An efficient computation of the signed distance for the remeshing process of PFEM

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1 Introduction

Recently, a new remeshing strategy for PFEM has been proposed (Fernández et al., 2023). This one uses a Level–Set (LS) function to map the topology of the domain and elaborate an element selection criterion that is more accurate than the Alpha–Shape (AS) algorithm. The LS-based remeshing strategy allows, for example, to keep the smoothness of the free surface and to reduce the amount of elements created during the contact, as illustrated in Fig. 1.

The key idea of resorting to an LS function is to obtain a signed distance function $\phi(\mathbf{x})$, i.e. a function that gives the distance from a point $\mathbf{x}$ to the fluid boundary, and indicating whether the point is inside the fluid (positive sign) or outside the fluid (negative sign), as illustrated in Figure 1. However, the computational cost of constructing the LS function is high, and even prohibitive in some cases, because a dense, ill-conditioned system must be solved to find the numerous parameters that compose the LS function. For this reason, this work will develop a more efficient method to obtain the signed distance. The idea here is to compute the signed distance only on the elements present at the fluid boundary and using only the topological information of the element. Thus, the criterion can be parallelized efficiently and without the need to solve a dense and ill-conditioned system.

The new methodology consists of using the surface normal at the fluid boundary to determine whether the element is inside or outside the fluid. For example, to create an element acceptance criterion, one can focus only on elements that have 3 nodes (2D) on the free surface, as illustrated in Figure 2a-2c. The centroid of these elements will be inside the fluid if the vector joining a node with the centroid is opposite to the normal of such node, as illustrated in Figure 2d, otherwise the element will be outside the fluid (Figure 2e). Having this information, it is possible to determine whether or not the external element can be accepted in the remeshing criterion, for example, based on the size of the element, the aspect ratio of the element, or its distance to the fluid boundary. In case the element is inside the fluid, an elimination criterion should be devised to allow fluid separation, as done by Fernández et al. (2023).

2 Objective

The aim of this work is to implement the ideas expressed above, i.e., the computation of the signed distance function on the boundary elements and the criteria of acceptance and removal of elements.

The student can carry out the work in MATLAB language, on a code that already has the PFEM formulation but which is limited to 2D. If the methodology proves successful, the student will be encouraged to write a scientific article and/or to transcribe the methodology into a C++ code with 2D and 3D functionality.

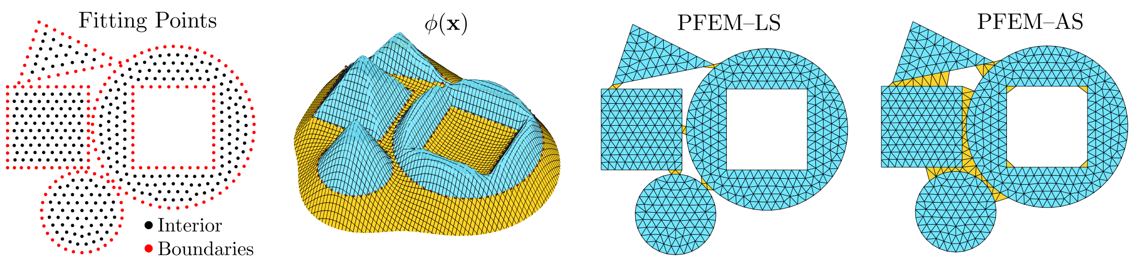

Figure 1: Illustration of the element creation during contact in PFEM.

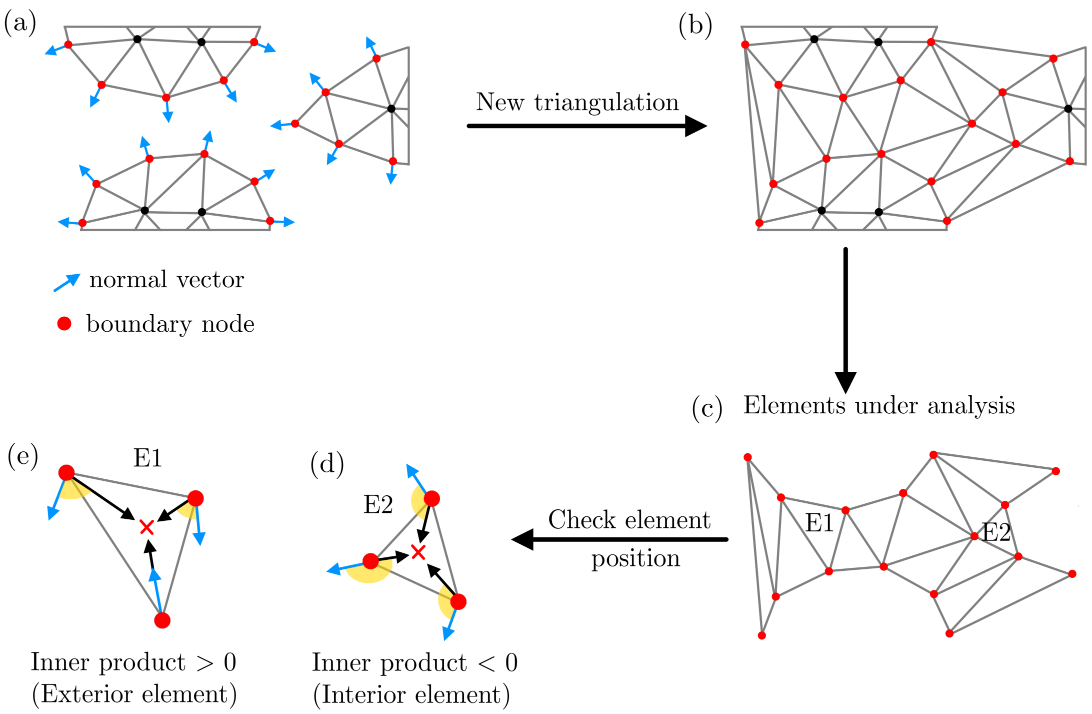

Figure 2: Approach to determine whether or not a new element belongs to the fluid. (a) The deformed mesh to be updated. (b) The new triangulation to be analyzed to verify which elements will be retained in the new mesh. (c) The elements under analysis, the ones with 3 nodes on the boundary. (d) An element that is part of the fluid and (e) one that is outside the fluid.

References

Fernández, Eduardo, Simon Février, Martin Lacroix, Papeleux Boman, Romain Luc, and Jean-Philippe Ponthot. 2023. "A Particle Finite Element Method based on Level Set functions." *Journal of Computational Physics* 487: 112187.