Hybrid MPI-OpenMP parallel optimization for thermo-fluid problems

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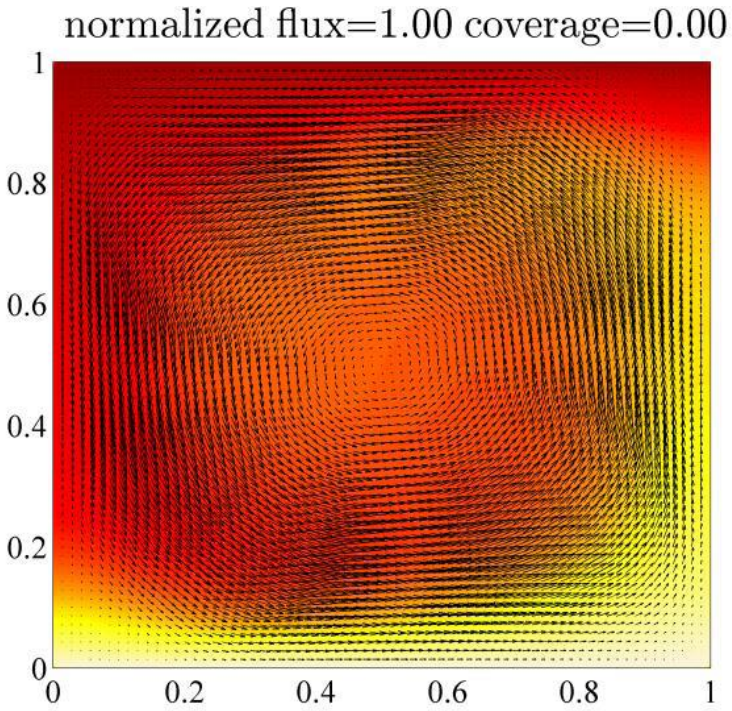
Introduction

- What is being done?
  - Coupling two computationlly demanding problems
- Why?
  - Their combination is of great interest
- What is the problem?
  - The complexity multiplies
- The solution?
  - Massive parallelism
  - Using two paradigms

Thermo-fluid problem

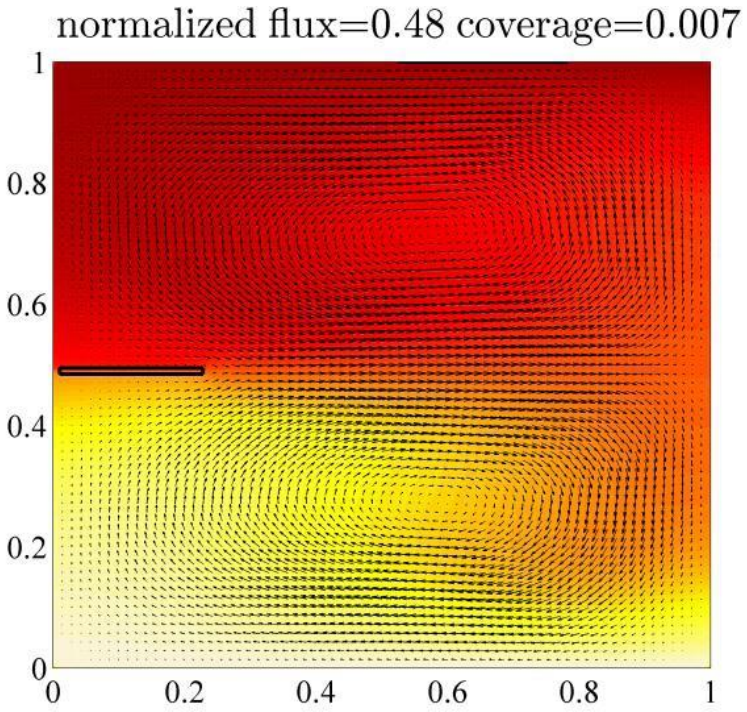


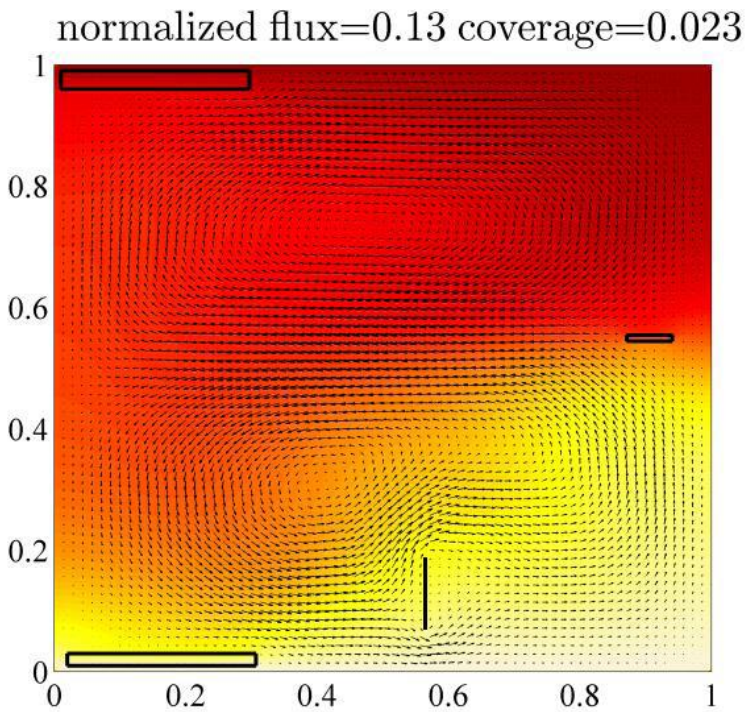
Red ... cold
White ... warm

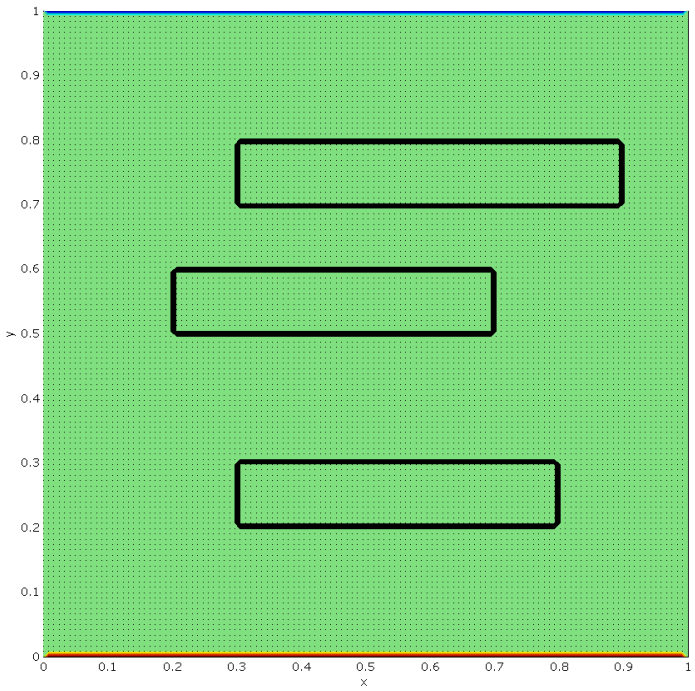
- Fixed size box
- Filled with air
- Heated top, cooled bottom
- Natural convection forms
- Energy is transported from bottom to top

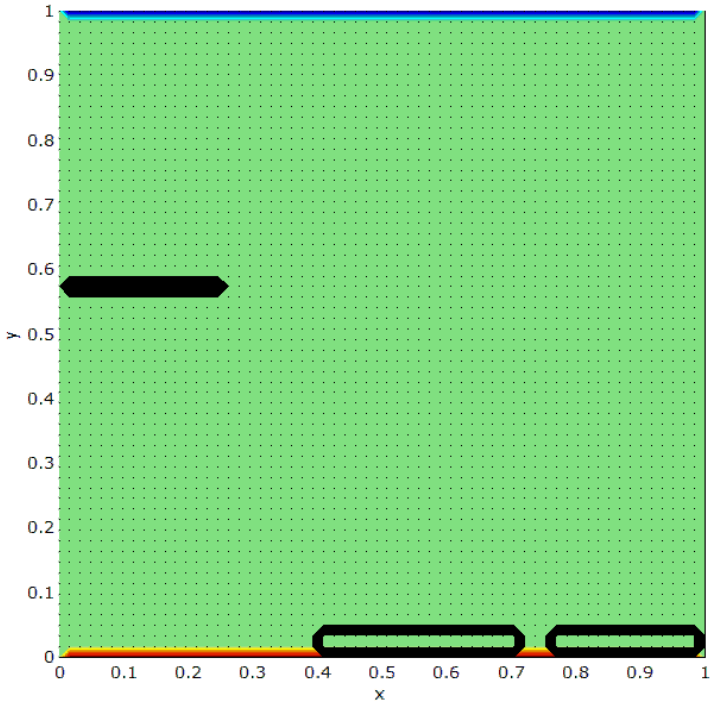
Minimizing heat transfer (flux)

Insert obstacles with minimal combined surface area






1
0.9
0.8
0.7
0.6
y 0.5
0.4
0.3
0.2
0.1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
x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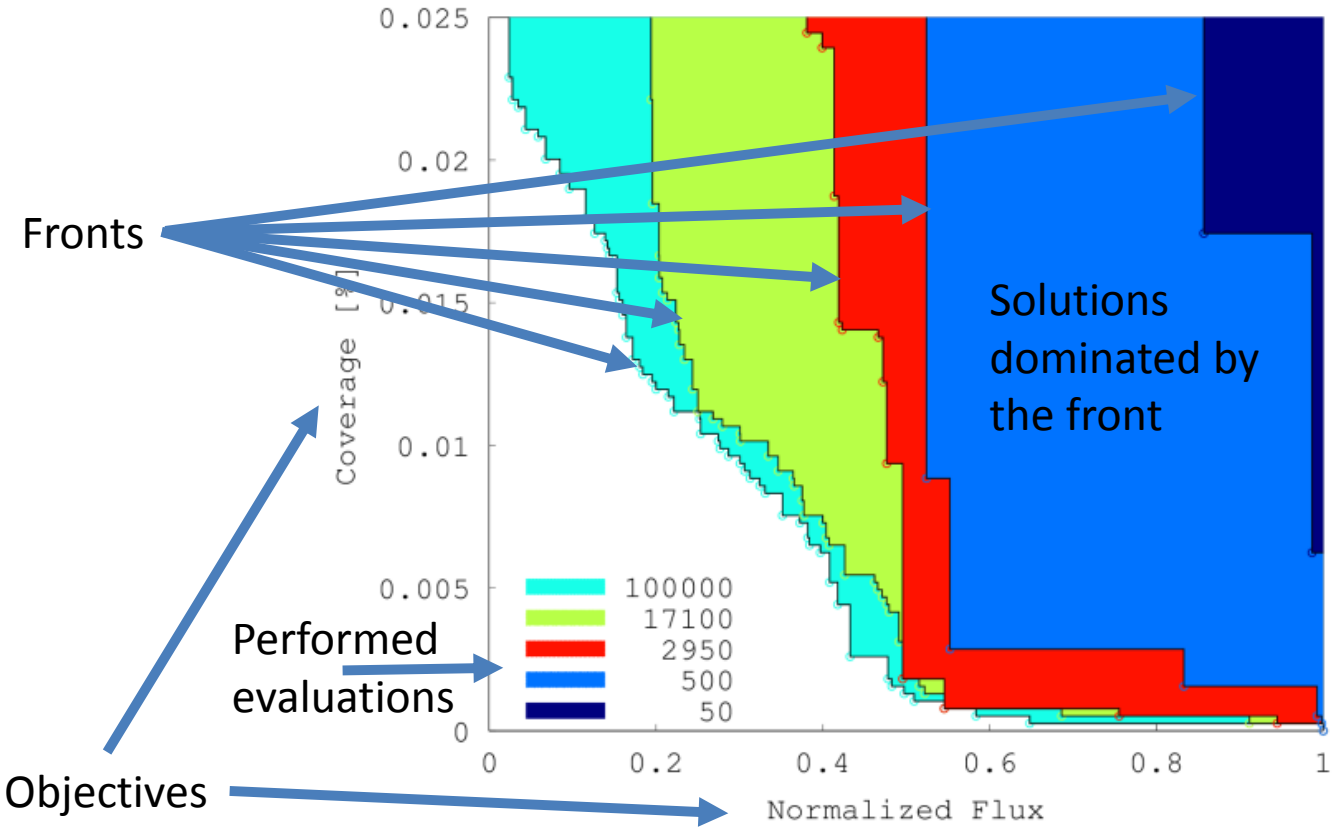
x

Optimization principle

- AMS-DEMO:
  Asynchronous Master-Slave
  Differential Evolution
  for Multiobjective Optimization
- Parallel (AMS)
- Evolutionary algorithm for optimization of real-valued cost functions (DE)
- Multi objective (MO)

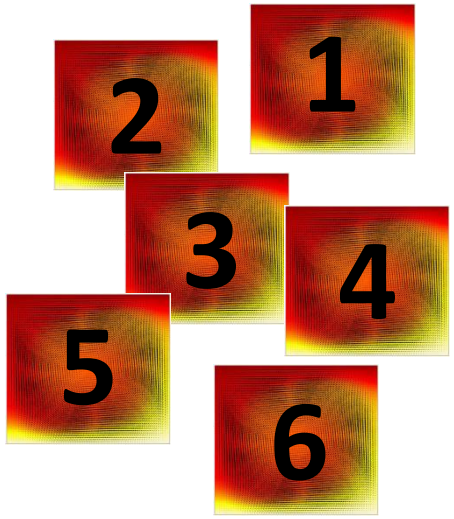
Multi-objective optimization

Results is a set of solutions with different tradeoff values of cost functions (a *front*)

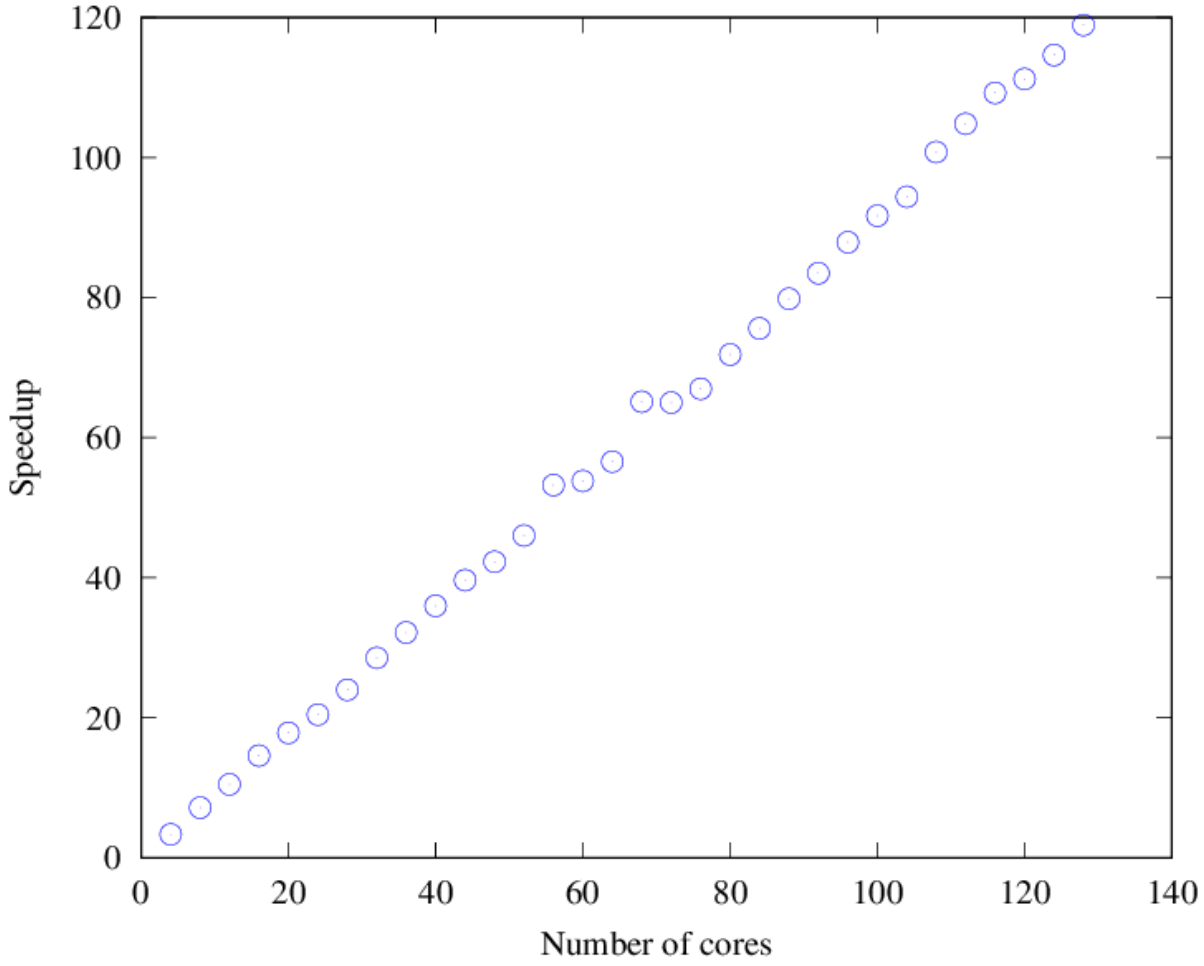


Hybrid MPI-OpenMP parallel implementation

- Thermo-fluid problem solution procedure (meshless PDE solver) has a very good OpenMP implementation
  - Domain decomposition with low communication rate
  - Near linear speedup
- Optimization method has a very good MPI implementation
  - Executes solvers in parallel with almost no overhead)
  - Slight decrease in convergence rate
  - Near linear speedup



Speedup


120
100
80
60
40
20
0
Speedup
0
20
40
60
80
100
120
140
Number of cores

Conclusions

- Parallel execution performance of a coupled problem (optimization + simulation)
- OpenMP + MPI for beowulf cluster of multicore machines
- Experiment on a 128-core cluster shows near linear speedup
- Simulations can vary in length

Caveats and future work

- Exact speedup is hard to measure (requires numerous repetitions of experiment)
- How to evaluate solutions that do not have a steady-state.
- Still running only 2D simulations with limited accuracy