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# Re-print of Direct Arbitrary-Lagrangian-Eulerian finite volume schemes on moving nonconforming unstructured meshes

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## Abstract

In this paper, we present a novel second-order accurate Arbitrary-Lagrangian-Eulerian (ALE) finite volume scheme on moving *nonconforming* polygonal grids, in order to avoid the typical mesh distortion caused by *shear flows* in Lagrangian-type methods. In our new approach the nonconforming element interfaces are *not* defined *a priori* by the user, but they are automatically detected by the algorithm if the tangential velocity difference across an element interface is sufficiently large. The grid nodes that are sufficiently far away from a shear wave are moved with a standard node solver, while at the interface a new set of nodes is inserted that can *slide along* the interface in a nonconforming manner. In this way, the elements on both sides of the shear wave can move with a different velocity, without producing highly distorted elements.

The core of the proposed method is the use of a space-time conservation formulation in the construction of the final finite volume scheme, which completely avoids the need of an additional remapping stage, hence the new method is a so-called *direct* ALE scheme. For this purpose, the governing PDE system is rewritten at the aid of the space-time divergence operator and then a fully discrete one-step discretization is obtained by integrating over a set of closed space-time control volumes. The nonconforming sliding of nodes along an edge requires the insertion or the deletion of nodes and edges, and in particular the space-time faces of an element can be shared between more than two cells.

Due to the space-time conservation formulation, the geometric conservation law (GCL) is *automatically* satisfied by *construction*, even on moving nonconforming meshes. Moreover, the mesh quality remains high and, as a direct consequence, also the time step remains almost constant in time, even for highly sheared vortex flows. **In this paper we focus mainly on logically straight slip-line interfaces, but we show also first results for general slide lines that are *not* logically straight.** Second order of accuracy in space and time is obtained by using a MUSCL-Hancock strategy, together with a Barth and Jespersen slope limiter.

The accuracy of the new scheme has been further improved by incorporating a special *well balancing* technique that is able to maintain particular stationary solutions of the governing PDE system up to machine precision. **In particular, we consider steady vortex solutions of the shallow water equations, where the pressure gradient is in equilibrium with the centrifugal forces.**

A large set of different numerical tests has been carried out in order to check the accuracy and the robustness of the new method for both smooth and discontinuous problems. In particular we have compared the results for a steady vortex in equilibrium solved with a standard *conforming* ALE method (without any rezoning technique) and with our new *nonconforming* ALE scheme, to show that the new nonconforming scheme is able to avoid mesh distortion in vortex flows even after very long simulation times.

**Keywords:** moving nonconforming unstructured meshes, slide lines in direct Arbitrary-Lagrangian-Eulerian (ALE) methods for shear flows, cell-centered Godunov-type finite volume methods, shallow water equations in Cartesian and cylindrical coordinates, hyperbolic conservation laws, well balanced methods.

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