Università della Svizzera italiana

Institute of Computing CI

Project 4: **Parallel programming with Message Passing Interface (MPI)**

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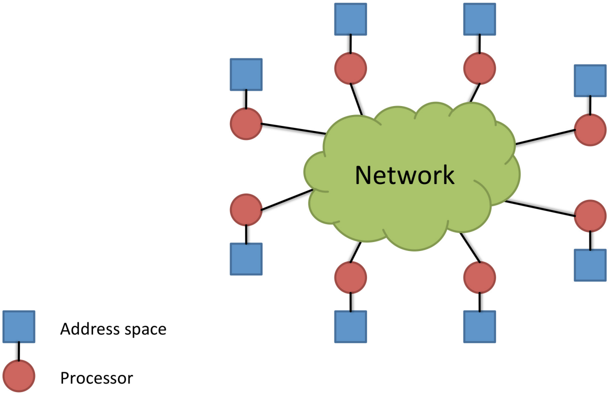
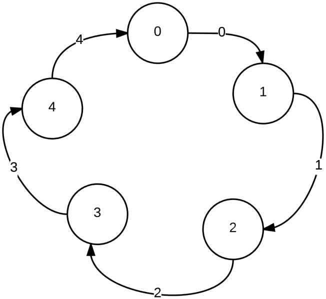
Message-passing model



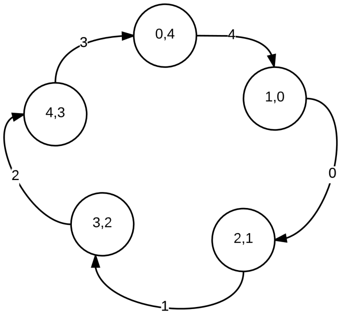
Overview of exercise sheet

1. Ring maximum using MPI.
2. Ghost cells exchange between neighboring processes.
3. Parallelizing the Mandelbrot set using MPI.
4. **Option A** : Parallel matrix-vector multiplication and the Power method.
5. **Option B** : Parallel PageRank Algorithm and the Power method.

Ring addition / maximum using MPI



Ring addition / maximum using MPI



Ghost cells exchange

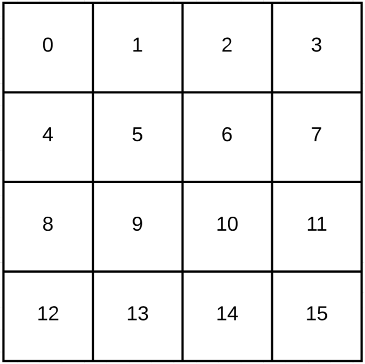
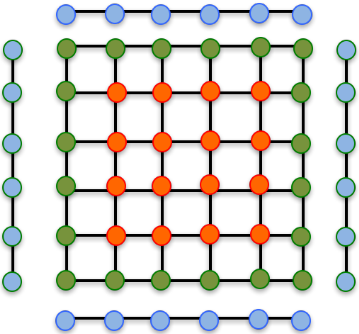


Figure: 4×4 Cartesian topology.

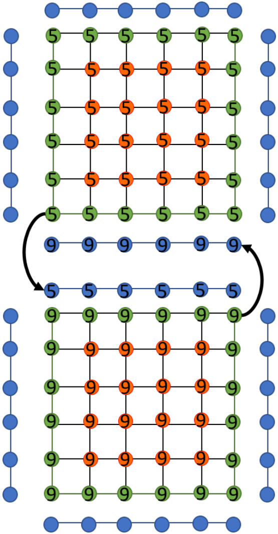
Question: How to create a Cartesian topology?

Ghost cells exchange

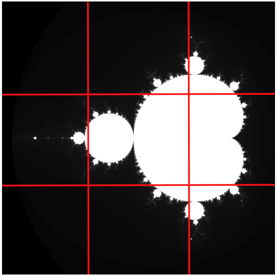


- Boundary cells need the information in ghost cells for some computation.
- The data in ghost cells depends on neighboring processes.

Ghost cells exchange



Parallelizing the Mandelbrot set using MPI



- Similar exercise performed with OpenMP.
- Create partition; that is create a Cartesian topology.
- Define the physical domain for each processor, then compute.
- Send local data to the root processor.

A : Parallel matrix-vector multiplication & the Power method

- A be a $n \times n$ matrix.
- Compute largest eigenvalue/eigenvector of A?
  Use power method.

Algorithm Power method

x is random vector of length n.
for $i = 1$ to N **do**
  $x \leftarrow x/||x||$
  $x \leftarrow Ax$
end for
$\lambda_{max} = ||x||$
$v_{max} = x/\lambda_{max}$

A : Parallel matrix-vector multiplication & the Power method

Given : Matrix dim n, number of processors p.
Assumption : n is divisible by p.

Step 1: Generate matrix A

- Each processor generates its own rows.

Step 2: Matrix-vector multiplication

Step 3: Implement power method

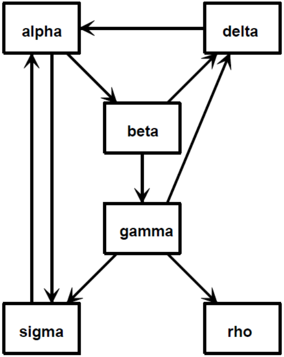
Experiments: Strong scaling and Weak scaling.

B : Parallel PageRank Algorithm & the Power method

- Used in the initial version of Google search engine.
- Ranks all the web pages.
- How? Generate the transition matrix A, then solve

$$x = Ax, \tag{1}$$

x is the vector of page ranks.
- Solve (1) with Power method!



B : Parallel PageRank Algorithm & the Power method

Transition matrix A?

$$A = pGD + ez^\top,$$

- G is a sparse matrix,
- D is a diagonal matrix,
- e and z are vectors and
- probability $0 \le p \le 1$.

Algorithm PageRank

1: $G \leftarrow pGD$
2: Compute z.
3: $x_i = 1/n$.
4: **for** $i = 1$ to N **do**
5: $\quad x \leftarrow Gx + e(z \cdot x)$
6: **end for**

B : Parallel PageRank Algorithm & the Power method

Given : Serial implementation.

To Do :

- Implement changes with MPI to get a parallel version.
- Benchmark your code on the provided datasets.
- Analyze and describe your results.

Questions?