intelligent ocean sampling using robotic kayaks

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the ocean is big

- problem: massive amount of knowledge to be gained; small number of oceanographers
- solution: autonomous systems
  - oceanographer handles broad goals
  - computer and vehicle network executes the experiment

autonomous systems

- computers – shore vs. vehicles
  - cost – risk of loss on vehicles
  - weight & power – affect vehicle battery life
- heavy, powerful computers on land
  - modeling
  - computationally heavy (but less time critical) tasks
- put light, low energy computers on the vehicles
  - time critical tasks

our science goal at PN07

- h. hornick – 10.15.07 seminar
- engineer's summary
  - physical structure of dabob bay
  - instrument – CTD (conductivity, temperature, depth)
- land-sea adaptive system could be extended to biology, chemistry, geology

our system

- kayaks – test platform
  - lightweight, inexpensive
  - surface only, short battery life
- modelseas – modeling computers
- network –
  the internet

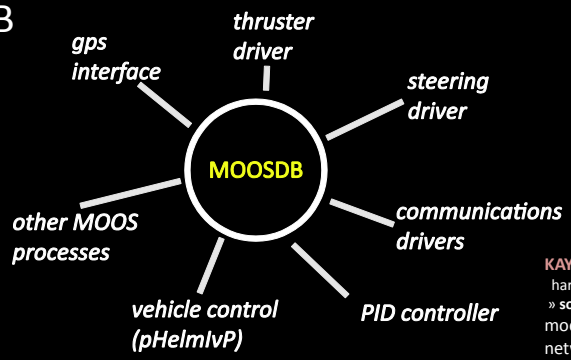
kayaks

- SCOUT
  - basic plastic kayak
  - computer
    - mini-itx
    - debian linux
  - propulsion
  - communications
    - 802.11 wireless
    - verizon internet
    - WHOI acoustic modem
- elanor – winch with CTD

KAYAKS
» **hardware**
software
modelseas
network

MOOS – vehicle software

- publish / subscribe architecture around a central database (MOOSDB)
- individual processes only interface through the MOOSDB



KAYAKS
hardware
» **software**
modelseas
network

pHelmIvP – vehicle control

- MOOS process that dictates vehicle motion from multiple behaviors
- behaviors – 'plug-in' modules
  - waypoint – go to a location
  - station keep – hold lat/long (compensate for currents, etc)
  - timer – do nothing for set amount of time
  - collision avoidance – avoid region around other vehicle

KAYAKS
hardware
» **software**
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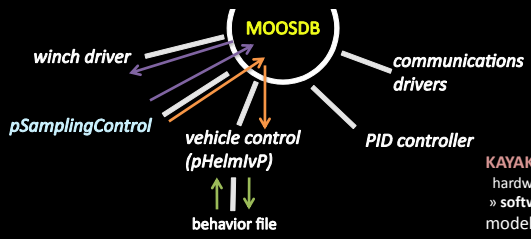
sampling control software

- combination of pSamplingControl and pHelmIvp behaviors
- pSamplingControl publishes variables for
  - winch driver – causes CTD to raise / lower
  - pHelmIvp – controls movement of the vehicle



KAYAKS
hardware
» **software**
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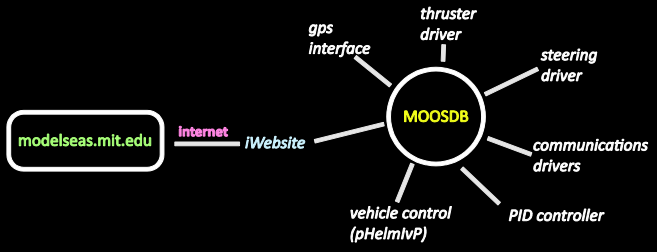
networking

- hardware
  - verizon wireless internet card
- software – MOOS process iWebsite
  - invoke 'wget' to get mission from server -> kayak
  - invoke 'scp' to send data from kayak -> server



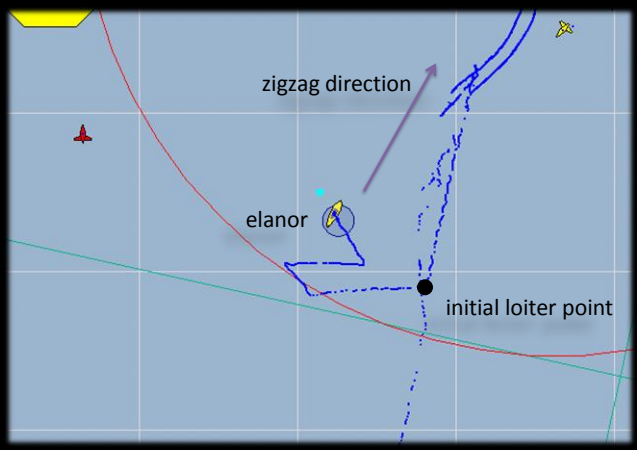
kayaks
hardware
software
modelseas
NETWORK

the missions

- mission 1
  - drift with CTD lowered for set time
- mission 2
  - hold station and raise/lower CTD at intervals
- mission 3
  - perform zigzag pattern, raise/lower CTD at intervals
- mission 4
  - station keep with CTD lowered for set time

results

- all four mission types successfully completed and data was immediately available



snapshot of mission type 3 (zigzag) in progress

cooperative vehicle test - setup

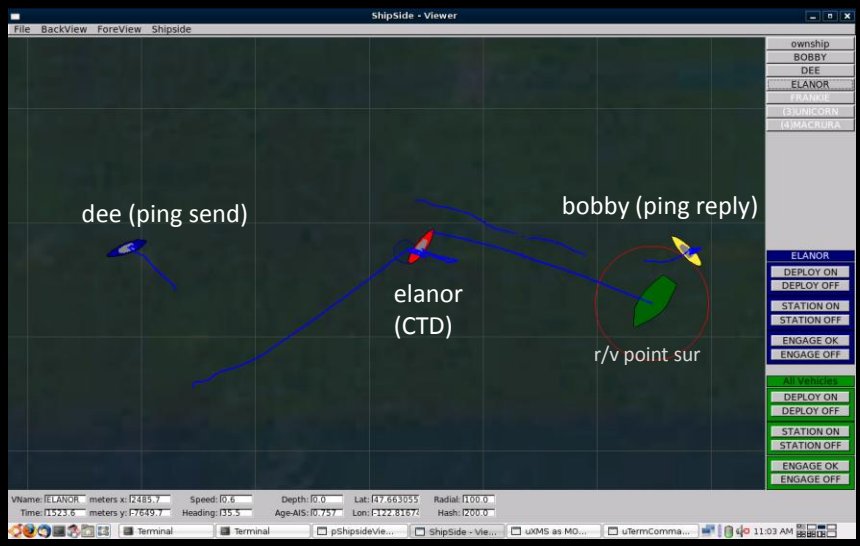
- extend CTD experiment to demonstrate multivehicle cooperation
- goal: measure sound speed in two independent ways using multiple vehicles
  - elanor (CTD vehicle): take CTD cast and compute sound speed
  - dee, bobby (modem vehicles): spread out 1 km (centered on elanor), ping modems and record transit time

cooperative vehicle test - modem

- WHOI Micro-Modem
  - can operate in four bands from 3-30 kHz
  - 2-4 km range
  - can ping another modem and calculate one way transit time with ~125 microseconds accuracy

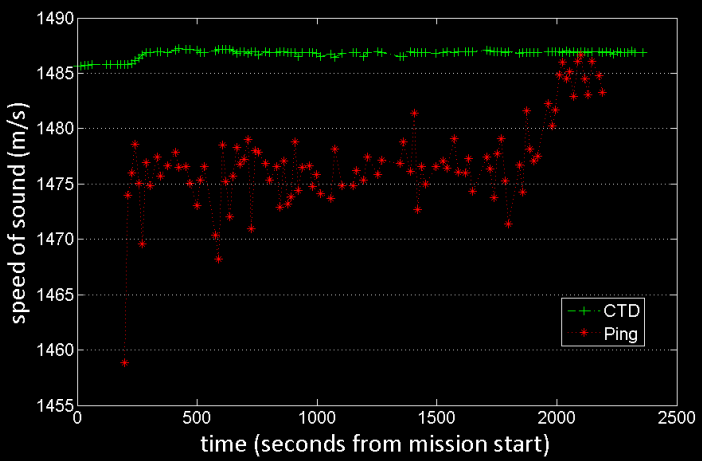
Reference: Freitag, L., Grund, M., Singh, S., Partan, J., Koski, P., Ball, K., "The WHOI Micro-Modem: An Acoustic Communications and Navigation System for Multiple Platforms," in IEEE Oceans Conference, Washington DC, 2005.

cooperative vehicle test - setup



video

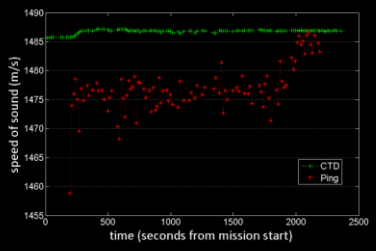
cooperative vehicle test - results

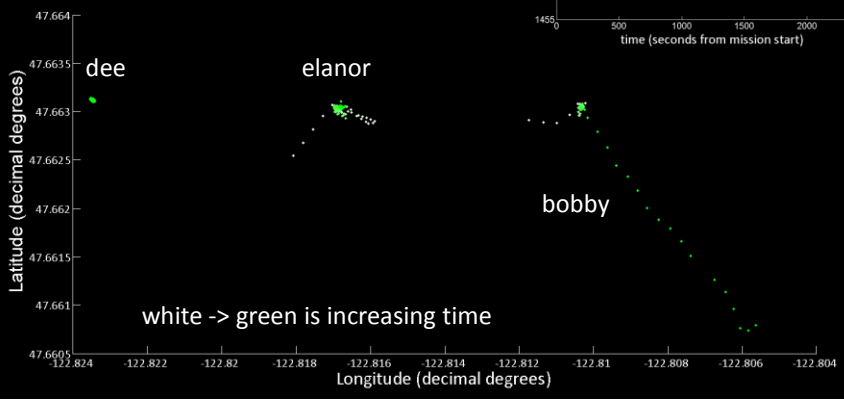


» deviation of ping from CTD is ~0.6%

cooperative vehicle test - results

- » deviation likely due to GPS fix inaccuracy
- » depth consideration





leveraging the web

- » vehicles send position (and other data) to a php/mysql web server.
- » web server provides kml file for google earth / google maps
- » will use as a realtime viewer and mission history
- » will even be able to see vehicle positions on a cell phone.

future work

- » incorporate modelseas model into determining missions
- » develop longer duration kayaks and deploy for weeks at a time
- » migrate this system to AUVs and incorporate other disciplines of oceanography

kayaks
hardware
software
MODELSEAS
network

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