CSC 3210 COMPUTER ORGANIZATION AND PROGRAMMING

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CHAPTER1 && 2

MULTIPROCESSORS

- Multicore microprocessors
  - More than one processor(core) per chip
- Requires explicitly parallel programming
  - Compare with instruction level parallelism
    - Hardware executes multiple instructions at once
    - Hidden from the programmer
  - Hard to do
    - Programming for performance
    - Load balancing
    - Optimizing communication and synchronization

SPEC CPU BENCHMARK

- **Benchmarks**: Programs used to measure performance
  - Supposedly typical of actual workload
- Standard Performance Evaluation Corp (SPEC)
  - Develops benchmarks for CPU, I/O, Web, …
- SPEC CPU2006
  - Elapsed time to execute a selection of programs
    - Negligible I/O, so focuses on CPU performance
  - Normalize relative to reference machine
  - Summarize as geometric mean of performance ratios
    - CINT2006 (integer) and CFP2006 (floating-point)

    - Geometric Mean = $\sqrt[n]{\prod_{i=1}^{n} \text{Execution time ratio}_i}$

SPEC SPEED 2017 INTEGER BENCHMARKS ON A 1.8 GHZ INTEL XEON E5-2650L

Description	*Name*	*Instruction Count x 10^9*	*CPI*	*Clock cycle time (seconds x 10^–9)*	*Execution Time (seconds)*	*Reference Time (seconds)*	*SPECratio*
Perl interpreter	perlbench	2684	0.42	0.556	627	1774	2.83
GNU C compiler	gcc	2322	0.67	0.556	863	3976	4.61
Route planning	mcf	1786	1.22	0.556	1215	4721	3.89
Discrete Event simulation - computer network	omnetpp	1107	0.82	0.556	507	1630	3.21
XML to HTML conversion via XSLT	xalancbmk	1314	0.75	0.556	549	1417	2.58
Video compression	x264	4488	0.32	0.556	813	1763	2.17
Artificial Intelligence: alpha-beta tree search (Chess)	deepsjeng	2216	0.57	0.556	698	1432	2.05
Artificial Intelligence: Monte Carlo tree search (Go)	leela	2236	0.79	0.556	987	1703	1.73
Artificial Intelligence: recursive solution generator (Sudoku)	exchange2	6683	0.46	0.556	1718	2939	1.71
General data compression	xz	8533	1.32	0.556	6290	6182	0.98
Geometric mean							2.36

SPEC POWER BENCHMARK

- Power consumption of server at different workload levels
  - Performance: ssj_ops/sec
  - Power: Watts (Joules/sec)

$$\text{Overall ssj\_ops per Watt} = \frac{\sum_{i=0}^{10} \text{ssj\_ops}_i}{\sum_{i=0}^{10} \text{power}_i}$$

ssj_ops: the number of operations performed by the system (e.g., transactions or computational tasks) at different performance states
power: Refers to the power consumed (in watts) by the system during each of these performance states.
Summation (Σ): Both the total operations and total power are summed across all performance states (from i=0i = 0i=0 to i=10i = 10i=10).
Division: The total operations are divided by the total power consumption to calculate the performance efficiency (operations per watt).

SPEC POWER_SSJ2008 FOR XEON E5-2650L

Target Load %	Performance (ssj_ops)	Average Power (watts)
100%	4,864,136	347
90%	4,389,196	312
80%	3,905,724	278
70%	3,418,737	241
60%	2,925,811	212
50%	2,439,017	183
40%	1,951,394	160
30%	1,461,411	141
20%	974,045	128
10%	485,973	115
0%	0	48
Overall Sum	26,815,444	2,165
∑ssj_ops / ∑power =		12,385

FALLACIES AND PITFALLS

- The purpose of a section on fallacies and pitfalls, which will be found in every chapter, is to explain some commonly held misconceptions that you might encounter.
- Fallacies: commonly held misconceptions
- Pitfalls: easily made mistakes, often pitfalls are generalizations of principles that are true in a limited context.

ONE EXAMPLE OF PITFALL: AMDAHL'S LAW

- Improving an aspect of a computer and expecting a proportional improvement in overall performance

$$T_{\text{improved}} = \frac{T_{\text{affected}}}{\text{improvement factor}} + T_{\text{unaffected}}$$

- Example: multiply accounts for 80s/100s
  - How much improvement in multiply performance to get 5× overall?

- Can't be done!

$$20 = \frac{80}{n} + 20$$

FALLACY: LOW POWER AT IDLE

- Fallacy: Computers at low utilization use little power

- Look back at i7 power benchmark
  - At 100% load: 258W
  - At 50% load: 170W (66%)
  - At 10% load: 121W (47%)
- Google data center
  - Mostly operates at 10% – 50% load
  - At 100% load less than 1% of the time
- Consider designing processors to make power proportional to load

PITFALL: MIPS AS A PERFORMANCE METRIC

- MIPS: Millions of Instructions Per Second

  Doesn't account for

  - Differences in ISAs between computers
  - Differences in complexity between instructions

$$\text{MIPS} = \frac{\text{Instruction count}}{\text{Execution time} \times 10^6}$$

$$= \frac{\text{Instruction count}}{\dfrac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}} \times 10^6} = \frac{\text{Clock rate}}{\text{CPI} \times 10^6}$$

CPI varies between programs on a given CPU

LET'S CHECK!

Measurement	Computer A	Computer B
Instruction count	10 billion	8 billion
Clock rate	4 GHz	4 GHz
CPI	1.0	1.1

a. Which computer has the higher MIPS rating?

b. Which computer is faster?

$$\text{MIPS} = \frac{\text{Instruction count}}{\text{Execution time} \times 10^6}$$

$$= \frac{\text{Instruction count}}{\frac{\text{Instruction count} \times \text{CPI}}{\text{Clock rate}} \times 10^6} = \frac{\text{Clock rate}}{\text{CPI} \times 10^6}$$

CONCLUDING REMARKS

- Cost/performance is improving
  - Due to underlying technology development
- Hierarchical layers of abstraction
  - In both hardware and software
- Instruction set architecture
  - The hardware/software interface
- Execution time: the best performance measure
- Power is a limiting factor
  - Use parallelism to improve performance

ATTENDANCE NUMBER

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