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# ROBUST POINT-LOCATION METHOD FOR LINEAR AND HIGH ORDER MESHES. APPLICATION TO PARTICLE TRANSPORT

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In computational geometry the point-location problem is a fundamental topic. In the Finite Elements Method (FEM) context, it is used to find which is the host element of a given point in the computational domain. This process is required in many application such as the measurament of flow properties on specific points (probes) in computational fluid dynamics (CFD), the projection from one mesh to another in adaptivity or for Lagrangian particle transport simulations.

In this work, an efficient solution to the point-location problem applied to FEM is presented. The robustness of the proposed approach is evaluated in the context of particle transport simulations in the respiratory system airways. Respiratory system simulations involve CFD and millions of transported particles along with tens or hundreds of thousands of time-steps [1]. As a consequence, the location process is one of the critical parts of the simulation. In other words, an efficient and robust inclusion test becomes essential not only for the accuracy of the results, but also to achieve a good computational efficiency.

Our algorithm is composed of four main steps: three consecutive filters are applied, followed by the evaluation of the iso-parametric coordinates of the point within the hosting element.

- *Filter 1: Bin/Oct tree.* A list of host element candidates is created using a bin/oct tree strategy [2].
- *Filter 2: Bounding box of the element.* The list of candidates is looped. The candidate elements which do not contain the target point within its bounidng box are discarded.
- *Filter 3: The inclusion test.* An inclusion test method based on ray casting [3] is used to check if the candidate element is the host element between the remaining candidates. This method is based on counting ray intersections with edges or nodes and apply the odd/even parity rule (if the number of intersections is odd, the point belongs to the element). Care must be taken to avoid a ray intersections an edge of the element because invalidates the parity rule.
- *Calculation: Iso-parametric coordinates.* Once the host element is known, the iso-parametric coordinates of the point inside the element can be calculated. To solve the shape function

equation which allow to transform global coridnates into local ones, a Newton-Raphson iterator is used.

In figure 1, a flowchart is shown outlining the aforesaid steps.

In this work, special emphasis will be put on two aspects. First, on the numerical and implementation details that ensure the robustness and efficiency. Second, on the peculiarities of intersection calculus for high order elements, which analytic solution may not exist, making necessary the inclusion of a root finding algorithm. In this case, based on a second Newton-Raphson iterative approach.

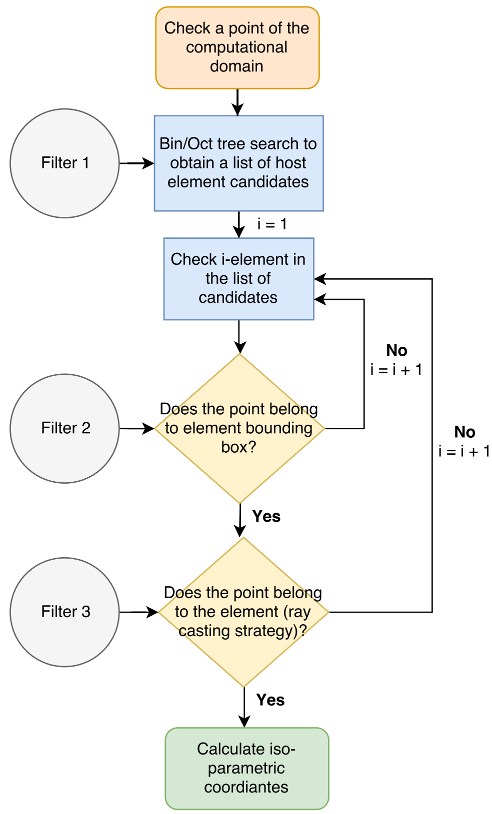


**Figure 1**: Flowchart of the point-location process.

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