Verifying volume-of-fluid implementations with a manufactured solution

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ABSTRACT

Code verification is an essential part of CFD software development, which ideally preceeds solution verification and validation. The main goal is to verify that the governing equations are solved correctly, meaning that the numerical errors decrease upon mesh and/or time step refinement with the theoretical order of the implemented methods. This requires a problem for which the exact solution is available, typically constructed with the method of manufactured solutions [3]. The construction assumes that the exact solution is sufficiently differentiable to be substituted into the equations. But this assumption is problematic for volume-of-fluid models, which are meant to capture a discontinuity in the flow field.

One way to overcome the problem and successfully manufacture solutions for the verification of volume-of-fluid implementations is to use the same error function $\mathrm{erf}(x)$ that is used in the theoretical proofs of mesh convergence. The discontinuity can thus be approximated by an arbitrarily steep, but continuously differentiable function. Based on this idea, we present a manufactured solution for the coupled mass, momentum and volume fraction equations that form the core of many CFD packages. The manufactured solution loosely resembles a sinusoidal wave in deep water but covers both water and air, including the discontinuity between them [1]. We then give an example of its use by verifying the baseline volume-of-fluid implementation in ReFRESCO [2]. The results warn against high accuracy expectations of these kind of methods.

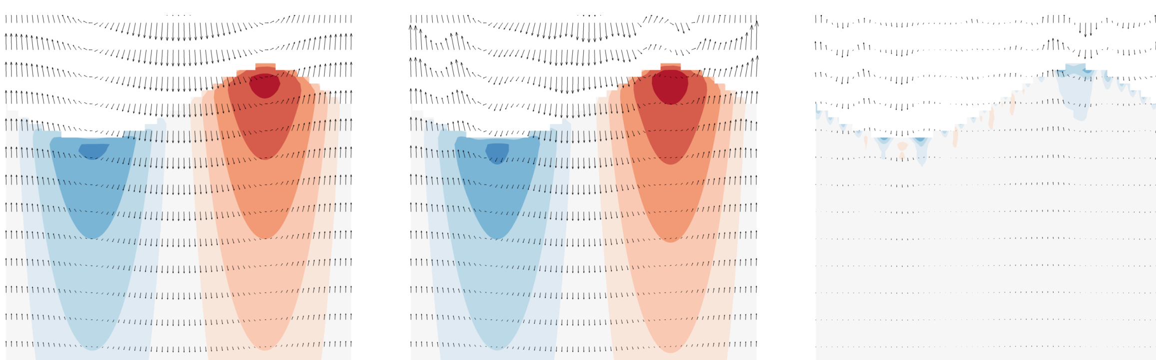

Figure 1: Exact manufactured solution (left), numerical approximation (middle) and its error (right).

REFERENCES

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