Design of Parallel and High-Performance Computing

Fall 2019

Lecture: Organization

Instructor: Tal Ben-Nun & Markus Püschel

TA: Timo Schneider

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Course Name

- **Design of Parallel and High-Performance Computing**
- **Design of Parallel and High-Performance Computing Platforms?**
- **Design of Parallel and High-Performance Computing Applications?**
- **Design of Parallel and High-Performance Computing Systems?**

- **Design of Parallel and High-Performance Computing:**
  Understand principal issues involved in software and system development for parallel computing

The Team

- **Professors: Tal Ben-Nun & Markus Püschel**
- **TA: Timo Schneider**
  & Others

- **Guest lecturer: maybe**
- **Possibly consultants for projects**

- **Course website: http://spcl.inf.ethz.ch/Teaching/2019-dphpc/**

Administrative

- **Lecture: Mo 13:15 – 16:00**
- **Recitation: Do 13:15 – 15:00**
  - Takes place as announced on website
  - Sometimes used as lecture or swapped with lecture
  - Room was changed to CHN C 14
- **Help:**
  - Email Timo: timo.schneider@inf.ethz.ch

Administrative

- **Website: http://spcl.inf.ethz.ch/Teaching/2019-dphpc/**
- **Will contain all material (slides, homeworks, schedule, etc.)**
- **Mailing list: https://spcl.inf.ethz.ch/cgi-bin/mailman/listinfo/dphpc-2019**

- **Background material:**
  - Maurice Herlihy and Nir Shavit: The Art of Multiprocessor Programming. Morgan Kaufmann, 2012
  - Papers as mentioned

Work and Grading

- **Work during semester:**
  - Regular homeworks
  - Project
- **Grade:**
  - 50% Project
  - 50% Written exam (120 minutes, in exam period as usual)

Project: Rules

- **Each project is done in teams of four.**
- **You can use the mailing-list *dphpc-forum-2019* (everybody is subscribed inititally) to find project partners, offer a project etc.**
- **Once you have a team (even without project) email the TA and we will take you off the list**
- **Ideas for projects: see below. Projects have to be approved by the TAs/lecturers (see next slide)**
- **We will track progress during the semester**

Project: Timeline

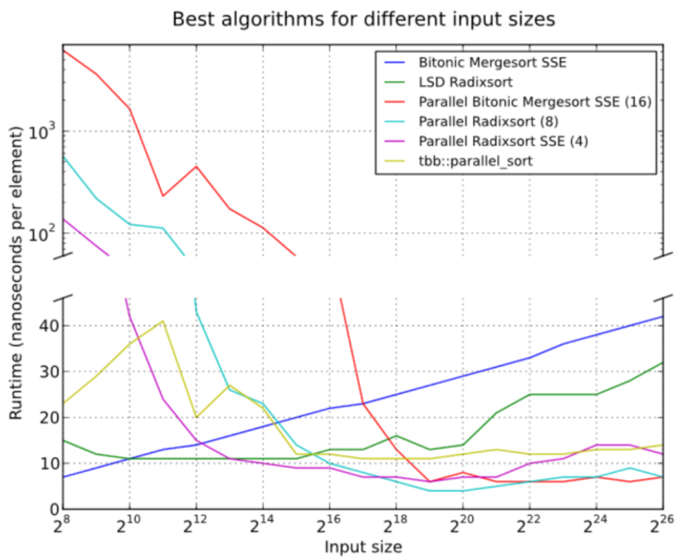
- **Before October 11:** Find team (let TA know names). Find project. If you have a suggestion send email with topic and rough plan and references to TAs and lecturer for approval. Note that this may take more than one iteration.
- **October 11:** You have a team and an approved project.
- **During semester:** We will check progress in some way. Procedure and possible dates to come.
- **End of semester:** Project presentations during lecture/recitation hours.
- **January 17:** Project reports due (6 pages, conference style, information on web).

Projects: Performance Optimization

- **Pick an important algorithm/application**
- **Develop a parallel implementation that scales well on multicore**
- **Includes thorough benchmarking and experimental evaluation**
- **You are in charge of the project: *shrink or expand as necessary!***

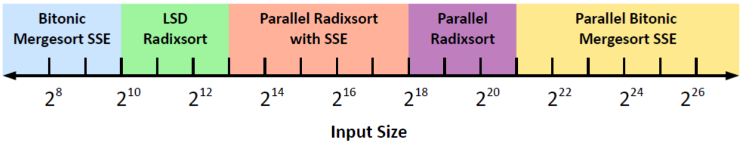
- **Requirements:**
  - No numerical algorithm (dominated by floating point operations)
    Exceptions possible if directly related to student's research
  - Not sorting or anything that is mainly sorting

Example From Before



Example From Before

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



Project Ideas

Parallel Data Structure: Example Priority Queue

- **Modified specification:** 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 continued**
  - 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≤j<n-1)
  - a set of output elements $o_{j,p}$ (0≤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 Algorithms: Example BFS

- **Generate an Erdős–Rényi graph G(n,p) given n and p**
- **Perform a breadth-first search (BFS) 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)
  - Single-source shortest path (SSSP)
  - All-pairs-shortest path (APSP) - 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)
- ***Always implement infrastructure to validate your code!***

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!
  - Reason about the performance obtained
  - Many more (be creative!)
  - Or talk to TA
- **Remember: you have until the October 11th**
  - You can also check the slides from last year for later lecture topics
  - This is of course all up to you