Electric sense based perception for underwater robots

Stéphane Bazeille
Vincent Lebastard
Frédéric Boyer
Ecole des Mines de Nantes

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SUBCULTRON

SUBMARINE CULTURES PERFORM LONG-TERM ROBOTIC EXPLORATION OF UNCONVENTIONAL ENVIRONMENTAL NICHES

- EU FET project started in April 2015.

- **Goal:** Collective long-term monitoring of the Venice lagoon.

- **Why Venice?** To understand changes due to humans activities to protect the lagoon.
About Venice

Length: 51 km
Width: 12 km

Shallow water embayment of 540 km²
8% land above sea
92% water composed of:
channels (12%) shallows, mud flats and salt marshes (80%)

Problems: confined, turbid, varying salinity, water current, various biological activities.
Why electric sense?

• There is no sensor technology equipping underwater robots in confined spaces and turbid waters...
  
• Sonar fails due to multiple echoes...
• Vision fails due to turbidity...

• Some fish living in such an environment developed a new sense (electric sense). Taking inspiration from nature we developed artificial electric sense for robots.
Main goal of subCULTron

- Monitor a complex environment for underwater robots.

- Idea: Collect long-term data collection with a robot swarm:
  pH, temperature, salinity, conductivity, turbidity, pressure, water level, information about marine fauna and flora.

The swarm composed of 3 different robots:
- aPads: floating platforms used as geolocalization satellites and recharge station for the swarm.
- aMussels: robot sat on the seabed used as landmarks for aFish as well as storage station.
- aFish: AUV used to explore the environment and collect data.
3 robotic species inspired by nature

5 aPADs (water lily)

25 aFISH (elephant fish)

120 aMUSSELS (razor shell)
aPads

- Size: 70 cm x 70 cm, 30 kg
- Motors: 4 thrusters positioned in X configuration
- Long autonomy: big battery and solar panels
- Recharge base, plier for autonomous docking
- Globally localized (GPS) and communication with humans, coordination of the swarm.
aMussels

- Size 630 x 120mm
- Max depth: 15 m
- Motor: active buoyancy
- Autonomy: 1 month
- Energy harvesting: microbial fuel cells,
- Sensors: Acoustics and electric sense
aFish (still not produced)

- Size: 350 x 140 x 100 mm
- Motors: 4 thrusters in rear part
- Max depth 15 m
- Max current 1 m/s
- Autonomy (4-5 hours)
- Sensors: Acoustics and electric sense
To perceive their environment, e-fish polarize an electric organ / body.

Elephant fish: 
*Gnathonemus petersii*

By comparing the currents crossing the skin with and without object, the fish perceives the environment.

- 2 modalities: active and passive if it is not emitting
- Short range sense: passive (3l) active (1l)
Use of electric sense

In nature:
- Used by fish to recognize and communicate with their congeners and hunt their preys (passive electric sense),
- To navigate in cluttered environment by detecting obstacles and recognize shape, size, electric color (active).

On AUV this omnidirectional short range sense can be used for
- for reactive navigation (active),
- object localization and recognition, SLAM (active),
- communication between robots (active/passive),
- autonomous docking (passive),
Use of electric sense for robotics

We developed the following sensor technology:

Angels’ technology

Insulating shell with electrodes obeying a left/right symmetry
Principle of emission: U imposed by a wave generator
Principle of reception: I is measured (only amplitude), ILAT, IAX.
Experiments on 4 use cases

- Experiment with 1 active aFish.
  - Reflex behavior « track/avoid any object ».

- Experiment with 1 active aFish.
  - Memory based behavior « follow the boundaries of an object ».

- Experiment with 1 passive aFish.
  - Autonomous docking on an emitter.

- Experiment with 1 active aFish.
  - Localization and recognition of an object.
Reflex behaviours based on electric sense

Simple behaviors for aFish

- The robot emits a field in its surrounding (A)
- The field is reflected by an object (B)

- Then, the robot reacts to the reflected field according to simple control laws

A: Attracted by a conductive object
B: Attracted by a conductive object and repulsed by insulating ones...
All behaviors can be reversed.
Memory based behaviours

With more electrodes, we can build complex behaviors.

Only robot requirements:
- The left/right symmetry
- Compressed shape (flat).

All these behaviors can be performed without any model of the environment.

Revolve around objects
Autonomous docking
Ellipse localization and recognition

Estimate the 6 parameters of the ellipse (x, y, a, b, theta, color).

- Prior knowledge:
  - conductivity,
  - robot localization in a global frame of reference

- Brute force method based on an analytical model able to estimate the 6 received currents giving a scene [Boyer2012].
- For each object tested a fitting score is summed up along the trajectory.
Localization and size estimation for a conductive ellipse 33 x 16mm

Will be improved with an optimized trajectory...

Example for a spherical object.
Resolution x, y: 0.002 [-0.2;0.2]
Resolution r: 0.002 [0.002;0.03]
Project subCULTron

Coordinator and Bio-inspired controllers

Hardware development

Firmware and algorithms

Experiments

Electric Sense

Culture and Society

Electronics development
Bibliography


aMussel experiment subCULtron

From a passive aMussel estimate the direction and the distance of an emitter

Plot: 4 measured currents vs angle (directional detection)

Plot: 4 measured currents vs distance (omnidirectional range detection)
aMussel experiment subCULTron (salt water 1S/m)