Mixed-Precision Strategies in Spectral Element Codes: Accuracy-Aware Approximation for Energy-Efficient Simulations

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Abstract

Approximate computing via mixed precision arithmetic offers a promising path to energy-efficient high-performance computing. However, identifying where and how to apply reduced precision without compromising solution accuracy remains a key challenge in scientific simulations. In this talk, we present a comprehensive methodology for enabling mixed-precision in spectral element codes using floating-point analysis tools, roofline modeling, and empirical verification. We apply our strategy to Nekbone and Neko-two fluid dynamics solvers-by combining reduced-precision iterative solvers with double-precision critical operations such as dot products and global communications. Our method is supported by Verificarlo's Monte Carlo arithmetic and precision emulation, which help detect numerically stable kernels for approximation. The resulting mixed-precision versions deliver up to 2.38x faster time-to-solution and 2.8× lower energy-to-solution, while retaining double-precision-level accuracy. This work highlights a practical, accuracy-aware approach to integrating approximation into large-scale legacy applications, making them fit for future exascale platforms.

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