ELS-XV-2015 Abstracts
ELS-XV-2015-158-2
Electromagnetic & Light Scattering XV 2015, Leipzig

Controlled time integration for numerical simulation of electromagnetic scattering

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In this study, we concentrate on simulating time-harmonic electromagnetic scattering in time domain. In principle, the time-harmonic solution can be reached by simple time integration (asymptotic approach), but we accelerate the convergence rate by using the exact controllability technique pioneered by Bristeau, Glowinski, and Périaux (1998). Essentially, the approach is a controlled variation of the asymptotic approach with periodic constraints, in which the time-dependent equation is simulated in time, until the time-harmonic solution is reached. A natural quadratic error functional is the squared energy norm of the system, allowing the minimization by the conjugate gradient (CG) method operating in Hilbert spaces.

The finite difference time domain (FDTD) method, introduced by Yee, has been used for several decades as a common method for solving electromagnetic problems in space-time domain. Originally, the method is restricted to cubic elements. Since the simple cubic mesh is a relatively rare construction in the natural crystals, we concentrate on the structures based on more natural space lattices. In particular, we consider high-quality mesh structures mimicking the geometry of the close packing in crystal lattices which is a typical structure for elemental metals and inter-metallic compounds.

We present the scattering problem in terms of differential forms, and the discrete exterior calculus (DEC) is used for the spatial discretization. The approach follows the groundwork presented by Marsden's group (Desbrun et al. 2005). Accordingly, the discrete spaces and exact differential operators mimic their continuous counterparts preserving the the physical properties of the problem. As combined with the exact controllability method, this approach gives significant savings in computing time compared with the conventional schemes. For demonstrating the method, we present numerical experiments of radar reflections from plasmatic objects and light scattering by dust particles.

References

Bristeau, M. O., Glowinski, and R., J. Périaux, J. (1998). Controllability methods for the computation of time-periodic solutions; application to scattering, Journal of Computational Physics, 147(2):265–292.

Desbrun, M., Hirani, A. N., Leok, M., and Marsden, J. E. (2005). Discrete exterior calculus. Preprint, arXiv:math/0508341v2 [math.DG].