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Vectorised spectral/hp element matrix-free operator for anisotropic heat transport in tokamak edge plasma

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A highly efficient matrix-free Helmholtz operator with single-instruction multiple-data (SIMD) vectorisation in Nektar++ [1] and applied for the anisotropic heat transport in tokamak edge plasma. A tokamak is currently the leading candidate for a practical fusion reactor using the magnetic confinement approach to produce controlled thermonuclear fusion power. The transport of heat in magnetized plasma is important to the stability and control of thermonuclear fusion process in tokamak. Due to the presence of magnetic field and the ionized nature of plasma, the heat transport of the magnetized plasma is highly anisotropic. In this article, a variational form is proposed to simulate the anisotropic heat transport in the magnetized plasma. The details of its mathematical derivation and practical implementation are presented. To design a reliable and accurate exascale software to account for a plethora of different complex physical phenomena in the tokamak edge plasma, a highly scalable and efficient algorithms is crucial. To this end, a matrix-free Helmholtz operator together with SIMD vectorisation technique is proposed in Nektar++ framework. The sum-factorization and matrix-free are two important concept to effectively accelerate the evaluations of elemental and global matrix operations with significantly lower operation counts. Furthermore, the matrix-free and sum-factorisation algorithms can be further optimized by using instruction set extensions, such that multiple pieces of data can be executed by one operation, the single-instruction multiple-data (SIMD) technique. In this article, the mathematical accuracy and the efficiency of the implemented matrix-free operator together with SIMD optimization is evaluated in both steady and unsteady cases of anisotropic heat transport.

REFERENCES

[1] Cantwell, Chris D., et al. "Nektar++: An open-source spectral/hp element framework." Computer physics communications 192 (2015): 205-219