Improving performance of sparse direct methods via fill-preserving permutations

Scientific Achievement

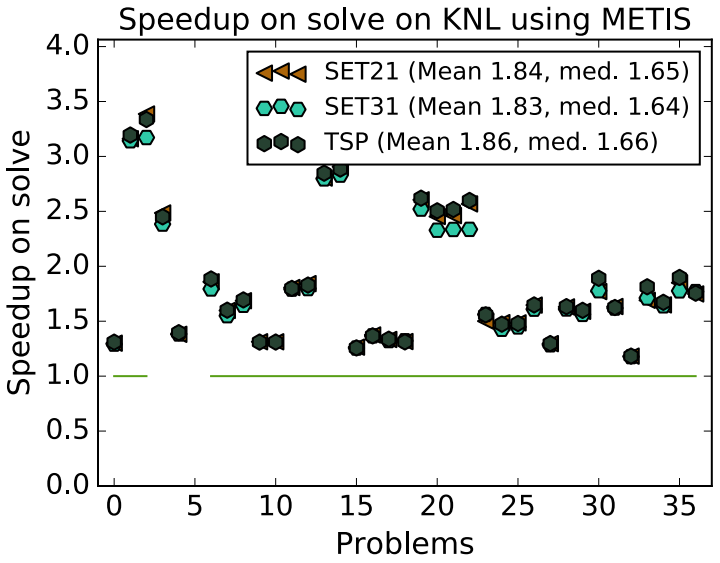
Development of fast implementations of a preprocessing step in sparse matrix factorization to improve dense block structure that enhances the performance of sparse direct solvers.

Significance and Impact

The preprocessing step reduces the number dense blocks in sparse matrix factorization while preserving the number of the nonzeros in the triangular factors, thereby generally increasing the block sizes. This affects data movement and results in a reduction of triangular solution times, which is important when linear systems with the same coefficient matrix but many right-hand sides vectors are to be solved.

Research Details

- Triangular factors of sparse matrices exhibit dense block structure.
- The columns of a factor can be partitioned into sets of columns so that the columns in a set, referred to as a supernode, share the same sparsity structure in the off-diagonal part.
- The columns within a supernode can be permuted without increasing the number of nonzeros in the triangular factor, but will change the number of dense blocks and the block sizes.



The plot shows the improvement of sparse triangular solution on a single core of an KNL node over a set of test matrices when fill-preserving reorderings were applied. The matrices were pre-ordered by using METIS. TSP, SET21, and SET31 are three different fill-preserving reordering algorithms that attempt to reduce the number of dense blocks in a sparse matrix factorization. The speedup ratios (in solution times) were relative to the performance of triangular solution when no fill-preserving reorderings were applied.

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