Automatic shape optimization of non-linear multi-physics problems

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The Python package AutoFreeFEM [1] is developed for the purpose of automatic shape optimisation of non-linear multi-physics problems in FreeFEM++. Additionally, the package outputs expressions for use in LaTeX. As an input, the objective function and the weak form of the problem must be specified only once, ensuring consistency between the simulation code and its documentation. In particular, AutoFreeFEM provides the linearization of the state equation, the adjoint problem, the shape derivative, as well as a basic implementation of the level-set based mesh evolution method for shape optimization [2]. For the computation of shape derivatives, we utilize the Lagrangian approach for differentiating PDE-constrained shape functions. Differentiation is done symbolically using Sympy. In numerical experiments, we verify the accuracy of the computed derivatives. Finally, we demonstrate the capabilities of AutoFreeFEM by considering shape optimization of a non-linear diffusion problem, linear and non-linear elasticity problems, a thermo-elasticity problem and a fluid-structure interaction problem.

References:

[1] https://gitlab.tugraz.at/autofreefem/autofreefem

[2] Grégoire Allaire, Charles Dapogny, and Pascal Frey. Shape optimization with a level set based mesh evolution method. Computer Methods in Applied Mechanics and Engineering, 282:22–53, 2014.

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