OpenMAUVe: an open-source Modelica-based simulator for multibody underwater vehicle dynamics - demo

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Abstract

The modelling and dynamic simulation of complex underwater vehicles are rendered particularly complicated when internal moving components, such as rolling masses, are involved. This work's contribution is the development of a modular and open-source software framework designed to simulate different types of underwater crafts in a unified manner. The associated software framework and the demo video can be accessed open-source at: https://github.com/grande-dev/OpenMAUVe.

Keywords Autonomous Underwater Vehicles · Simulation · Modelica

1 Introduction

Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs) are conventionally modelled by means of 6 Degree Of Freedoms (DOFs) rigid-body dynamics, resulting in 6-dimensional models of Ordinary Differential Equations (ODEs) [1]. In contrast, the modelling of Underwater Gliders (UGs) and Hybrid Autonomous Underwater Vehicles (HAUVs), employing movable masses as actuators, involves additional DOFs, resulting in higher dimensional models. Including additional movable masses results in models of 9 dimensions and above, leading to a noticeably increased complexity in the derivation of the equations of motion [2].

A broad range of AUV simulators were developed for the purpose of testing new vehicle designs, notably to validate the functionality of sensors and to analyse the interaction with the marine environment [3, 4, 5]. As of 2025, development efforts are still ongoing to define a unifying framework targeting *complex* vehicles, e.g. UGs and HAUVs.

Complex AUVs with internal movable actuators can be conveniently modelled as multibody systems, i.e. by assembling separate rigid bodies. To investigate the dynamics of multibody systems, tailored simulation techniques and tools have been devised over the years, one of them being Modelica, an open-source object-oriented modelling *language* for the modular simulation of large and multidomain engineering systems. Preliminary works on Modelica simulators for underwater vehicles focussed on ROVs [6] and UGs [7]. Nevertheless, a unifying paradigm to simulate the full range of underwater vehicles dynamics is yet to be defined, and represents the target of the present work.

Owing to the open-source nature of the proposed work leveraging OpenModelica as Integrated development environment of choice, we denote the resulting library OpenModelica Autonomous Underwater Vehicles (OpenMAUVe).

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2 OpenMAUVe simulation framework

The modelling of the underwater vehicles hydrodynamic effects underlying the current work was derived from conventional manoeuvring literature [1], relying on the definition of several reference frames, i.e., among others, the Earth-centred inertial (ECI) and a body-fixed frame, to define the states of a craft. Several models of the hydrostatic forces are included in the software tool, as well as several classical hydrodynamical models. Moreover, actuators commonly mounted onboard underwater crafts such as thrusters, shifting and rolling actuators, control surfaces and Variable Buoyancy Device (VBD) are readily available and can be included in the vehicle model as drag and drop components.

The overarching idea behind OpenMAUVe is the possibility to easily assemble complex underwater vehicles by joining together pre-developed models.

This demo is concluded by validating the simulated dynamics by comparison with publicly available datasets for two complex vehicles, namely the ROGUE UG [2] and the Seawing UG [8].

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