Underwater Robotics: a Prospective

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Conclusion

The near future of underwater robotics is distributed.

Challenges:

- communication
- localization
- navigation
- cooperation

A Story

This talk based on work with Julien Damers, Kopadia / ENSTA Brest, and Hervé de Forges, Kopadia

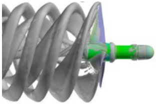
- survey article submitted to special issue of the *Leibniz Transactions on Embedded Systems* on Distributed Hybrid Systems
- `http://dhs.gforge.inria.fr/#journal`

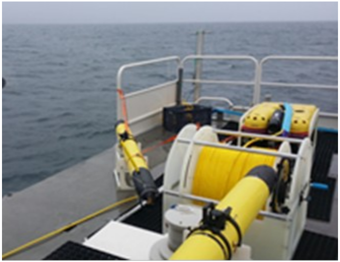
Further based on presentation by Hervé at DHS 2019 workshop in Amsterdam

- *Praised be the times when we could travel*
- `http://dhs.gforge.inria.fr/2019/`
- I'm stealing some of Hervé's slides

Further based on the kindness of Luc Jaulin ...

Kopadia in a nutshell





Underwater robotics:

- Technical developments
- Offshore operations

Company

- Created early 2017
- Team of 8 peoples
- 9 light AUV
- Based in Orsay and Nantes

1 Communication

2 Localization

3 Navigation

4 Cooperation

Communication: Acoustics

- sonar: standard tech for underwater comm
- 500 kbps / 10 m – 1 kbps / 1000 m
- bandwidth limits $\Longleftarrow$ reflections
- relays

Communication: Optical

- Underwater Optical Wireless Communication (UOWC)
- relatively new tech
- up to 1 Gbps, up to 200 m (?)
- depends heavily on water conditions
- limits $\Longleftarrow$ absorption & scattering
- relays

Communication: Optical

Distance	Power	Source	Data Rate
30-50 m	1 W	Laser	1Gbps
20-30 m	500 mW (avg)	Blue LED	$\approx$ kbps
2 m	10 mW	Laser diode	1 Gbps
31 m (deep sea) 18 m (clean ocean) 11 m (coastal)	0.1 W	LED	1 Gbps
30 cm tank (turbid)	6 V_{pp} (vol.)	Semiconductor Laser	5-20 Mbps
30 m (pool) 3 m (ocean)	5 W	LED	1.2 Mbps 0.6 Mbps
64 m (clear ocean) 8 m (turbid harbor)	3 W	Laser	4 Gbps 1 Gbps
7 m (coastal)	12 mW	Laser	2.3 Gbps
20 - 30m	30 mW	LED	1 Mbps (30m) 10 Mbps (20m)
200 m	5 W	LED	1.2 Mbps
4.8 m	40 mW	Laser	1.45 Gbps
5.4 m	15 mW	Laser	4.8 Gbps

Localization

There Is No GPS Underwater.

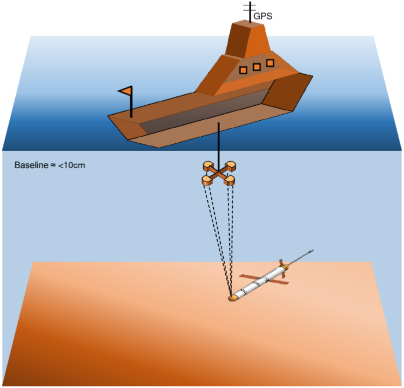
Localization: Inertial Methods

- Inertial Navigation System (INS)
- continuously integrate acceleration & angular velocities to determine position
- *blind driving* $\Longrightarrow$ drift
- periodically return to surface for recalibration?
  - at least once an hour!
- INS plus Doppler velocity log

Localization: Acoustic Methods

Ultra-Short Baseline Localization:

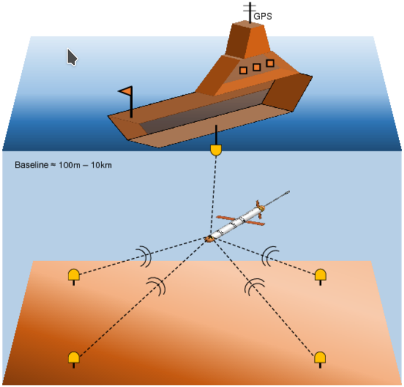
- transponder on AUV
- 4 hydrophones on surface vessel
- surface vessel calculates AUV position
- needs surface vessel
- max. distance 5 km



Localization: Acoustic Methods

Long Baseline Localization:

- 4 beacons in fixed positions
- transponder+hydrophone on AUV
- ping-pong
- AUV calculates own position
- needs beacons deployed
- (no need for surface vessel)



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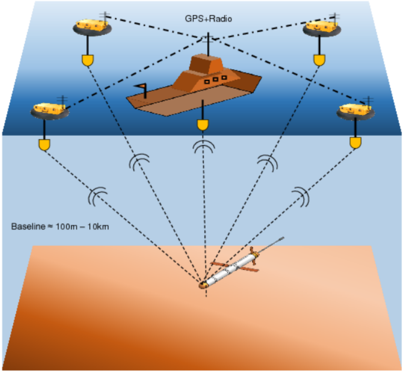
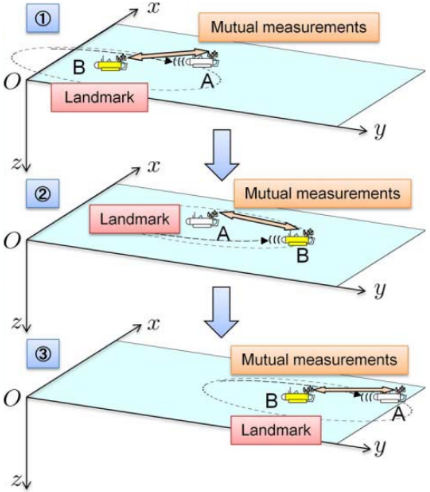


Navigation: Terrain-Based

- using INS plus maps, plus sonar
- Simultaneous Localization And Mapping (SLAM)
- also using optical sensors when close to seabed
- often using isobaths

Navigation: Alternating Landmark

- specifically for swarms
- some AUVs know position, stay fixed, act as beacons
- others use beacons for LBL
- later, roles are switched

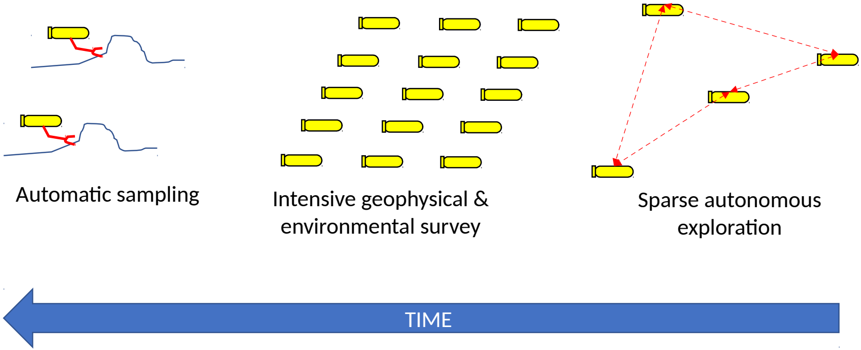


Cooperation

- distributed system of underwater robots
- heterogeneous: AUVs / ROVs / hybrid ROVs
- low-bandwidth communication; uncertain localization; imprecise navigation
- (some of these are treated in the theory of distributed robotics)
- *still preferable* over single-AUV missions!
- resistance to failures

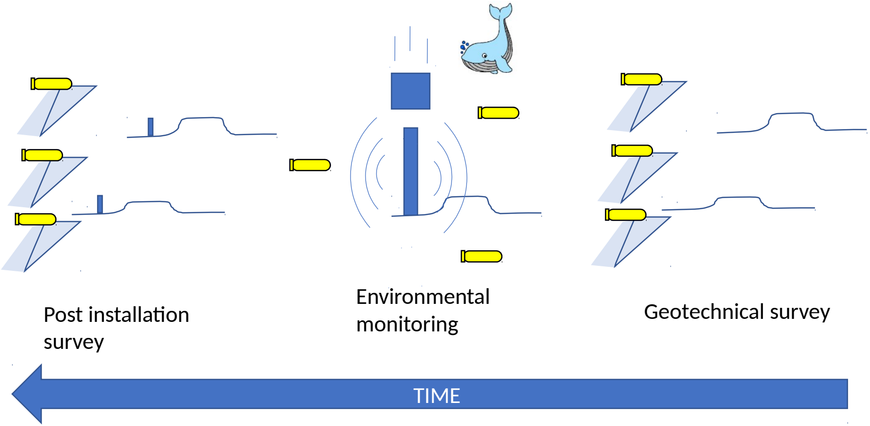
Typical 2030 underwater activity

Goal, to crop mineral resources from seabed
Phase 1: exploration



Typical 2030 underwater activity

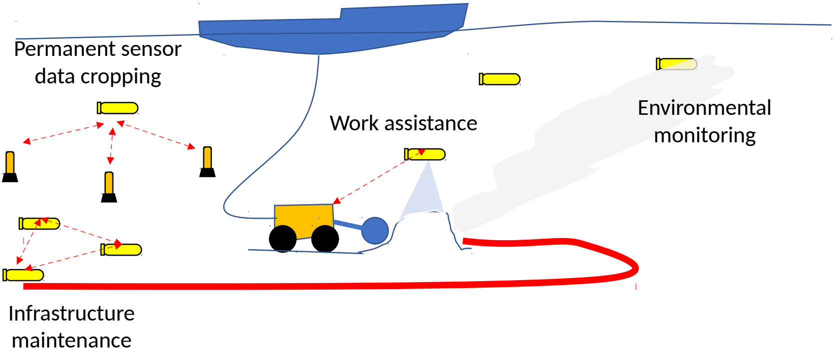
Goal, to crop mineral resources from seabed
Phase 2: installation



Typical 2030 underwater activity

Goal, to crop mineral resources from seabed

Phase 3: exploitation



And the Military Said

Euronaval conference 13 October 2020

And the Military Said

Daniel Scourzic, ECA Group:

- there is a military use for AUV swarms, for example for mine clearing
- need to be *quiet*: no sonar
- then, how does the swarm coordinate?
- *urgent need* for research on underwater communication beyond sonar

Conclusion

- for near-future underwater missions, need heterogeneous swarms of underwater robots
- difficulties in communication, localization, navigation, cooperation
- much research and progress in communication, localization, navigation
- for cooperation, the theory of distributed systems / distributed robotics may help
- So Exciting!