Overview: Underwater sensing

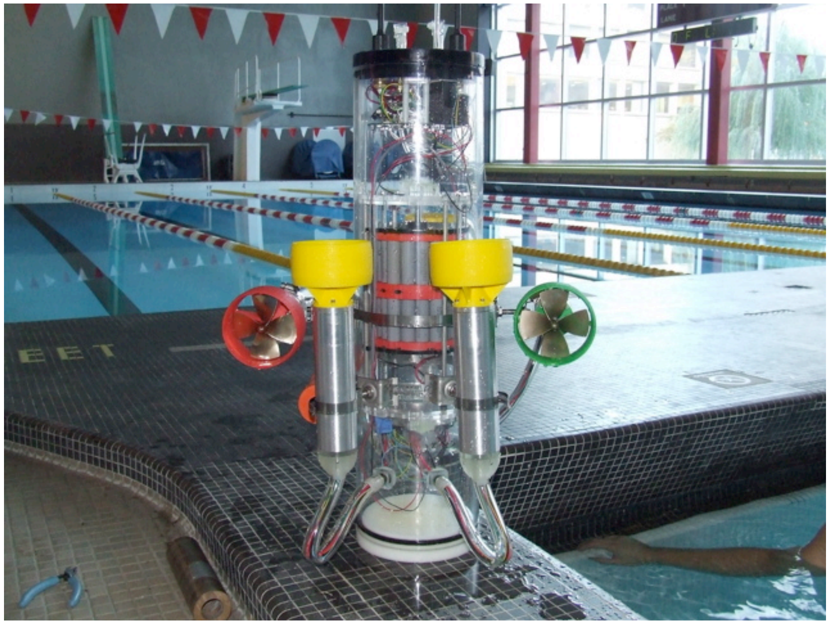
- Vasilescu, I., Kotay, K., Rus, D., Dunbabin, M., and Corke, P. **Data collection, storage, and retrieval with an underwater sensor network**. In *SenSys '05*
  - Experimental results from using optical underwater + data muling
  - Data muling allows mobile nodes to collect data from fixed nodes: E.g., useful when flying a slow moving aircraft over the sensor field to collect the sensed data. No need to route and would not face the cost of increased data rates near base stations
    - In this paper, they also use muling to synchronize clocks

Hardware used - Aquafleck

- Aquafleck - static sensor, water tight, brightly colored, able to float straight up (so that it can easily be picked up)
  - Fleck processor, 512 KB flash for data logging, 4KB RAM
  - Optical communications: 2.2 m or 8 m (with lens) range, 320 kbps, 30 degree cone
  - Acoustic module: 20 m range for ranging
  - Pressure, temperature, camera sensor 255x143 resolution. Not enough storage to store images and so images are directly uploaded from camera and sent to the AUV (ie pictures show the AUV and not other marine objects)
  - 170mm road for beaconing AUVs (LED) and pickup
  - 40% negatively buoyant

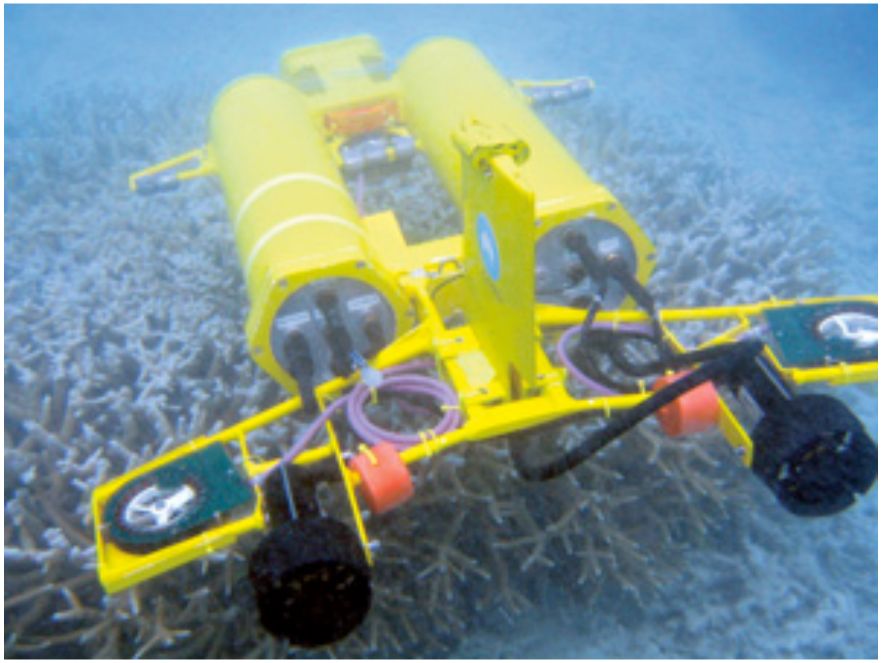
Hardware used - Amour

- Amour: Mobile robot, can pick up aquafleck, not designed for long distance motion, balanced
  - http://groups.csail.mit.edu/drl/wiki/index.php/AMOUR
- 4 thrusters, two horizontal, two vertical, 150 W total
- Magnetic compass



Hardware used - Starbug

- Starbug (CSIRO): mobile robot, can guide amour to go for longer distances. Primarily designed with visual navigation in mind. Endurance, maneuverability and functionality
  - 1.2 m long, 6 thrusters, 2 vision heads one looking down and one looking forward with a 3W white LED light



Application scenario

- Disperse aquaflecks in a reef
  - Amours dropped near first aquafleck, amour knows map of deployment. Rises to surface, uses GPS for location. Sinks to the bottom, use spiraling motion to local first aqufleck. Hover and collect data. Use magnetometer to locate next aquafleck in a raster fashion.
  - Starbug hover over amours and hauls data away
  - Not described in this paper

Interesting observations

- Optical - 320 kB/sec
  - Luxeon - 700 mw radiated, 6W input
    - Receiver: PDB-C156 photo diode senstive to IR and red!!
  - $50/node
  - Works best in blue-green color range
  - Aquaflecks are looking up, towards the sun which affects the signaling efficiency in shallow waters
- Acoustic -
  - WHOI modem - 220 bps, 5 km range, 10W
  - Aquacomm - 480 bps, 200 m, 0.45W
    - 1.3 days to transmit sensed data of 6.86 MB
    - Multihop would require 6.2MJ
  - $3000/node (I suspect it is the long range modem)
  - As discussed in last class: affected by waves, sound etc.

Experimental characterization of optical

- Possible range:
  - Clear indoor swimming pool - 8m
  - Charles river - highly turbid water - 1m
- Using a 60mm lens and holding the sensors with hand in clear swimming pool water, achieved 96% reception from 7m range
  - Harder to achieve with the AUV because of currents
- Energy consumption: 1094 nJ/bit
  - Mica motes use 760nJ/bit in terrestial wireless

Optical ranging component

- Few optical sensors are suited for underwater because of coupling issues between sensor and water
  - Panasonic unit - $20
  - Sealed using hot-glue
- Tested under water in swimming pool and Charles river at depth of 30-40 cm
  - River: 50 Hz at 5.8 m for controlled experiments
  - Pulse position modulated data: 41 mbps at 15m

Data retrieval using mobility

- Locate first sensor - GPS plus spiral motion
- Locate next sensor in sequence - compass + active beacon (amour) and visual (starbug - 5Hz does not work with depth - requires ambient light) - 5m
- Control hover mode to collect data (visual servoing for starbug and active beaconing by amour)
- Data transfer - 239 byte check-summed packets
  - actively transferred to the AUV from camera
- Synchronize clock - global sync harder. All aquaflecks synchronize with the AUVs
  - When data collection, compensate for clock drift using simple numerical averaging

Summary

- Under water communication is difficult. Acoustic has higher range, omnidirectional, higher cost and lower data rate
  - Requires multi-hop to reach base station
- Optical has lower range, directional, lower cost and higher data rate
  - Requires mobility to hover and haul data away
- Effects of longer term water immersion (slime buildup) is not addressed. Likely to be more of a problem for optical communications
  - Depth of operation issues
- Data hauling and 3D sensing?
  - Tethers are an obstacle course for mobility

Mobility based sensing

- Lessons learnt from Zebranet to underwater
  - Turns out that Zebra rip the solar panel in a few days
- Lessons learnt from underwater to Zebranet
  - Hovering in air is much harder - bulky, energy, noisy
- ???

Wrapup

- Book outlined important aspects such as scalability, energy conservation, small size/cost …
- Sensors bridge physical and computational worlds
  - Depending on the sensed environment, each manifests differently:
    - Habitat monitoring: Duck island - longevity
    - Zebranet: Mobility induced communication
    - Volcano: Fidelity of capture is important
    - Surveillance: Traditional sensing (unless you add aircraft muling etc.)
    - Underwater communications is hard
      - Acoustic
      - Optical with mobility
- Lesson: Important to focus on the application scenario