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Parallel Numerics

Exercise 7: Sparse Matrix–Vector Multiplication & MPI Communicators

1 MPI Communicators

a) Give examples for some network topologies (e.g. cartesian grids, hypercubes, tree). How are the standard mpi ranks mapped onto such topologies?

b) Which topology fits perfectly to Cannon's algorithm?

c) Besides a topology, a mpi communicator holds a group, a communication context (communicator specific tagging) and communicator specific buffers. Thus, e.g. collective operations act only for elements of the same communicator. Make yourself familiar with the communicator concept.

d) Give an application domain for mpi communicators.

2 Red-Black Colouring

The idea of any colouring approach for an iterative algorithm is to assign evaluations to different computing steps (colours). Afterwards, these steps are executed sequentially.

a) What are typical properties of elements of one colour?

b) Derive a colouring scheme for a 5-point stencil on a cartesian two-dimensional grid.

c) Why is bicolouring for a 9–point stencil on a cartesian two-dimensional grid not well-suited? Derive an improved colouring.

3 Sparse Matrix-Vector Multiplication

The solution of the matrix-vector product $A \cdot b$ with a sparse matrix $A \in \mathbb{R}^{n \times n}$ and $b \in \mathbb{R}^n$ should be calculated. Write different procedures for the calculation of the matrix-vector multiplication. Implement the storage schemes for matrix A that have been discussed in the lecture:

1. storage in coordinate form
2. compressed sparse row format (CSR)
3. compressed sparse column format (CSC)
4. CSR with extraction of the main diagonal entries
5. diagonal–wise storage (for band matrices)
6. rectangular, row–wise storage scheme
7. jagged diagonal form

Test your routines for large sparse matrices whose elements are randomly distributed as zeros or as non-zero values. Compare the computation time to the time needed by applying the full matrix storage scheme.