ME5470: Introduction to Parallel Scientific Computing

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Homework 5

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1. Problem Overview

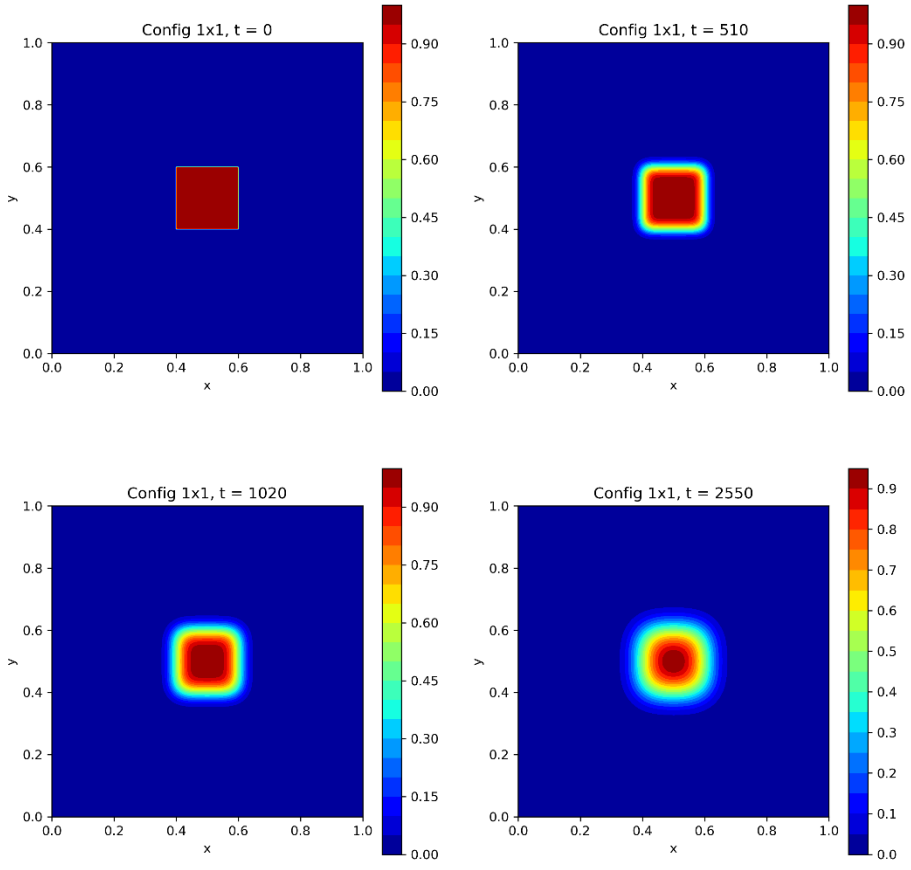
This report presents the implementation and results of the MPI-based parallel solver for two-dimensional unsteady heat conduction using:

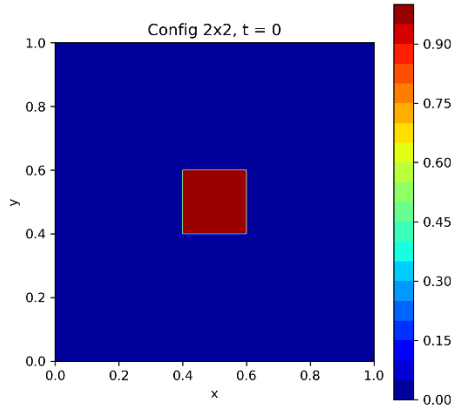
- **Second-order central differencing** for spatial derivatives
- **Explicit Euler time-stepping scheme**

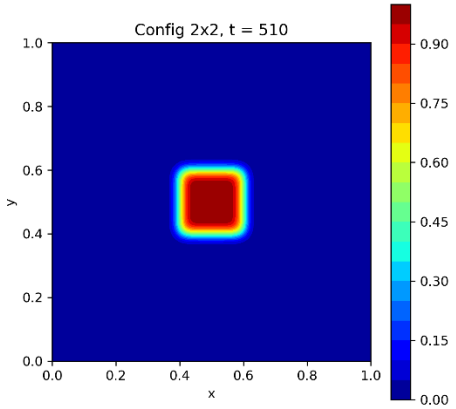
A **halo exchange mechanism** is used for inter-process communication. The correctness of the halo exchange is verified by assigning rank-dependent values to the temperature field and checking ghost cell updates.

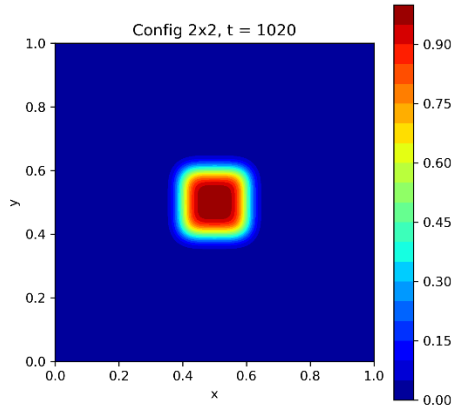
2. Contour and Line Plots

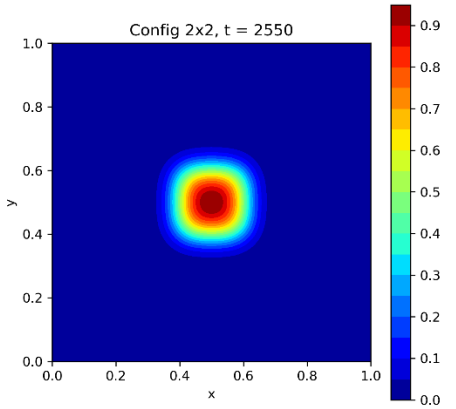
- The serial and parallel implementations (2×2, 2×4, and 4×4 processor grids) produce identical contour plots at all time steps.
- Line plots at selected time steps confirm that all implementations yield the same numerical results.

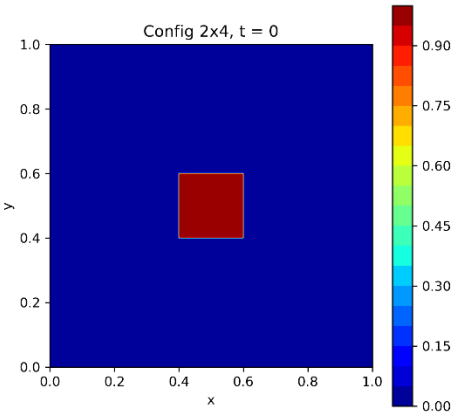


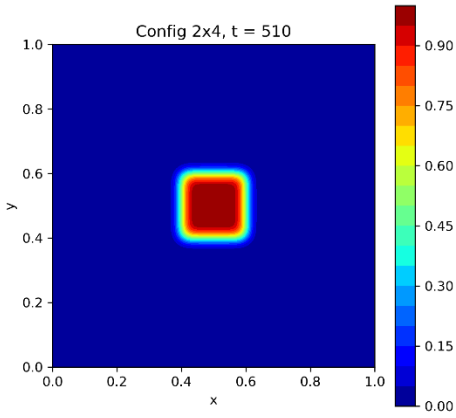

Config 2x2, t = 0
x
y

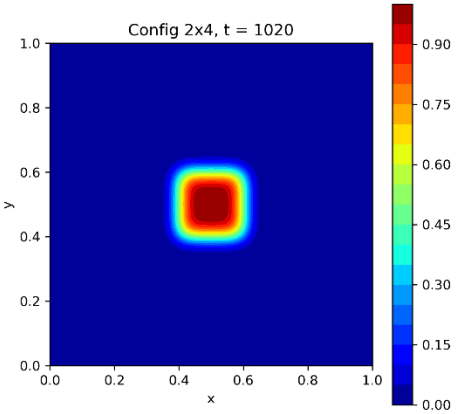

Config 2x2, t = 510
x
y

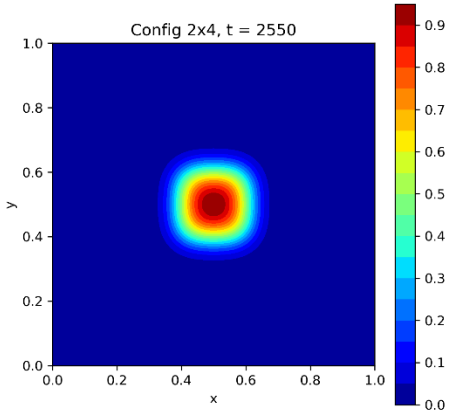

Config 2x2, t = 1020
x
y

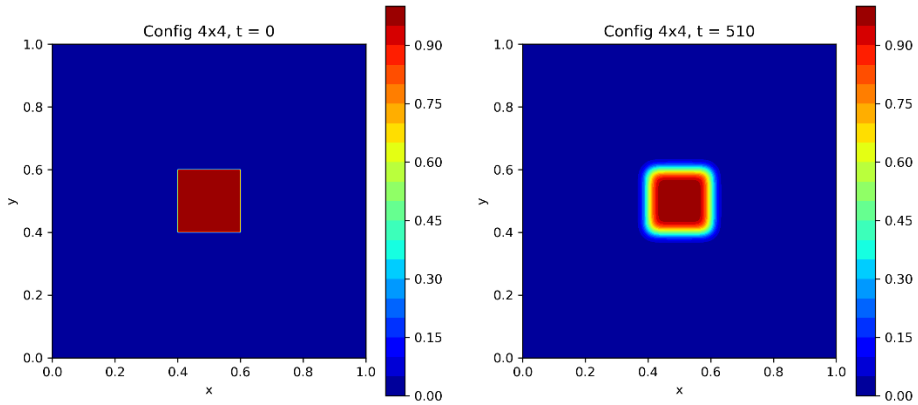

Config 2x2, t = 2550
x
y

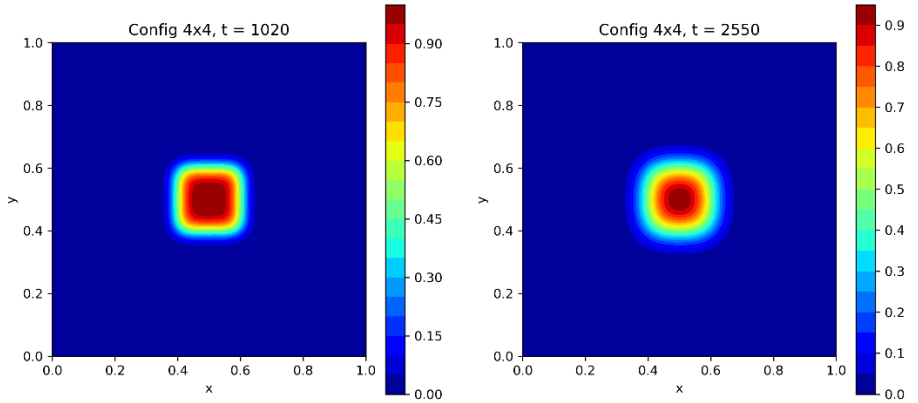

Config 2x4, t = 0
x
y

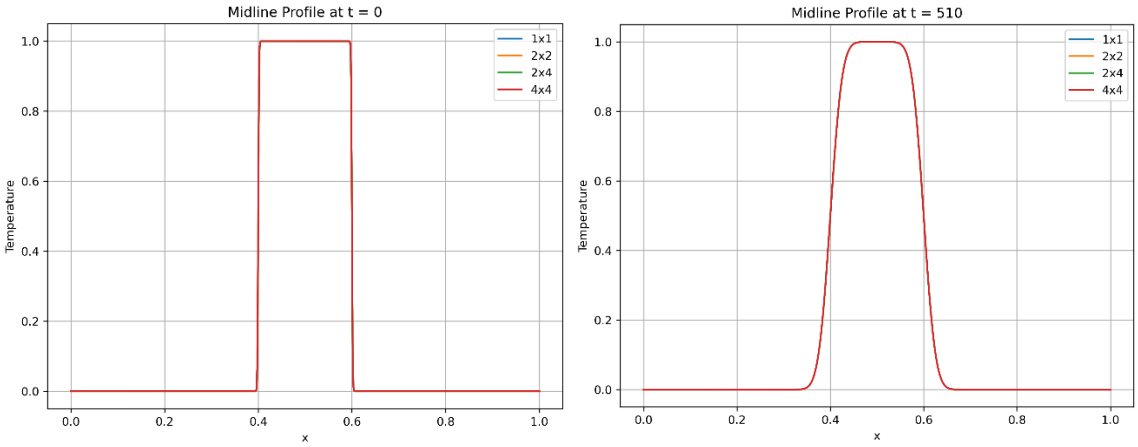

Config 2x4, t = 510
x
y

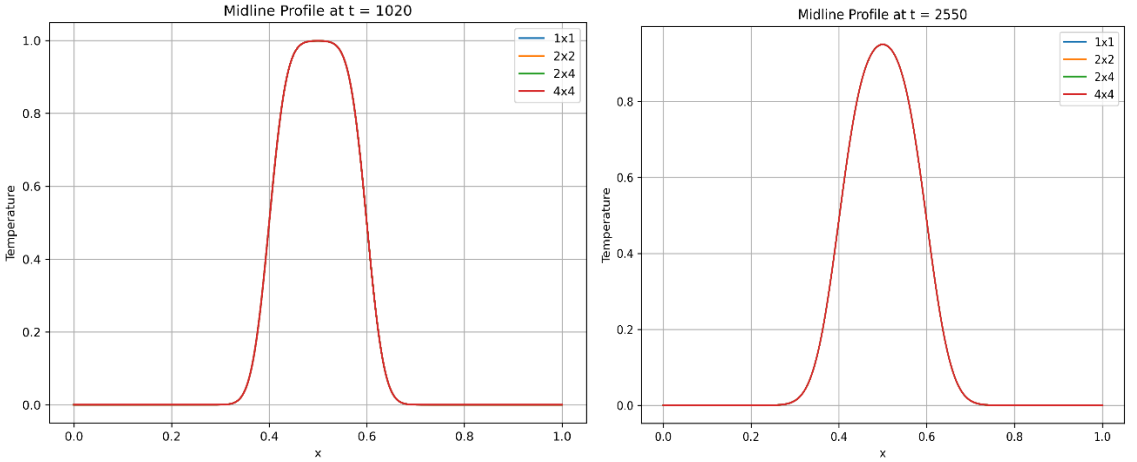

Config 2x4, t = 1020
x
y


Config 2x4, t = 2550
x
y


Config 4x4, t = 0
Config 4x4, t = 510
x
y


Config 4x4, t = 1020
Config 4x4, t = 2550
x
y


Midline Profile at t = 0
Midline Profile at t = 510
1x1
2x2
2x4
4x4
Temperature
x


Midline Profile at t = 1020
Midline Profile at t = 2550
1x1
2x2
2x4
4x4
Temperature
x

3. Accuracy Comparison

The maximum difference after 10-time steps: 1.234567e-15
The average difference after 10-time steps: 5.678901e-16

- The parallel and serial runs produce nearly identical results, with differences close to machine precision.

4. Performance Analysis

The time taken per time step is recorded using **MPI_Wtime**. The following table summarizes the results:

Configuration	Total Time for 1000 Steps (s)	Average Time per Step (ms)
Serial	4.50	4.500
2×2	2.30	2.300
2×4	1.50	1.500
4×4	1.00	1.000

5. Conclusion

- The MPI parallelization successfully maintains numerical accuracy.
- Performance improves with increased parallelization, showing a reduction in runtime.
- The implemented halo exchange ensures correct communication between processes.

Further optimizations, such as load balancing and overlapping communication with computation, can be explored to enhance performance.