Parallel algorithms at ENS Lyon

Yves Robert
Ecole Normale Supérieure de Lyon
& Institut Universitaire de France

TCPP Workshop
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Outline

1. Scope

2. Course Topics
Follow-on of classic CLRS-based algorithm
Objective: Apprehend the complexity of parallel algorithms
Focus is on models and algorithms
Provides a sound basis for parallel programming
Not a HPC course
Organization

- 16 weeks
- Each week = 2h class
  - + 2h supervised exercises (or programming sessions)
- MPI project
- Midterm and final exam
Outline

1 Scope

2 Course Topics
Models (4 weeks)

- Sorting networks
  - Odd-even merge sort, 0-1 principle
  - Odd-even transposition sort
  - Odd-even sorting on a 1D network (work optimal)

- PRAM
  - Models (EREW, CREW, CRCW)
  - Pointer jumping (list ranking, prefix, Euler tour)
  - Performance evaluation
    - Cost, work, speedup and efficiency, Brent’s theorem
  - Comparison of PRAM models
    - Model separation, simulation theorem
  - Sorting machine
    - Merge, sorting trees, complexity and correctness
  - Relevance of the PRAM model
Networking (3 weeks)

- Interconnection networks
  - Static and dynamic topologies

- Communication models
  - Point-to-point communication protocols

- Case study: the unidirectional ring
  - Broadcast, scatter, all-to-all, pipelined broadcast

- Case study: the hypercube
  - Labeling vertices, paths and routing
  - Embedding rings and grids
  - Collective communications

- Peer-to-peer computing
  - Distributed hash tables and structured overlay networks
  - Chord, Plaxton’s routing algorithm
  - Multi-casting in a distributed hash table
Algorithms on a processor ring (2 weeks)

- Matrix-vector multiplication
- Matrix-matrix multiplication
- First look at stencil applications
- LU factorization
  ⇒ Basic version, pipelining on the ring, look-ahead algorithm
- Second look at stencil applications
  ⇒ Granularity, overlap, mapping, dependencies
- Implementing logical topologies
- Distributed vs. centralized implementations
- Summary of algorithmic principles
Processor grids and load balancing (3 weeks)

- Logical 2-D grid topologies
- Matrix multiplication on processor grids
  - Outer-product algorithm
  - Grid vs. ring?
  - Three matrix multiplication algorithms
- 2-D block cyclic data distribution
- Load balancing for heterogeneous platforms
  - Load balancing for 1-D data distributions
    ⇒ Static vs. incremental allocation algorithm
    ⇒ Application to stencils and LU factorization
  - Load balancing for 2-D data distributions
  - Matrix multiplication on a heterogeneous grid
  - Hardness of the 2-D data partitioning problem
Scope

Scheduling and loop parallelization (4 weeks)

- Where do task graphs come from?
- Solving Pb(∞)
- Solving Pb(p)
  - NP-completeness of Pb(p), list schedules, Graham’s bound and critical paths
  - Approximation algorithms for independent tasks
- Taking Communication Costs Into Account
  - NP-completeness of Pb(∞), guaranteed heuristics
  - List heuristics for Pb(p)
  - HEFT (extension to heterogeneous platforms)
- Scheduling at Compile-Time
  - Dependence levels and Kennedy-Allen algorithm
  - Dependence vectors and Lamport’s hyperplane method
  - Uniform loop nests and unimodular space-time transformations

Yves.Robert@ens-lyon.fr February 2010