Recent Exemplars in Hybrid ROVs and Hybrid Control

James Kinsey, WHOI

- Wireless underwater communication and hybrid ROVs are a reality
- Our ability to interact with robots is a direct artifact of the communications links we have to them
  - Vertical axis (left) shows the varying communication modalities available in the underwater domain
  - Horizontal axis (bottom) illustrates the degrees to which humans interact with underwater robots
- Advancing hybrid control is the next step
  - Hybrid control: one definition is the ability to go between comms interfaces (ideally seamlessly)
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ROVs and AUVs – Bookend These Scales

- ROVs possess unlimited telemetry
  - Real-time video and manipulation
  - Tether imposes constraints
- AUVs occupy the low end
- Acoustic modems transformed AUV operations
  - Enables real-time re-tasking but we don’t have all the data
- Comms and interface are static – robots can’t go between them
- Autonomous Science (Mars Rovers) will improve interactions over limited links
- Optical modems are enabling data muling
Hybrid ROVs - Enabling “Switching”

- Hybrid ROVs (HROVs) use varying comms modalities
  - Lightweight fiber enables multi-km standoff
  - Optical allows for wireless high bandwidth over short distances
  - Acoustic allows for low bandwidth over longer distances
- Early Nereus operations – when the fiber broke a pre-programmed mission was executed to return the robot to the surface
- A one-way switch – once executed, you can’t go back!
NUI – An Improved One-Way Switch

- DSL’s 4th HROV, *Nereid Under-Ice* (NUI), a polar capable HROV
- Architecture accommodates fiber, optical and acoustic
- If the fiber breaks, NUI executes a series of guided “mini-missions” transmitted to it acoustically but falls back to completely autonomous operation if necessary.
- The interface to operators changes automatically based on the available comms

**NUI Specs**
- Depth: 2000m
- Range: 40km @ 1m/s
- Sample Payload: 20kg
- Displacement: 1800kg
- Single van system
2012 – Truly Hybrid ROVs at 2300m

- Ocomms provided telemetry *from* robot – e.g., video
- Acomms provided
  - telemetry *to* robot – i.e., pilot commands, manipulation
  - telemetry *from* robot when range was too great for Ocomms
Conclusions

- The communications technologies exist
  - Acoustic modems are widespread
  - Optical modems have arrived
- Lightweight intervention HROVs are being used in the field
- Hybrid control is nascent but notable field results exist
  - Increasing robustness and autonomy in hybrid control are next steps
- Implications for OOI
  - Data muling from remote sensor nodes
  - Lightweight intervention capability from smaller vessels
  - Permanently stationed HROVs
OComms – Enabling the Two-Way Switch

- Optical communications (Ocomms) is opening up new dimensions for HROVs
- 2012 Nereus Demonstration:
  - Ocomms provided telemetry \textit{from} robot – e.g., video
  - Acomms provided
    - telemetry \textit{to} robot – i.e., pilot commands, manipulation
    - Telemetry from robot when range was too great for Ocomms – e.g., while transiting
  - Robot moves back and forth between comms modalities

Communication Bandwidth

- High
- Tethered
- Lightweight Fiber
- None

Optical Modem

Acoustic Modem

Low

Predive Data
Execute Mission Plan
Subsampled in-situ data
In-situ retasking

Human Interaction

Low

Video
Joystick
High