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New techniques for solving the steady free surface flow problem

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Steady free surface (FS) flows of water and air are often encountered in maritime and hydraulic applications, such as flow around ships or in confluences. The behaviour of these flows can be simulated numerically using either capturing or fitting methods. The former uses a marker to transport the FS through the mesh, the latter deforms the mesh along with the FS. Fitting methods are iterative and consist of two steps: solution of the flow and update of the FS position. In these steps, the kinematic (KBC) and dynamic (DBC) boundary conditions have to be addressed: the FS must be impermeable and the pressure constant.

Most fitting methods use (pseudo-)time-stepping and are therefore inefficient for solving steady flows [1]. The *steady iterative method* [2] is a truly steady method and therefore much faster. This is achieved by using a combination of the two FS conditions in the flow solver. On the downside, this combined boundary condition requires a dedicated flow solver. The goal of this research is to develop a truly steady method which can be used with a general purpose (black box) flow solver. For that purpose, the KBC will be used in the flow solver and the DBC during the surface update.

Inviscid free surface flow over a flat bottom is studied analytically, to better understand the physics of the problem. When a sinusoidal perturbation is given to the free surface position, potential flow theory gives the pressure at the FS in function of the wavelength (relative to the depth) and Froude number. Based on this theory, a simple update method is constructed, for which a Fourier stability analysis is performed that shows how different error modes behave. From this perspective, several more complex update methods are developed and tested numerically in 2D. Quasi-Newton techniques are used to stabilize the iterations and accelerate convergence. Scaling of the method with respect to the mesh size is improved using multi-grid-like techniques.

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