Design of Parallel and High Performance Computing

Fall 2016

About projects

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Project: Rules

- **Count 50% of the grade (work, presentation, report)**
- **Teams of three**
  - Important: organize yourselves
  - You may use the mailinglist
- **Topic: Some suggestions in a minute**
- **Timeline:**
  - Oct 13th: Announce project teams to TAs
  - Oct 20th: Present your project in recitations
  - Nov 7th: Initial progress presentations during class
  - Last class (Dec 19th): Final project presentations
- **Report:**
  - 6 pages, template provided on webpage, due January

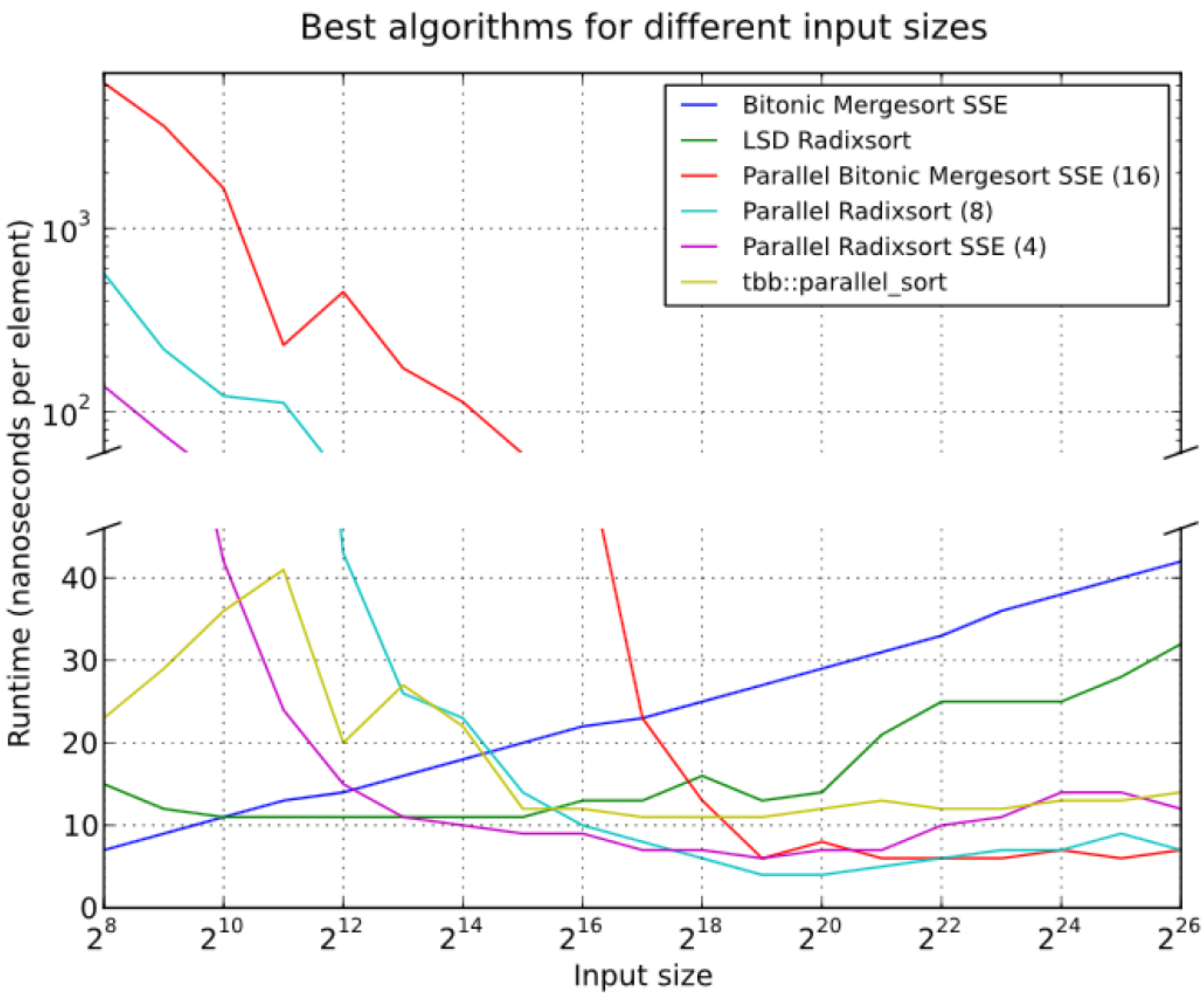
Projects: Performance Optimization

- **Pick an important algorithm/application**
- **Develop a parallel implementation that scales well on multicore**
- **Includes thorough benchmarking and experimental evaluation**

- **Requirements:**
  - No numerical algorithm (dominated by floating point operations)

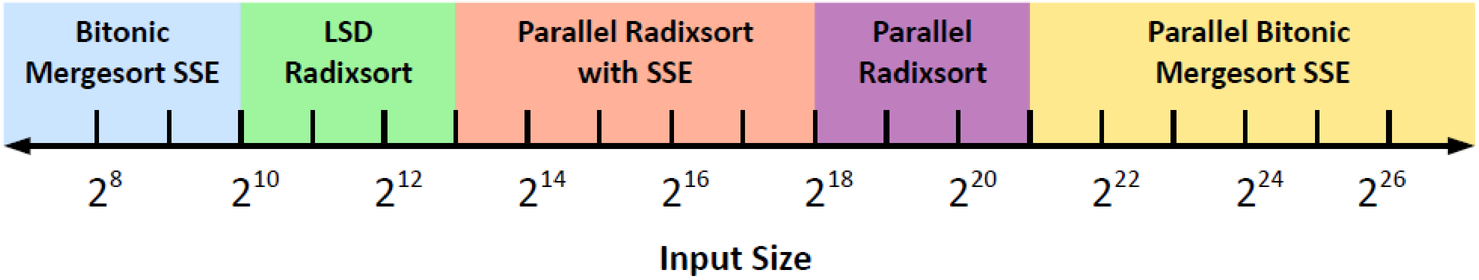
    Exceptions possible if directly related to student's research
  - Not sorting or anything that is mainly sorting

Example From Before



Example From Before

- Uses our fastest implementations depending on input size and adapts #threads accordingly



Project Proposal Ideas

Parallel Priority Queue (I)

- Maintain a collection of data items, identified by a key. Finding the k smallest items (with the k smallest keys) should be supported in O(k) time. Finding any item by key should also be supported.

Required Operations

- queue_t init()
- void insert(queue_t q, void* data, uint64_t key)
- void*find(queue_t q, uint64_t key)
- void delete(queue_t q, uint64_t key)
- void*pop_front(queue_t q, int k) // returns k smallest elements
- void finalize(queue_t q)

Parallel Priority Queue (II)

- **Requirements contd.**
  - Multiple threads will be accessing the queue simultaneously (with all operations)
  - Code may be written in C/C++ (gcc inline assembly is allowed ;-))
- **Tips:**
  - Experiment with different locking strategies and compare the performance
  - Pay attention to larger number of threads
  - Maybe try MPI-3 One Sided

Collective Communications

- **Assume P threads in shared memory**
- **Each thread p has:**
  - a set of input elements $i_{j,p}$ $(0 \leq j < n-1)$
  - a set of output elements $o_{j,p}$ $(0 \leq j < n-1)$
- **The post-condition (result) is:**
  - $o_{j,p} = \sum_{p=1}^{P} i_{j,p} (0 \leq j < n)$
  - i.e., all $o_{j,p}$ are identical on all p
- **Tips:**
  - Use the memory hierarchy and CC protocols (inline assembly is allowed!)
  - First optimize small n, then large n

Parallel BFS

- **Generate an ER graph G(n,p) given n and p**
- **Perform a breath first search from n/2 vertices**
  - Print the average maximum distance for any vertex
- **Your implementation should exploit all available cores and perform the BFS as fast as possible**

Parallel Graph Algorithms

- **Many more!**
  - Connected Components (CC)
  - SSSP
  - APSP (maybe too simple, looks like MatVec)
  - Minimum spanning tree (MST)
  - Vertex coloring
  - Strongly connected components
  - … pick one and enjoy!
- **Others**
  - A* search
  - Various ML and AI algorithms (only nontrivial ones)

Mind the Lecture!!!

- **Try to relate your project to the contents of the lecture!**
  - E.g., analyze sequential consistency (was very successful!)
  - E.g., deal with memory models!
  - E.g., write litmus tests for Xeon Phi (would be very cool)
  - Analyze overheads of atomic operations on Xeon Phi in detail
  - Maybe even write a checking tool?
  - Many many more (be creative!)
  - Or talk to the TAs/Assistants

- **Remember: you have until the end of October**
  - You can also check the slides from last year for later lecture topics
  - This is of course all up to you

Schedule

- **Some recitations will be used to demonstrate concepts in practice**
  - E.g., OpenMP basics, MPI basics, …
- **We will discuss “how to measure and report performance”**
  - This is a complex topic often done wrong