A Coupled Simulation Tool for Autonomous Underwater Vehicles engaged in Environmental Monitoring Missions

Introduction

Hydromea SA is an EPFL spin-off founded in 2014 by Dr. Felix Schill and Dr. Alexander Bahr, that aims to bring recent microtechnology and robotics knowledge to the environmental fields. One of its biggest achievements is the development of the Vertex AUV (autonomous underwater vehicle), designed to be deployed in swarms. Capable of carrying many different types of sensors (CTD, pH, Oxygen, Chlorophyll, etc.), this vehicle enables new possibilities for water measurements. It is designed to be deployed in swarms. As radio waves do not travel well underwater, it is hard to have any control over an AUV once it is underwater. Therefore, a proper simulation solution is very important and a comprehensive and faithful simulator for the vehicle has been developed. However, this simulator is only about the vehicle and does not include any information about the environment. Thus, it is not possible to simulate any environment dependent behavior. This project aims to add this perspective.

Objectives

Provide a flexible environmental model in which different behaviors can be tested, for various conditions. Include this model as a plugin in Hydromea code project.

Working principle

- Use a realistic existing lake model as boundary conditions
- Create a higher resolution grid suitable for simulation
- Add custom distributions of pollutants or parameters
- Simulate using advection-diffusion equation with finite differences

Meteolakes

Developed and maintained by Theo Baracchini, as a part of his PhD thesis at EPFL (APHYS), Meteolakes is a project which aims to monitor lake Leman. It takes MeteoSwiss data as an input to compute hydrodynamical variables for the whole lake. It is used as boundary conditions for the model of this project, which requires a better resolution, but for which accuracy to the real lake is less important.

Methodology

At the beginning of the project, the goal was to use an existing environmental model directly. The search was quickly oriented toward Meteolakes. However, the scope of such a realistic model is not to perform simulation in it, its spatial resolution being about 300 m. Then the needs were reevaluated. To test behaviors for the robots, accuracy is not so important, but time and spacial resolution are. It is also very useful to be able to define custom scenarios. It was therefore decided to use Meteolakes only as boundary conditions to create a finer grid, in which one can add various parameter distributions, whose evolution can be simulated.

The biggest part of the project was then to create the Python plugin, integrated with the rest of the project.

Results

The result of the project is a Python plugin with which the users can do the following:

- Select a region of the lake and a time of interest to generate a fine grid of desired resolution for water velocity, optionally interpolating from Meteolakes
- Save and load existing grids
- Add initial distributions of parameters (gaussian, linear, defined by a map), add noise
- Launch the simulation live and query for measurements (as an autonomous underwater would do in the lake).

The water velocity is assumed constant and the results are given by advection-diffusion equation. One possible distribution is shown on Fig. 3.

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Fig. 1: VERTEX AUV developed by Hydromea SA, image taken on 18th April from http://www.hydromea.com/

Fig. 2: Illustrations of the results of the platform Meteolakes.ch (here: depth averaged water velocity) – Taken from http://meteolakes.ch/

Fig. 3: [Qualitative] Y-Z profile of a gaussian distribution of a parameter, at initial time (left) and after a few steps of simulation (right). Here, convection dominates diffusion and the current is mostly directed toward X (out of plane). The center of the gaussian gets further from the visualization plane.