TEXAS STATE UNIVERSITY
The rising STAR of Texas

A Gentle Introduction to Heterogeneous Computing for CS1 Students

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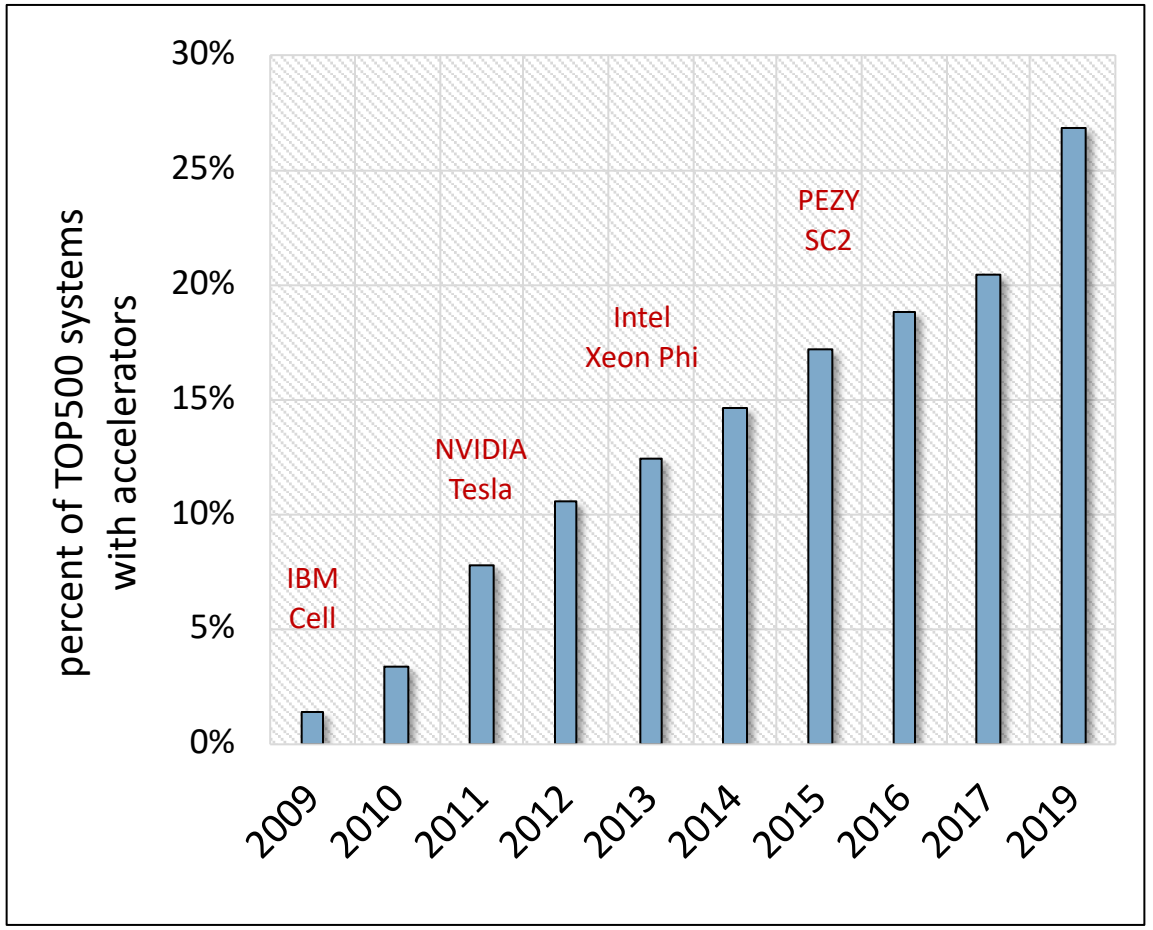
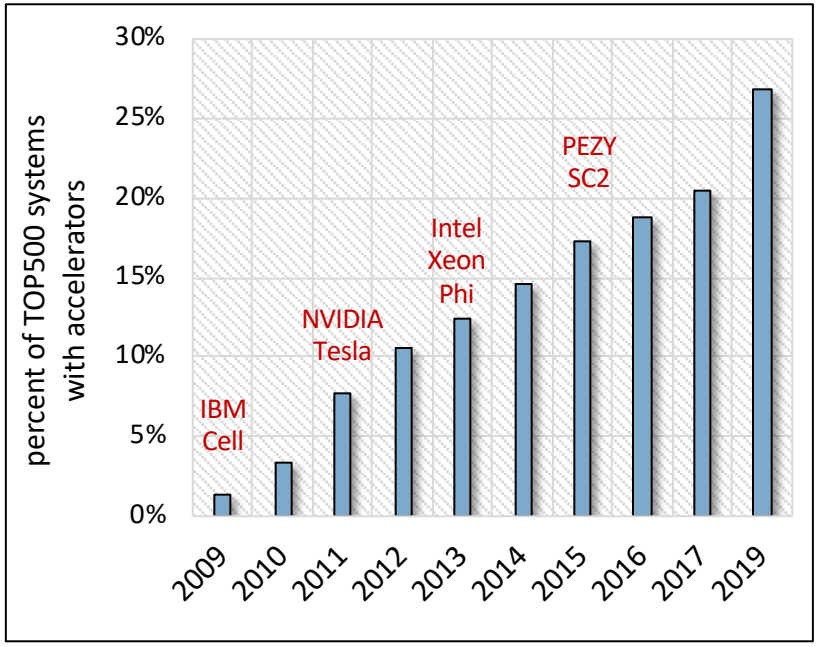
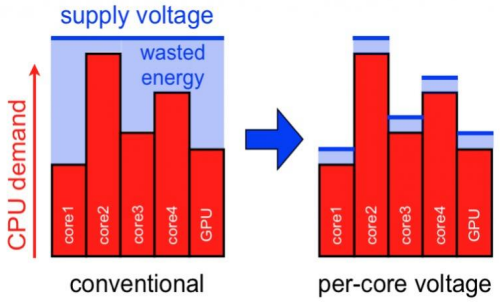
The Rise of Heterogenous Computing

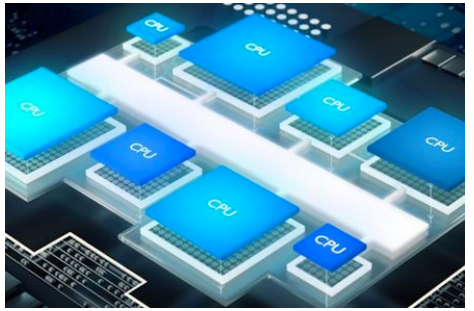


The Rise of Heterogenous Computing

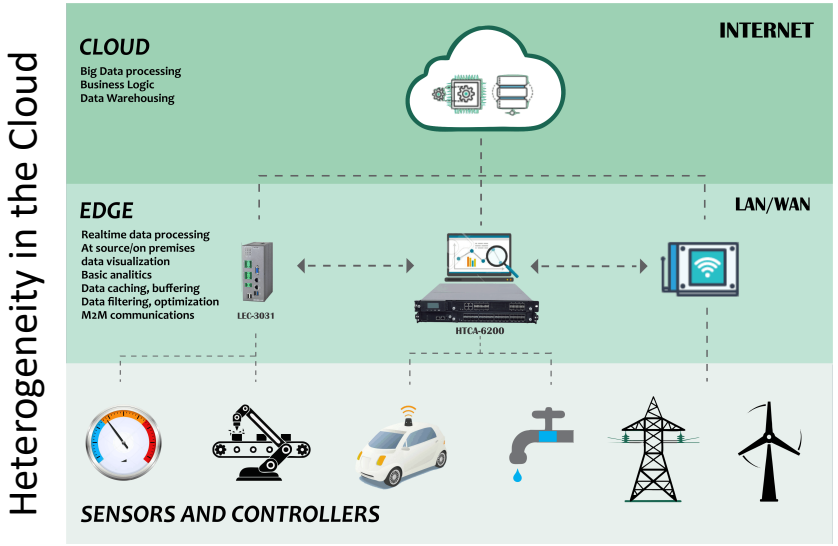


DVFS





Fat and Thin Cores



HC in the Undergraduate Curriculum

The One Vision That Intel, AMD And Nvidia Are All Chasing – Why Heterogeneous Computing Is The Future

The Floodgates are Opening: The Promise of Heterogeneous Computing

Heterogeneous Computing: Here to Stay

Hardware and Software Perspectives

Given current industry trends, it is critically important that CS/CE undergraduates are exposed to heterogeneous computing concepts as a required part of the curriculum

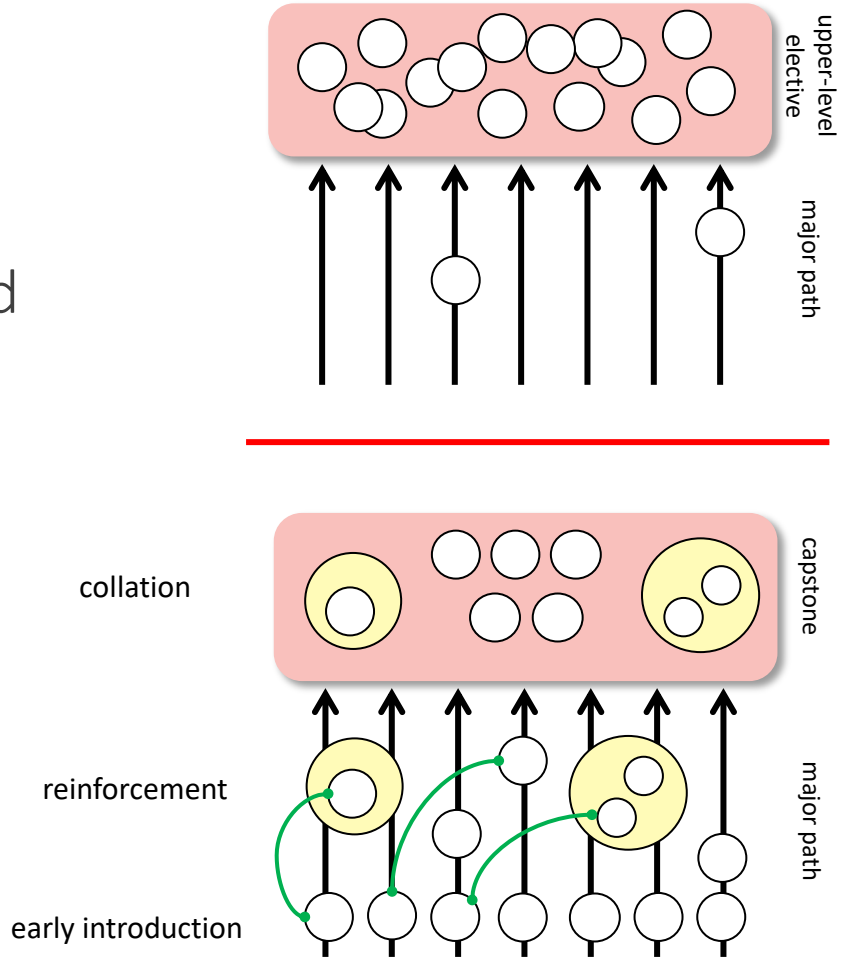
- The ToUCH project was initiated with this goal in mind
- The CS1 module was developed as part of this initiative

Outline

- Motivation
- Design Principles
- Module Description
  - Lecture slides
  - In-class Demo
  - Lab
- Assessment
- Conclusions and Future Work

The Early-and-Often Approach

- Breaks away from the traditional approach of teaching a topic X as an upper-level elective
- Introduce X early in the curriculum in required courses
- Repeat key concepts in different courses throughout the curriculum
- Tie concepts together in an upper-level capstone course



Design Principles

- modules should be classified and introduced based on level of *abstraction*
  - Cover Amdahl's Law in CS1; memory coherence in a senior-level course
- modules should provide heterogeneous *context* to existing content
  - Introduce soft heterogeneity when discussing threads scheduling in OS
- modules should be *self-contained* for easy adoption across different institutions

An HC Module for CS1

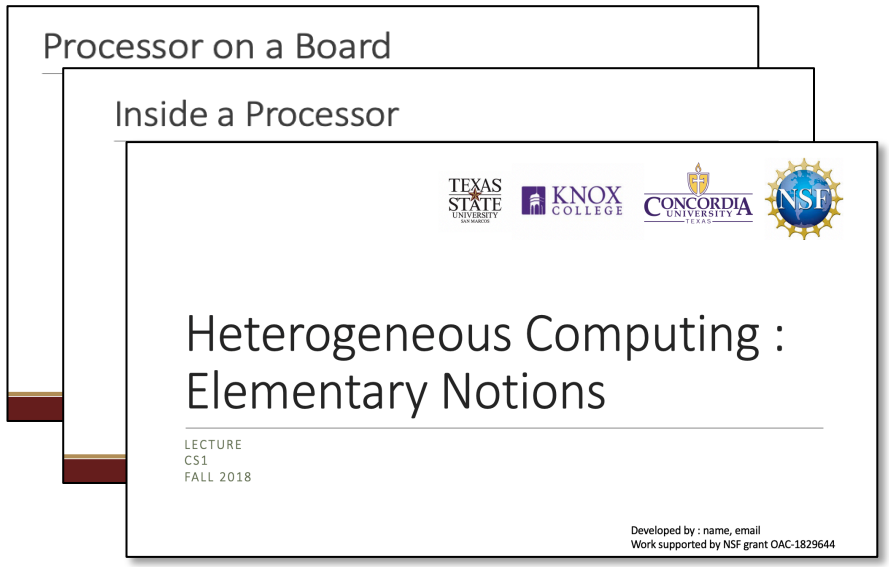
- Content
  - Covers fundamental concepts at a high-level of abstraction
  - No programming, but students are exposed to programming languages and tools
- Context
  - CS1/CS2 students
- Length
  - One hour and twenty minutes lecture + lab
- Pedagogy
  - Emphasis on active learning: in-class demo + lab

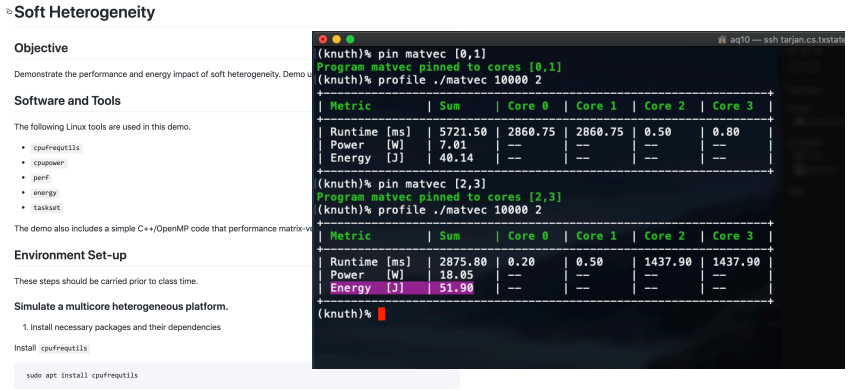
Topics and Learning Outcomes

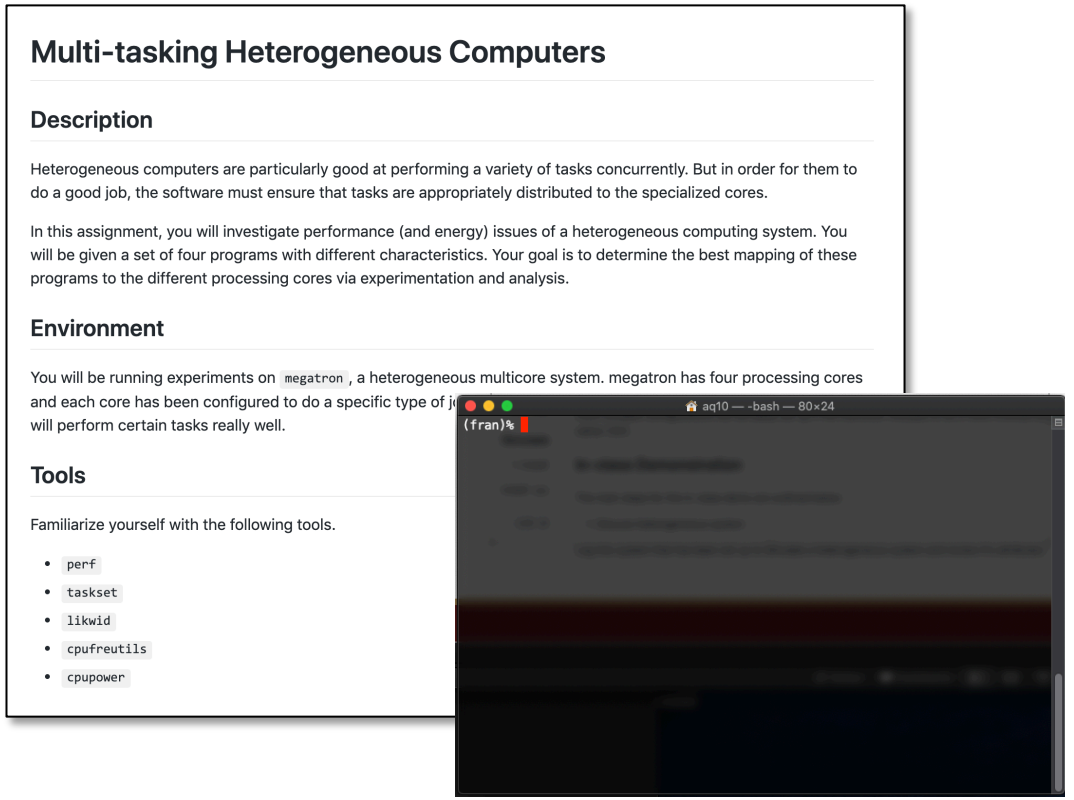
	Topic	Bloom Classification
1	Concurrency and Parallelism	Knowledge
2	Multicore Processors	Knowledge
3	GPGPU	Knowledge
4	System-on-Chip	Knowledge
5	Energy Efficiency	Knowledge
6	Tasks and Workloads	Knowledge
7	Task Mapping and Scheduling	Knowledge
8	Amdahl's Law	Knowledge/Comprehension

- Describe and distinguish between different forms of heterogeneity
- Recognize the importance of energy efficiency on current computing systems
- …

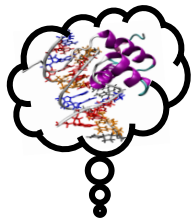
What's included







https://github.com/TeachingUndergradsCHC

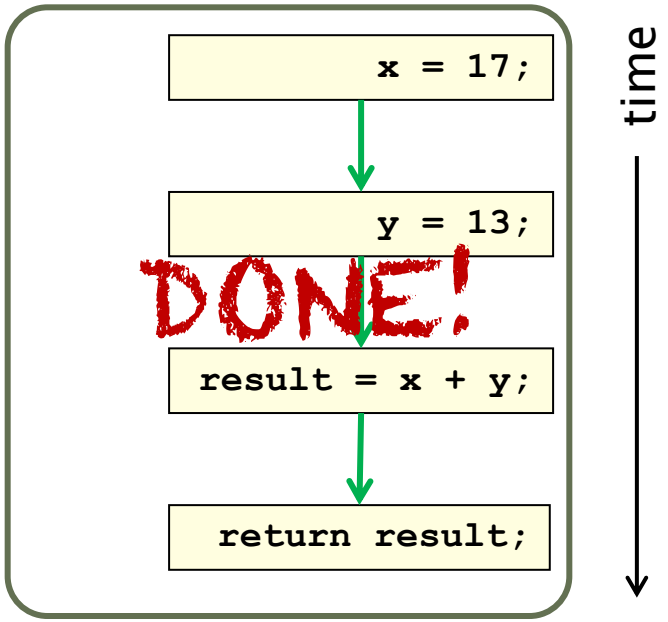


Parallel Program Execution

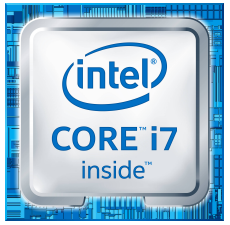
code

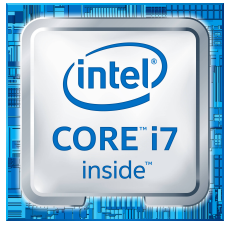
```
int main() {
  int x, y, result;
  x = 17;
  y = 13;
  result = x + y;
  return result;
}
```

compile

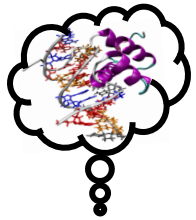


The two assignment statements
x = 17; and y = 13; will execute in parallel





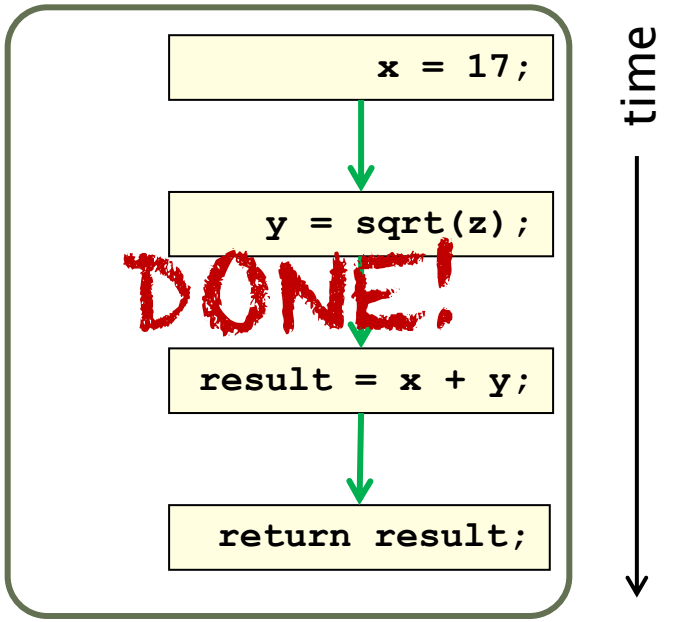
Heterogeneous Program Execution



code

```
int dostuff(int z) {
        int x, y, result;
        x = 17;
        y = sqrt(z);
        result = x + y;
        return result;
}
```

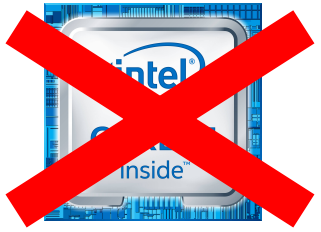
compile

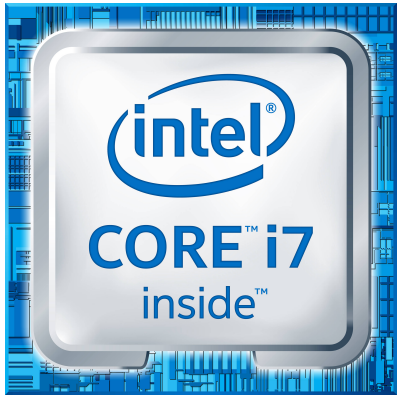


"Big" processor is twice as powerful

Assign heavier computation to the "bigger" processor

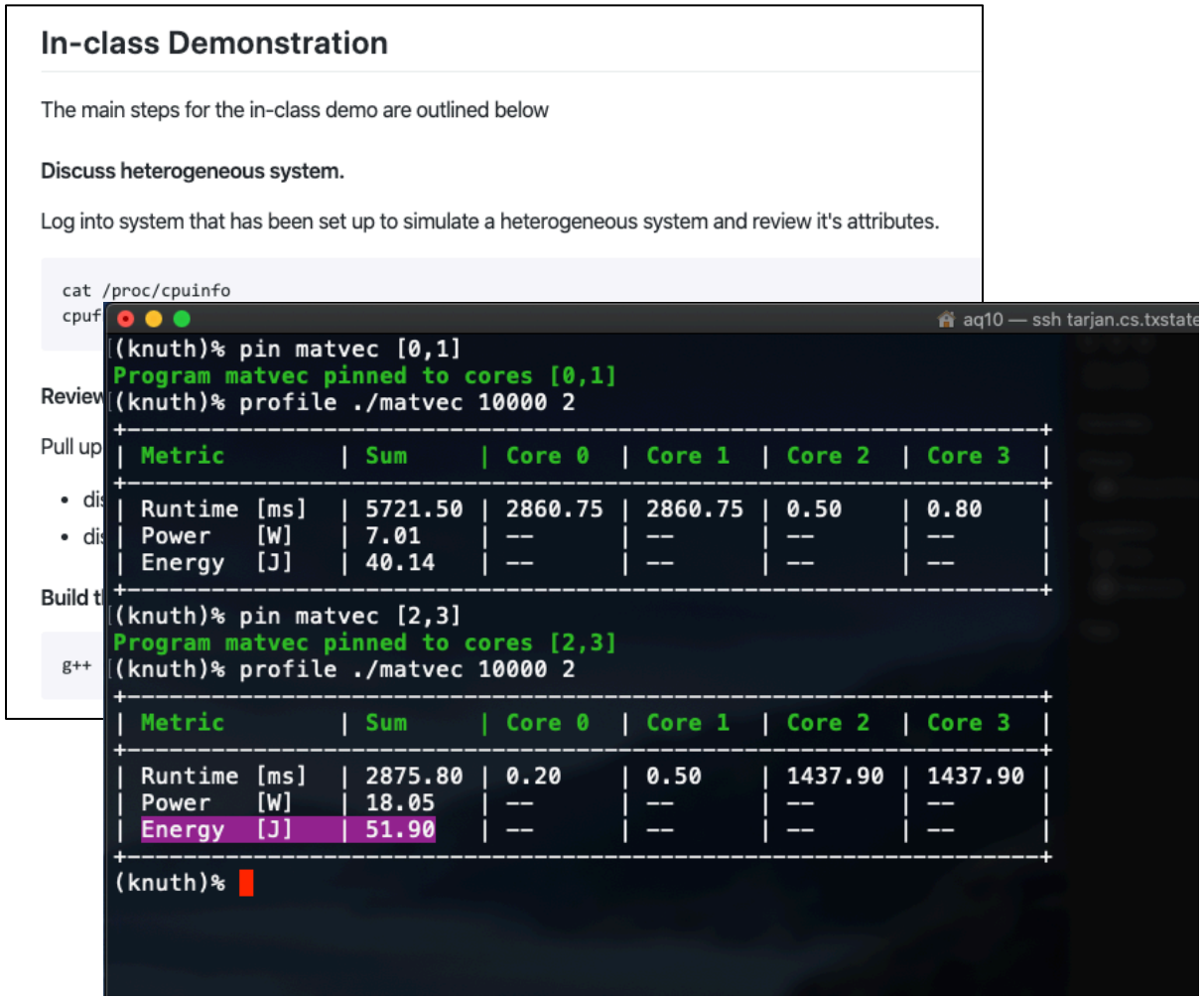
inefficient mapping





Demo: Soft Heterogeneity

- Objective
  - demonstrate performance and energy tradeoff on heterogeneous multicore systems
  - serve as a preview of the lab to follow
- Preparation
  - Set up a multicore system to simulate Big-Little behavior with DVFS tools
  - Install performance and power profiling tools on system
- Main steps
  - Familiarize students with a heterogeneous environment
  - Build and execute *simple* code on Little and Big cores
  - Discuss performance and energy differences



Lab: Multi-tasking Heterogeneous Computers

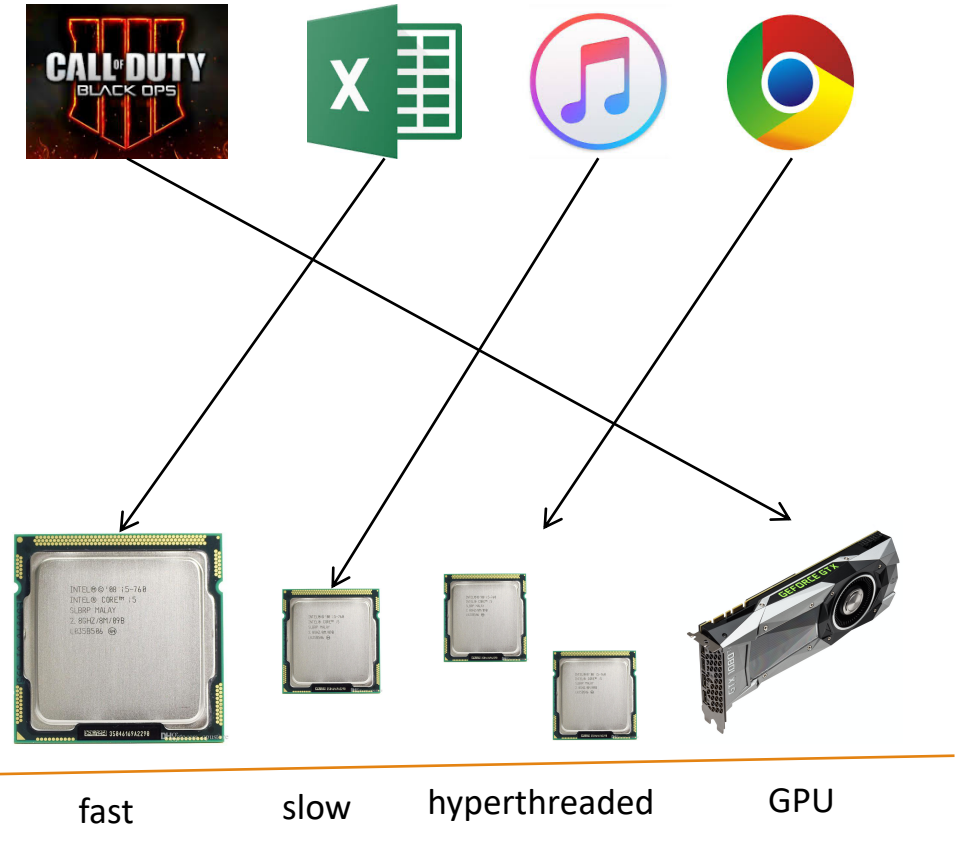
Synthetic workload captures application characteristics such as graphics, floating-point math, multimedia streaming and multithreading

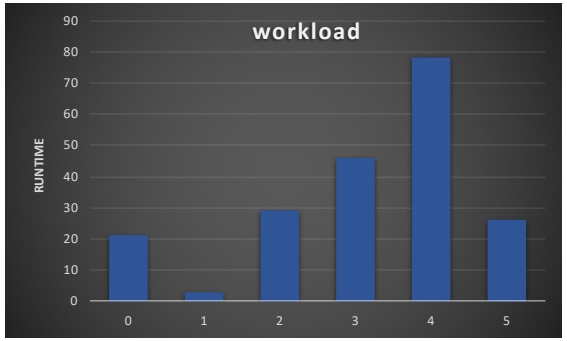
Students conduct experiments and analyze the performance and energy impact of task mapping

Tools used: **`pin`** and **`profile`**
(under the hood: **`perf, likwid, taskset`**)

Simulated multicore heterogeneous server with consist of fast and slow cores; hyperthreaded cores and a GPU

Tools needed **`cpufrequtils`** and **`pin`**

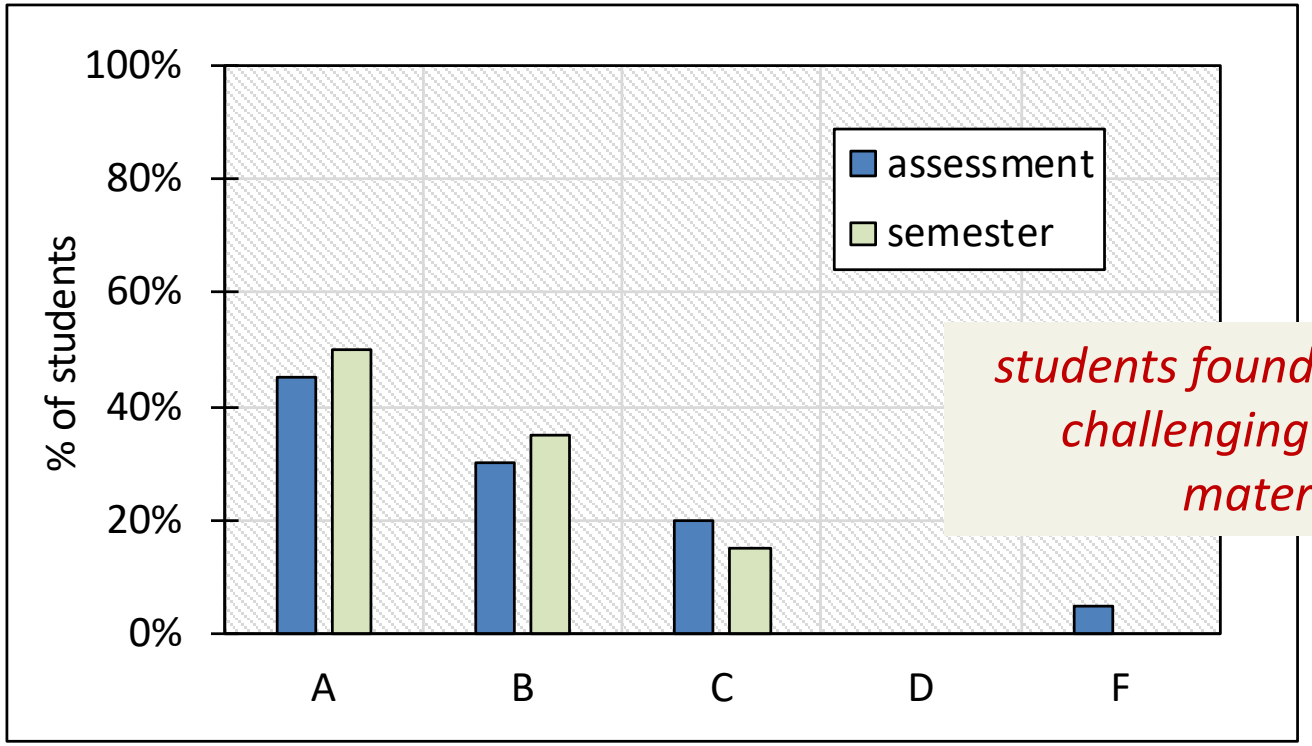




Assessment

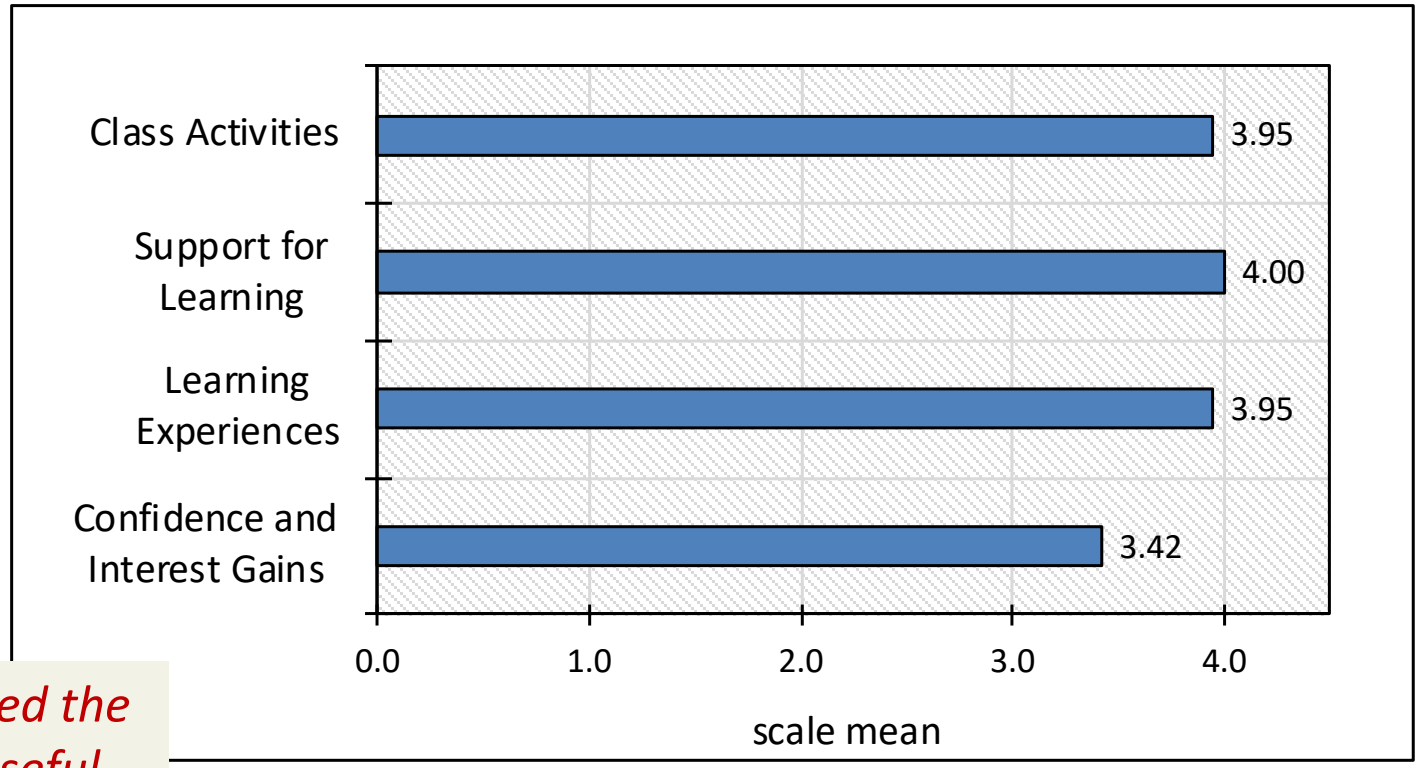
- Module was implemented in a CS1 course at Texas State in Fall 2018
  - class teaches sequential programming in C++
- The class is designated as an Honors section
  - over achievers
  - lower cap
- Learning outcome evaluated via exam questions and the lab
- Student engagement and interest evaluated via SALG survey

Learning Outcome



students found HC topics a little more challenging than the rest of the material in the class

Student Engagement and Interest Gains



students perceived the module to be useful

Conclusions and Future Work

- Preliminary evaluation is promising both in terms of student learning outcome and engagement
  - specifically the hands-on assignment and use of experimental tools
- Material might be too much to cover in a regular CS1 class
- Calibrate content for future installments
- Implement a more structured evaluation plan

Thank you!

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