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A Multi-Solver Algorithm for Electromagnetic Modeling of Complex Objects

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1. Extended Abstract

Numerical methods for solving highly complicated engineering electromagnetic (EM) problems have been widely studied and developed over the last few decades. The choice of a method depends on the structure and material composition of the object. Surface-integral-equation-based methods, such as the method of moments (MoM), are very efficient for modeling large and impenetrable or homogeneous objects, whereas partial-differential-equation-based methods, such as the finite element method (FEM), is preferred for modeling objects with inhomogeneous and/or anisotropic materials. The hybrid finite element and boundary integral (FE-BI) method, which combines the advantages of both the MoM and the FEM, is one of the most popular methods to solve large and complex EM problems [1]. However, if an object is electrically large and a large portion of the object is modeled by the FEM, the efficiency of the FE-BI method decreases because the poorly-conditioned FEM subsystem deteriorates the condition of the combined system. To improve the capability of modeling electrically large and highly complex objects, domain decomposition methods (DDMs) have been developed. One of the most advanced DDMs, the dual-primal finite element tearing and interconnecting method [2], is introduced by first tearing the computational domain into non-overlapping subdomains and then constructing the interface problem by applying transmission conditions at the subdomain interfaces. After solving the interface problem, the electromagnetic fields inside the subdomains can be calculated independently.

In this work, a multi-solver (MS) algorithm is proposed to model electrically large and complex objects. In this algorithm, the object under consideration is decomposed into multiple non-overlapping subdomains, and each subdomain is modeled by an individual solver best suited for the subdomain. For example, the subdomains with inhomogeneous materials are modeled by the FEM or the FE-BI method, and the subdomains with impenetrable or homogeneous materials are modeled by the MoM. Among several FEM, FE-BI, and MoM formulations, the most accurate and efficient formulation is studied and applied to the subdomains. The fields in different subdomains are then coupled by either the Robin-type transmission condition [3] or the combined field integral equation [4]. Although the MS algorithm is accurate, flexible, and robust in modeling large and complicated objects, the computational cost is still prohibitively high when it is used for extremely large EM simulations. To solve such a problem efficiently, the MS algorithm is accelerated on distributed computing systems. The multilevel fast multipole algorithm [5] employed in the MoM solution is parallelized to enable the computation on many processors. To accelerate the convergence of the iterative solution, a preconditioner based on absorbing boundary conditions is applied. Finally, several numerical examples are given to validate the proposed method and show the capability of the MS algorithm.

2. References

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