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A Hybrid Classical-Quantum Algorithm for Boundary Integral Equations of Scattering Theory

Authors : Damir Latypov

Abstract : A hybrid classical-quantum algorithm to solve boundary integral equations (BIE) arising in problems of electromagnetic and acoustic scattering is proposed. The quantum speed-up is due to a Quantum Linear System Algorithm (QLSA). The original QLSA of Harrow et al. provides an exponential speed-up over the best-known classical algorithms but only in the case of sparse systems. Due to the non-local nature of integral operators, matrices arising from discretization of BIEs, are, however, dense. A QLSA for dense matrices was introduced in 2017. Its runtime as function of the system's size N is bounded by $O(\sqrt{N}\text{polylog}(N))$. The run time of the best-known classical algorithm for an arbitrary dense matrix scales as $O(N^{2.373})$. Instead of exponential as in case of sparse matrices, here we have only a polynomial speed-up. Nevertheless, sufficiently high power of this polynomial, ~4.7, should make QLSA an appealing alternative. Unfortunately for the QLSA, the asymptotic separability of the Green's function leads to high compressibility of the BIEs matrices. Classical fast algorithms such as Multilevel Fast Multipole Method (MLFMM) take advantage of this fact and reduce the runtime to O(Nlog(N)), i.e., the QLSA is only quadratically faster than the MLFMM. To be truly impactful for computational electromagnetics and acoustics engineers, QLSA must provide more substantial advantage than that. We propose a computational scheme which combines elements of the classical fast algorithms with the QLSA to achieve the required performance.

Keywords : quantum linear system algorithm, boundary integral equations, dense matrices, electromagnetic scattering theory
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