Data-driven, reduced-order modelling and simulation of free-surface flows

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ABSTRACT

Great is the interest in realistic fluid simulation for the research community. The reason of the fairly attributed importance to this still open problem is its potential for its application in many ongoing developments, among which we can find improvements in surgery simulation or robots able to manipulate liquids, to name a few. Nevertheless, we still try to fight against a main drawback: the computation time of free-surface fluid simulations, which complicates the generation of credible results.

With regard to this limitation, we aim to explore various learning strategies to analyze the dynamics of the sloshing problem from data available to construct a new data-driven integrator capable of working in real time. It will provide realistic, as well as physically accurate, representations of the fluid. Essentially, a model representing the main features of the dynamics has been developed from the data available, which consists of a set of snapshots representing the state of the particles that shape the fluid at discretized time steps. We consider that the sloshing dynamics studied could be embedded in a slow manifold. To this end, three manifold learning strategies have been employed. To begin with, POD [1] has been tested. Nonetheless, due to the strong non-linear nature of the phenomenon, also non-linear methodologies, and more specifically Locally Linear Embedding (LLE)[2] and Topological Data Analysis (TDA)[3], have been employed.

As we have already mentioned, we aim to develop a data-based numerical method which will give a physically consistent result as outcome. GENERIC[4] provides a framework to analyze the thermodynamic structure of any phenomenon. With it, we can develop an integration scheme, which will strictly fulfill the basic principles of thermodynamics, by building the *slow manifold* [5] of the sloshing dynamics.

The results obtained by the application of the three reduction strategies have been compared. Linear methodologies do not seem to be effective for this purpose since the method requires a high number of modes to obtain an acceptable result. In contrast, non-linear strategies succeeded in capturing the features of the sloshing dynamics in a slow manifold. As a result, a time integrator of the sloshing dynamics was finally developed.

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