

Questions?