Accurate Solutions of Volume Integral Equations Based on Nyström-like Point-matching Scheme

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Abstract — Volume integral equations (VIEs) are indispensable for solving electromagnetic (EM) problems with inhomogeneous or anisotropic materials by integral equation approach. Traditionally, the VIEs are solved by the method of moments (MoM) in which the unknown volumetric electric and magnetic currents are represented with the Schaubert-Wilton-Glisson (SWG) basis function. The SWG basis function is defined over a pair of tetrahedrons with a common face and requires conformal tetrahedral meshes in geometric discretization. The conformal meshes will result in a high cost in discretization, especially for multiscale structures in which the meshes with different sizes need to perfectly merge near material interfaces.

The conformal meshes imply that the tetrahedral elements cannot stride across material interfaces or each tetrahedron cannot include inhomogeneous materials in the geometric discretization. This is because the SWG basis function cannot be defined over a discontinuous material boundary. Therefore, we have to locate the material boundaries for a given arbitrarily inhomogeneous structure and discretize each material individually without striding across its boundary. However, if we need to discretize the geometries along their material boundaries, why do we need to bother the VIEs? The surface integral equations (SIEs) can also be used and are more convenient to implement if we must locate the boundaries because they only require discretizing the material interfaces. Hence, it seems that solving the VIEs is unnecessary in the case when the material boundaries are impenetrable in geometric discretization.

In this work, we propose a Nyström-like point-matching scheme to solve the VIEs. The scheme does not use any basis function and only works with individual tetrahedrons instead of tetrahedron pairs. Therefore, the scheme allows an inhomogeneity of materials in each tetrahedron or permits to stride across material boundaries without enforcing a conformity in geometric discretization. Due to this distinctive feature, the scheme can handle arbitrarily inhomogeneous or anisotropic structures with much convenience. Numerical examples for electromagnetic scattering will be presented to demonstrate the scheme and its robustness can be observed.