Automatic Error Estimator and Mesh Refinement for the CFIE

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Mesh quality and resolution are key issues in the accurate and efficient solution to any numerical problem. One open challenge is how to achieve a desired level of accuracy in the whole considered discretized structure that could contain smooth parts and non-smooth ones such as edges and corners. A possible solution is to implement an adaptive mesh refinement that needs to fulfil two necessary parts: (i) the detection of inaccuracies, i.e. regions where the solution is not properly discretized; (ii) a scheme able to improve the solution accuracy by locally acting in these selected regions.

Here, we will investigate this issue for the discretization via Rao-Wilton-Glisson (RWG) basis functions and the method of moments (MoM) solution of the surface combined integral equation (CFIE) in the case of metallic objects. The main goal of the present work is to propose a method able to automatically select the inaccurate regions and then choose the resolution of approximation for a desired level of accuracy.

Due to the Calderon identity (G. C. Hsiao and R. E. Kleinman, IEEE Transactions on Antennas and Propagation, vol. 45, no. 3, 1997), the error in the approximate solution can be bounded by the residual error of the discretized surface integral equation. This allows to improve the overall accuracy by locally refining the mesh where the residual is larger. Hence, we have developed an error estimator based on the residual error associated with individual elements of the initial mesh. The error estimator involves a local measure of the boundary condition error, via testing on half-RWG functions defined on fine triangular cells (that represent the highest possible mesh resolution). Then, the mesh of the selected regions is automatically refined via a sub-meshing. In order to limit the refined mesh to the regions of interest and to avoid elongated cells, a non-conformal mesh is introduced where half-RWG functions are defined, and the refined overall structure is solved via a Discontinuous-Galerkin scheme (Z. Peng, K.-H. Lim, and J.-F. Lee, IEEE Transactions on Antennas and Propagation, vol. 61, 2013). The implementation of the approach in fast solver will be also discussed, together with numerical results to prove the effectiveness of the approach in the case of multi-scale structures.

Finally, with respect to authors' previous publications (e.g. J. A. T. Vasquez et al., IEEE International Conference on Computational Electromagnetics, Hong Kong, 2015), here the automatic mesh refinement is performed in one shot, avoiding a costly iterative procedure, and the use and implementation of higher order basis functions is not required.