Envirobot

AUTOMATED SURVEYING OF SURFACE WATER QUALITY BY A PHYSICAL, CHEMICAL AND BIOLOGICAL SENSOR EQUIPPED ANGUILLIFORM ROBOT

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What it's about…

Developing an aquatic robot which can "smell" polluting substances, using integrated biological and chemical sensors.

Context and project goals

Envirobot is an ambitious high end project with the major aim to develop and construct a demonstrator robot platform (the Envirobot) that samples and measures a set of relevant water quality parameters in surface water bodies by the incorporation of optical, physical, chemical and biological sensors. The Envirobot platform will be based on existing segmented anguilliform Amphibots, but with important adaptations in terms of energy use and efficiency, sensory decision programming, and communication possibilities. The Envirobot is invented to perform autonomous surveying or autonavigation. In autonomous surveying the robot will sample and analyze water bodies according to a preset path and defined number of waypoints.

During autonavigation, the robots must guide its movements and sampling on the basis of the sensory input. Autonavigation is challenging but extremely interesting, since Envirobot would be able to track and follow gradients of chemical pollution in water bodies. Envirobot will thus go significantly beyond what is currently feasible with automated buoys or sampling platforms.

The second major aim of the project consists in particular in the development and incorporation of a range of biological sensors useful for both functioning modes of the Envirobot. Biological sensors provide the best ecotoxicological information on water quality and can be both broadly responsive to any 'general distress' or very precise to quantify individual compound concentrations. By contrast, they have a wide range of response times (ms hours). Robust but slow response time biosensors (min hours) will consist of bioreporter bacteria or trout fish cell lines producing de novo fluorescence in response to pollutant stress, which will be used for water sample analysis during autonomous surveying. In order to produce rapid response time biosensors (ms min), which can actually guide the robot's movements, we will exploit:

1. bacterial chemotaxis towards and away from toxicants, and on toxicant induced changes in real time bioluminescence
2. electrophysiological or calcium (Ca) dependent fluorescence changes in signaling cascades employing insect chemoreceptors
3. real time observations of heart beat and leg movement frequencies of Daphnia magna (water flea) individuals.

All biological sensors are to be embedded in easy exchangeable microfluidics chambers with integrated life support, with optical or electrical detectors and with autosampling capacity, which will fit into body segments of the robot. Biological sensors are further complemented by a variety of miniaturized physical, optical and chemical sensors with rapid response times that can analyze a set of general water quality parameters.

How it differentiates from similar projects in the field

Aquatic robots are typically driven by telemetric operation. Here the project is integrating biological and chemical sensors into an existing aquatic robot that should permit the robot to operate and measure chemical pollution autonomously. The final goal is that the robot can seek and relocate its movement to the source of pollution based on continuous measurement inputs.

Quick summary of the project status

A new version of the anguilliform robot was fabricated with larger modules and improved swimming capacity. Data communication between modules and sensors was established. First physico-chemical sensors were tested and implemented in individual robot modules.

Robot swimming was improved and algorithms were developed to allow source tracking. Important progress was made with miniaturization and calibration of biological sensor elements. Rainbow trout gill and gut cell lines were benchmarked to a wide range of toxicants and wastewaters. A method for automated movement detection from Daphnia individuals captured in microfluidic cages was developed, that can be used to monitor distress upon pollutant exposure.

A microfluidic impedance measurement system was optimized to study the activity of ligand-induced voltage channels in Xenopus oocytes, which in the future can be implemented with a variety of channels.

Finally, bacterial bioreporters sensitive to pollutants were constructed and calibrated in miniaturized fluidic systems, ready for implementation in the robot module.

Success stories

The consortium is extremely dynamic, meeting in plenary every 3 months and with important key interactions between different groups. For example, development of *Xenopus* oocyte and fish gill cell microfluidics impedance (UNIL-CIG, Eawag and LMIS4), incorporation of bacterial sensors in microfluidics / electrochemical units (UNIL-DMF, LEPA and LMIS4), and robotic sensor implementation (BIOROB and HES-SO).

General "course" work has been incorporated to promote better understanding of mutual technical aspects (e.g., electrochemistry, modeling, voltage channels).

The inauguration of the new Envirobot model attracted a lot of attention during the 2015 Annual Meeting and was broadcast on radio Suisse-Romande.

Presence in the media:

Der Nase nach zur Quelle der Verschmutzung, SRF, 2015.

Arsen im See? Ein Schlangerroboter soll es finden, SRF, 2015.

Produced video:

Measuring heart beat of Daphia: Uploaded movie on http://www.youtube.com/watch?v=fbTwfCm7eD0

Main publication

Auke Ijspeert, Biorobotics: Using robots to emulate and investigate agile animal locomotion, Science 10 October 2014: 346 (6206), 196-203.

“Giving robots a biological sense of smell!”