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**Manuscript submission to the ACM Transactions on Parallel Computing**

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Prof. David A Bader

Editor-in-Chief   
ACM Transactions on Parallel Computing

Dear Prof. Bader,

Please find attached our manuscript titled

“Recursive Algebraic Coloring Technique for Hardware-Efficient   
Symmetric Sparse Matrix-Vector Multiplication”

by Christie Louis Alappat, Georg Hager, Olaf Schenk, Jonas Thies, Achim Basermann, Alan R. Bishop, Holger Fehske, and Gerhard Wellein, which we would like to submit for consideration as a regular article in the ACM Transactions on Parallel Computing.

In this work, we propose a novel coloring algorithm which is motivated by hardware constraints of modern compute nodes and thus eliminates the shortcomings of previous coloring methods in terms of hardware efficiency and parallelization overhead. Though our method is generally applicable to distance-k colorings we validate its hardware efficiency by applying it to the thread-level parallelization of symmetric sparse matrix vector multiplication (SymmSpMV). Using the distance-2 coloring of the underlying sparse matrix provided by our method, this important kernel can be efficiently parallelized. We find that our approach substantially outperforms both parallelization of SymmSpMV using standard colorings and the widely used SymmSpMV implementation provided by Intel in its math kernel library (MKL). We validate our results across a set of 31 sparse symmetric matrices from various application areas and demonstrate its high hardware efficiency by comparison with a roofline type performance model for SymmSpMV, which is also presented for the first time in this submission. Beyond the SymmSpMV kernel our coloring approach can of course also be used for hardware efficient parallelization of iterative solvers having dependencies such as Gauss-Seidel (distance-1) or Kaczmarz (distance-2). Our method further does not rely on a specific storage format or is generally applicable to symmetric matrices, i.e., undirected graphs.

We believe that our findings will be of broad interest to the readership of the ACM Transactions on Parallel Computing. Sparse iterative solvers on symmetric matrices are used in various application areas including classic disciplines like quantum physics and chemistry as well as new rapidly developing fields such as machine learning and social graph analysis. In contrast to general sparse matrix vector multiplication, the SymmSpMV kernel has only attracted little attention in the past decade. Efficient parallelization has to consider potential write conflicts if only a triangular part of the matrix is used. We demonstrate that our new approach is a promising contribution to the solution of this problem. Moreover, the potential use of our coloring approach in iterative solvers or smoothers should attract additional interest in our work.

This manuscript has not been published and is not under consideration for publication elsewhere. Part of it has been presented by our lead author at the ACM Student Research Competition at SC18. As he won this competition, he submitted a 5-page summary of the work to the 2019 ACM Student Research Competition (SRC) grand finals, where he came second place (see https://src.acm.org). However, this should not conflict with the submission at hand as the ACM SRC report lacks any details on the implementation of the method, the performance model, and the detailed performance analysis.

If you feel that the manuscript is appropriate for your journal, we suggest Rich Vuduc from the Georgia Institute of Technology as the review (or associate) editor.

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All authors have approved the manuscript and agree with its submission to the ACM Transactions on Parallel Computing. We look forward to hearing from you at your earliest convenience.

Yours sincerely,

Christie Louis Alappat, Georg Hager, Olaf Schenk, Jonas Thies, Achim Basermann, Alan R. Bishop, Holger Fehske, and Gerhard Wellein