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Performance Analysis of SpMM in Distributed Parallel CFD Simulations

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Sparse matrix-vector product (SpMV) is the most computationally expensive routine in many large-scale simulations relying on iterative methods. Despite significant efforts dedicated to optimizing SpMV for various applications and cutting-edge computing environments, its low operational intensity poses strong limitations on its performance.

In some cases, a sparse matrix is to be multiplied by a set of vectors. For instance,

$$(\alpha\mathbb{I}_3 \otimes \mathsf{A})\,(\boldsymbol{x}_1, \boldsymbol{x}_2, \boldsymbol{x}_3)^T = \begin{pmatrix} \alpha\mathsf{A} & 0 & 0 \\ 0 & \alpha\mathsf{A} & 0 \\ 0 & 0 & \alpha\mathsf{A} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}_1 \\ \boldsymbol{x}_2 \\ \boldsymbol{x}_3 \end{pmatrix}. \tag{1}$$

Such a formulation applies to several scenarios in numerical algorithm implementations that are increasingly common. Examples are spatial reflection symmetries [1], parallel-in-time methods [2], multiple transport equations, or multiple parameter simulations [3].

This work is devoted to comprehensive performance analysis of the sparse matrix multiplication with multiple right-hand sides, also known as sparse matrix-matrix product (SpMM), in distributed-memory parallel CFD simulations.

References

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