ECE 574 – Cluster Computing Lecture 1

Vince Weaver

https://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

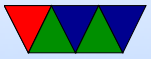
11am, Barrows 133

16 January 2024

ECE574

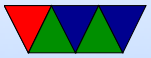
- Distribute and go over syllabus

  https://web.eece.maine.edu/~vweaver/classes/ece574/ece574_2024s.pdf



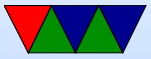
ECE574 Syllabus – Office Hours

- Office is 203 Barrows
- Office hours tentatively 11am-noon Monday/Wednesday, open door



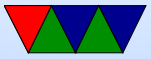
ECE574 Syllabus – Textbook

- None



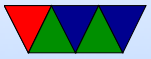
ECE574 Syllabus – Computer Accounts / Programming

- Will be handing out computer accounts, please use them responsibly.
- Will involve a lot of coding, mostly C or C-like languages.



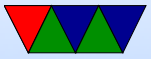
ECE574 Grading – Homeworks

- Homeworks, 50% – roughly 10, lowest dropped.
- Generally will be due on Thursday by beginning of class.
- Will usually have at least a week to do them.
- Submission by e-mail, grades sent in response to that e-mail
- Will send out e-mail when assignment posted on website.



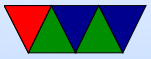
ECE574 Grading – Exams

- Two Midterms, totaling 25%, around spring break and near end
- No final exam



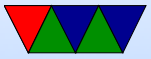
ECE574 Grading – Final Project

- Project, 20%
- HPC related project, open-ended
- Can program in any language
- Can work in groups
- Presentation during last week of classes
- Final writeup
- More details as we get closer.



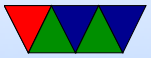
ECE574 Grading – Late Work

- Class participation: 5%
- Work will lose points for being late, but please turn in anyway, especially homeworks.
- Class notes will be posted on the website.



ECE574 — Other

- Covid Policy – if really sick, please don't come to class if slightly sick, wear a mask if possible
- Code Help – if you have questions often the most efficient way is to send me your code to look at via e-mail
- Academic Honesty – for coding assignments please only submit code you wrote yourself
- Standard UMaine boilerplate

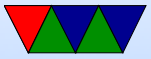


Cluster Computing

What is cluster computing?

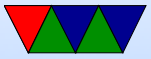
Basically it's just a large number of computers working together.

So why is that interesting?



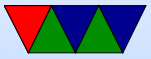
Road to Parallelism – Serial

- Originally computers were serial, did one thing at a time (though could hide this via multi-tasking)
- Moore's Law meant performance would increase
- At some point limit hit for serial execution, so much effort went into trying to find parallelism in code automatically in hardware (pipelining, out-of-order execution, superscalar)



Road to Parallelism – SMP

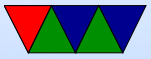
- Moore's Law continued, but serial speedup trailed off (Memory Wall a big issue) Instead transistors used for multiple-cores in system. Suddenly parallelism was everyone's problem
- If even a system with many cores doesn't give enough performance, that's when you move to clusters



Supercomputers/HPC

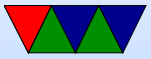
InsideHPC defines HPC: "High Performance Computing most generally refers to the practice of aggregating computing power in a way that delivers much higher performance than one could get out of a typical desktop computer or workstation in order to solve large problems in science, engineering, or business."

And a supercomputer is similarly vague, just a larger computer than the kind you'd normally use.



Related terms

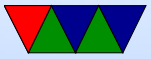
- Supercomputer – a large computer. No real definition, "I know one if I see one".
- High Performance Computing – using large computers
- Cluster – one way to make a large computer out of many small computers
- Grid computing – idea to make computing like the power grid, a utility you access to run your jobs. A large loosely coupled cluster.



- Cloud computing – more or less a newer and more buzzword-friendly term for grid computing. Often uses virtualization, not often used for high performance mostly because usually the network is not optimized in a cluster fashion.

- Datacenter – a large building with lots of network connected computers. Not a cluster unless they are working together. This gets complicated when things like google are involved.

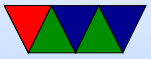
- Mainframe – a type of large computer. Usually



differentiated from a supercomputer because a mainframe concentrates on reliability and I/O performance rather than CPU performance.

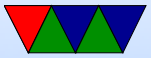
- Distributed systems – a system that is made out of many subnodes that communicate by passing messages to work on large problems. Sort of the old CS term for cluster computing.

- Parallel computing



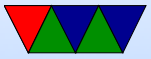
Cluster Definitions?

- Bunch of computers hooked together.
- Commodity Cluster – a large number of off-the-shelf machines hooked up via cheap off-the-shelf network (usually Ethernet)
- as opposed to a custom cluster that will be custom hardware and custom fast network.



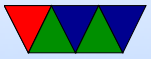
Parallel Programming

- It's hard
- It's really hard



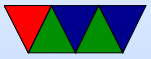
Parallel Programming

- Most systems, even embedded systems and cellphones are parallel these days
- Languages don't support it well
- Human brain has trouble grasping it
- It should probably be taught at a lower level
- Why not have compiler auto-parallelize code? Oh they try, how they try. And the combination of computer arch (OoO) and such wrings out as much as they can. Still not always good enough.



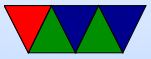
Parallel Programming Languages

- C?
- Fortran?
- C++?
- What about things like Javascript, Python?
  Python widely used but actual parallel stuff in C libraries
  (global lock means until recently Python couldn't scale)
- What about things like Go or Rust or Zig?



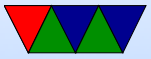
HPC Workloads

- Linear Algebra
- Modeling (weather, chemistry, biology, nuclear, aerospace)
- Business (high-speed trading)
- Simulation
- 3d rendering (movie studios, games)
- Data crunching (geology exploring)
- AI? Bitcoin Mining?



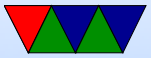
A note on Models

- "It's tough to make predictions, especially about the future." — Yogi Berra
- "All models are wrong, but some are useful" — George E. P. Box
- Wasted lots of time on computer architecture simulations
- GIGO

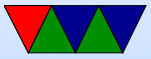


A little history

- 1960s Seymour Cray (interesting guy) CDC6600 (parallel) and 7600 (pipelined) and Cray 1 (vector) 1976.
- 1970s-1980s – clustered minicomputers, DEC, IBM, Tandem
- 1990s SGI = NUMA
- 1994 Beowulf clusters
  - Beowulf was a 1994 NASA project to build a gigaflop for less than $50k.
  - Managed a 16-node 486 cluster for $40k.

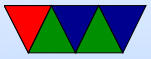


- (comparison – raspberry pi 2 gives you a gigaflop for $35)
- D.J. Becker and T. Sterling and D Savarese and J.E. Dorband and U.A. Ranawak and C.V. Packer "BEOWULF: A parallel workstation for scientific computation"
- Usually cheap headless off-the-shelf computers connected by Ethernet. Commodity cluster.



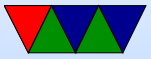
Are all supercomputers clusters?

- Back in early 2000s was much debate
- *High Performance Computing: Crays, Clusters, and Centers. What Next?* by Gordon Bell (DEC/MS) and Jim Gray (MS), 2001. They propose that everything was converging to all clusters, all the time for all supercomputer needs.
- In a fairly strongly worded rebuttal, Dongarra, Sterling, Simon and Strohmaier (*High performance computing: Clusters, constellations, MPPs, and future directions*



(2003)) said that no, the world is more complex than that and commodity clusters are not the end word.

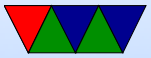
- Currently (2024) the top list is mostly commodity clusters



Supercomputer Features?

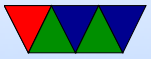
- From Dongarra et al.
- Is it clustered? meaning identical grouped together
  c for commodity, m monolithic
- How is the namespace organized?
  distributed means local variables on one node not visible on other
  d distributed, s shared, c cache coherent

- How is the parallelism?

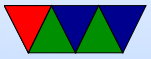


t for multithreading, v for vector, c communicating sequential
s systolic, w for VLIW, h for producer/consumer, p parallel process

- How does it handle latency/locality?
  c caches, v vectors, t multithreaded, m for processor in memory.
  f for prefetching, etc



Top500 List

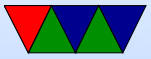


Top500 Historical Categories

Definitions from Dongarra et al.

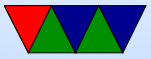
Cluster – system where inter-node communication is 10-1000 times slower than local memory access. (bell and gray)

- single-cpu = just one serial CPU
- simd = single instruction multiple data
- SMP = symmetric multiprocessing, more than one processor
- MPP = massive parallel programming, one machine with



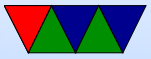
lots and lots of processors (see SGI)

- cluster = number of nodes outnumbers number of CPUs per node (dominant programming style distributed, MPI)
- constellation = each node has more CPUs than total nodes (dominant programming style would be multithread, OpenMP)



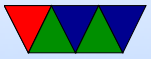
Top500 Historical Makeup

- In 1994, 20% single-cpu, 50% SMP, 24% MPP,7% SIMD
- In 1997, 0% single-cpu, 43% SMP, 0.5% cluster, 54% MPP, 0.5% SIMD
- in 2002, 40% Constellations, 18% cluster, 40% MPP
- in 2015, 90% cluster, 12% MPP



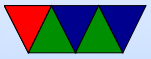
Software Concerns

- One OS image or multiple?
- single/smp/mpp = one image
- cluster = each node has own copy of operating system
- Shared memory (just write to memory and all cores can see it, hard work in hardware) vs Message Passing (have to explicitly send data before others see it, hard work in software)



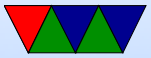
Heterogeneous Computing

- Unequal nodes
- ARM big/little
- clusters with GPUs
- xeon-phi (almost like a cluster on a PCIe card)



Example Top500 Listing

- From the November 2002 list, entry #332
- Location: Orono, ME
- Proc Arch: x86
- Proc Type: Pentium III, 1GHz
- Total cores: 416
- RMax/RPeak: 225/416 GFLOPS
- Power: ???
- Accelerators: None



Homework 1

- A brief homework for next class!
- Look up the info on the computer I sent
- Bring the info to class