In-situ three-dimensional water chemistry assessment

Using optical sensor on autonomous underwater vehicle to provide better understanding of spatial patterns of water chemistry in large water bodies

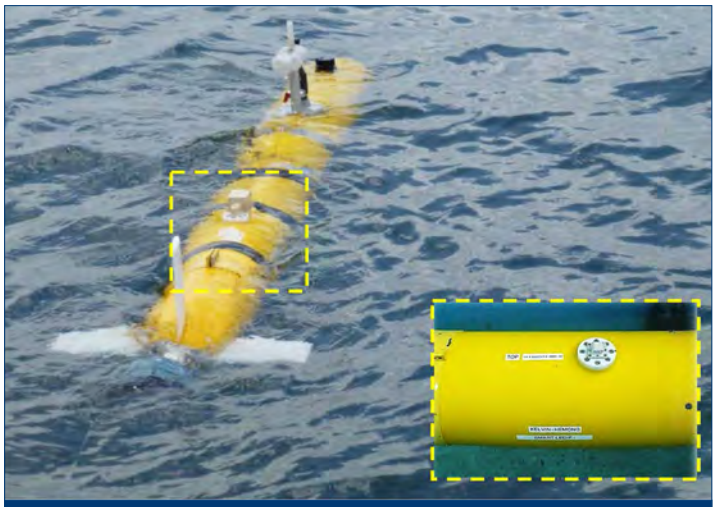

Fig . 1: The combined Light Emitting Diode induced fluorescence (LEDIF) – Small Team of Autonomous Robotic Fish (STARFISH) autonomous underwater vehicle (AUV) tested at Pandan Reservoir

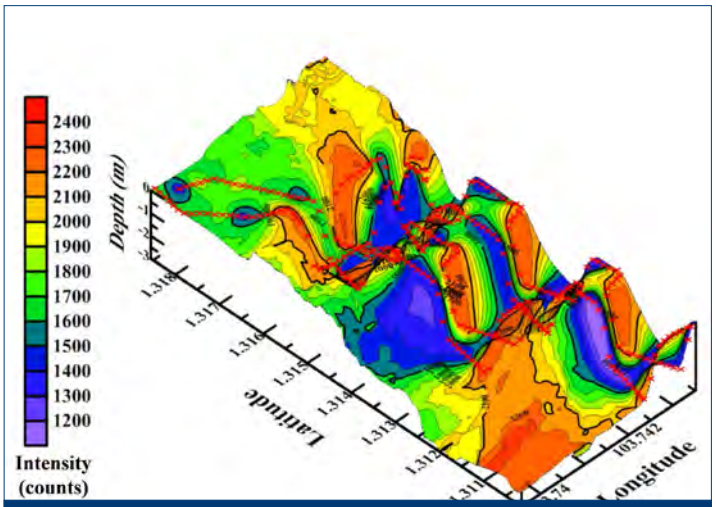

Fig . 2: A typical three-dimensional (3-D) chlorophyll mapping of LEDIF aboard the STARFISH AUV

Water chemistry assessment via sample collection has always been a labour-intensive exercise with many inherent physical limitations. The information collected is usually discrete in nature, with limited spatial extent that may not provide a detailed representation of the three-dimensional (3-D) water bodies.

The test-bedding project conducted by Singapore–MIT Alliance for Research and Technology (SMART) Centre and Tropical Marine Science Institute (TMSI) at Pandan Reservoir aims to mitigate such challenges through the construction of 3-D water chemistry maps. This study is possible through the use of Light emitting Diode induced fluorescence (LEDIF), an optical sensor, and the Small Team of Autonomous Robotic Fish or STARFISH, an autonomous underwater vehicle (AUV) designed for cooperative sensing (Fig. 1).

LEDIF is developed for the in-situ real-time sensing of water chemistry, and is generalised for multi-platform deployment. Users are able to define and automate sensing tasks based on operation needs. Its tri-optical principles of sensing are suitable for measuring multi-species contaminants and natural substances such as chlorophyll pigments, chromophoric dissolved organic carbon, high molecular weight hydrocarbons, low volatile hydro-carbons, pesticides, and other organic analytes in both freshwater and marine environments.

The STARFISH, meanwhile, is an extremely scalable robotic vehicle with a high level of hardware modularity and robotic flexibility that can be configured and deployed based on the needs of the research. Users are able to specify sampling tasks at points of interests to the vehicle. The vehicle then autonomously plans the paths to the points and executes the necessary tasks. The autonomy and flexibility is given by a group of software agents, acting in a similar manner as commanding officers on a navy vessel, that interact and decide on feasible solutions to accomplish the mission while providing adaptability to sensing needs.

For 3-D water chemistry assessments, LEDIF is mounted as payload onto the STARFISH and serves as the "scientist" to provide real-time water chemistry data. The STARFISH, together with the new "scientist", is not only able to execute a pre-planned survey mission but can autonomously alter the mission in real-time to adapt to sensing needs. Both components have been designed to integrate at the fundamental level and function as one standalone instrument.

A series of trials were executed to demonstrate the capabilities of LEDIF-STARFISH to quantify algae biomass at selected areas of Pandan Reservoir by programming LEDIF to measure the chlorophyll concentration. Traveling for more than 3 kilometres within 50 minutes, LEDIF-STARFISH has revealed potential areas of hotspots in the 3-D chlorophyll maps generated (Fig. 2), providing an unprecedented insight into the phytoplankton biomass distribution of the reservoir.

The results clearly demonstrate the strong capabilities of LEDIF-STARFISH to perform 3-D water chemistry assessment. These 3-D data can be used to study the effect of ambient conditions on spatial distribution of targeted analytes and complement real-time data from existing stationary monitoring platforms, allowing access to both spatial patterns and temporal trends of targeted water chemistry in the reservoir.

Researchers and affiliations

T.B. Koay
National University of Singapore

K. Ng
Singapore-MIT Alliance for Research and Technology Centre

Contacts

Teong Beng Koay; koay@arl.nus.edu.sg
Kelvin Ng; kelvinng@smart.mit.edu

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