VII International Conference on Mathematics and its Applications in Science and Engineering
(ICMASE 2026)

ICMASE 2026

Online Tensor Train Decomposition with Sequential Orthogonalization for In-Situ Compression of PDE Solutions

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Abstract

High-dimensional partial differential equation (PDE) simulations are fundamental to computational science and engineering, yet they generate large volumes of time-series data. This data generation creates memory and storage bottlenecks, as the time required to write data to disk can exceed the computation time itself. While Tensor Train (TT) decomposition [1] offers an effective algebraic framework for mitigating the curse of dimensionality, conventional batch-based TT algorithms require storing the full dataset in memory, making them computationally prohibitive for the in-situ compression of streaming simulation data. Conversely, existing online TT methods [2], which rely on recursive approximations, often suffer from numerical instability, ill-conditioned Gram matrices, and error accumulation over long temporal evolutions. In this work, we propose applying a deterministic online TT decomposition algorithm (Online TT-ALS) for the in-situ compression of streaming PDE solutions. Our method sequentially enforces orthogonal constraints on the TT cores during a single-sweep update. By preserving an exact orthogonal subspace at every time step, our approach completely avoids the inversion of ill-conditioned matrices. This property ensures long-term numerical stability, approximation accuracy without requiring an initial warm-up period, and low-latency processing suitable for dynamic environments. We formulate an online compression pipeline tailored for time-dependent PDEs and investigate its practical feasibility. To validate the algorithm, we conduct numerical experiments on fundamental benchmark models, including the high-dimensional heat equation. Preliminary results indicate that the proposed framework achieves significant data reduction while maintaining mathematical fidelity and computational efficiency. We evaluate the algorithm's temporal stability and compression performance, demonstrating its potential to scale to broader classes of multidimensional PDEs and to provide a robust in-situ compression strategy for scientific computing.

***K*eywords** TT decomposition · PDE simulation · data compression

References

[1] Oseledets I.V., Tensor-Train Decomposition, SIAM Journal on Scientific Computing, 33(5): 2295-2317, 2011.

[2] Thanh L.T., Abed-Meraim K., Trung N.L., and Boyer R., Adaptive Algorithms for Tracking Tensor-Train Decomposition of Streaming Tensors, 2020 28th European Signal Processing Conference (EUSIPCO), 995-999, 2021.

[3] Holtz S., Rohwedder T., and Schneider R., The Alternating Linear Scheme for Tensor Optimization in the Tensor Train Format, SIAM Journal on Scientific Computing, 34(2): A683-A713, 2012.

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