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# A Cut Finite Element Method for the Bernoulli Free Boundary Value Problem <sup>\*</sup>

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## Abstract

We develop a cut finite element method for the Bernoulli free boundary problem. The free boundary, represented by an approximate signed distance function on a fixed background mesh, is allowed to intersect elements in an arbitrary fashion. This leads to so called cut elements in the vicinity of the boundary. To obtain a stable method, stabilization terms are added in the vicinity of the cut elements penalizing the gradient jumps across element sides. The stabilization also ensures good conditioning of the resulting discrete system. We develop a method for shape optimization based on moving the distance function along a velocity field which is computed as the  $H^1$  Riesz representation of the shape derivative. We show that the velocity field is the solution to an interface problem and we prove an a priori error estimate of optimal order, given the limited regularity of the velocity field across the interface, for the the velocity field in the  $H^1$  norm. Finally, we present illustrating numerical results.

**Keywords.** Free boundary value problem; CutFEM; Shape optimization; Level set; Fictitious domain method

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