Accelerated BEM for 3D electrostatics

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Abstract

This research is concerned with a rigorous development of a fast spectral method for solving boundary integral equations in three-dimensional potential theory. Upon discretizing the underlying boundary integrals via a Galerkin approximation, the proposed method overlays the problem domain with a regular Cartesian grid that serves as an auxiliary platform for computation. With the aid of the Fast Fourier Transform, the necessary influence matrices of the discretized problem are rapidly evaluated on a regular grid in a sparse manner. Unlike traditional techniques dealing with boundary integrals, the sparse representation of the featured coefficient matrices results in a significant reduction in computer memory requirements. The computational cost associated with the sparse approximation of influence matrices is asymptotically lower than that of conventional methods. For an expeditious numerical solution of boundary integrals, a Krylov-subspace iterative method is further employed wherein the sparse influences are used to rapidly compute the matrix-vector products involved at each iteration. Several key features of the formulation, including the mapping of density distributions onto the regular Cartesian grid, are highlighted. Numerical experiments are presented to illustrate the performance of the spectral method. The proposed approach will find application in areas involving large simulations with complex moving boundaries.

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