CE1006/CZ1006
Computer Organisation and Architecture

Performance Metrics

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Why Measure Performance?

- Key to understanding underlying computer organisation and architecture
  - Why are some processors faster than others for the same program?
  - What are the hardware components that influence performance?
- Make intelligent design choices
- See through the marketing hype

Some Performance Metrics

- Millions of Instructions Per Second (MIPS)
- Floating Point Operations Per Second (FLOPS)
- Clock Frequency (MHz, GHz)
- Execution Time (seconds, miliseconds)
- Power Consumption (Watts)

Millions of Instructions Per Second (MIPS)

- In a second, my computer can execute 10 million instructions, while yours can execute only 8 million instructions. Therefore my computer is faster than yours!

- Different instructions take different amount **clock cycles** in different machines, for example:
  - Memory operations take longer than register operations
  - Floating-point operations require multiple instructions to execute

```
      MOV R0,R1
      MOV R1,R2
      MOVS AR,#6
Loop  MOV [R1],[R0]
      INC R0
      INC R1
      JDAR Loop
```

- **MIPS** can be obtained by choosing an instruction mix that minimises **Cycles Per Instruction** (**CPI**)

Clock Frequency

- My computer runs at 2.5GHz, yours only at 1.7GHz. So my computer is better than yours!

	Ultrabook	Tablet	Gaming Laptop	Ultra Portables	MacBook
Processor Name	Intel Core i5 3xxxU	Qualcomm SnapDragon S4	Intel Core i7 3xxxXM	Intel Core i5 3xxxM	Intel Core i5 3xxxM
Processor Speed	1.7 Ghz	1.5 Ghz	3 Ghz	2.5 Ghz	2.5 Ghz
RAM	4 GB	2 GB	16 GB	4 GB	8 GB
Graphics	Intel HD Graphics	Qualcomm Ardeno	Nvidia GeForce	Intel HD Graphics	Intel HD Graphics
Storage	128 GB	64 GB	2 TB	256 GB	512 GB
Operating System	Win8	Android	Win8	Win7	Mac OS

- Can we use clock frequency (1/Clock Cycle) alone to determine if computer A is faster than computer B?

Execution Time

$$\underbrace{}_{}\frac{Time}{Program} = \overset{\text{Instruction Count}}{\frac{Instructions}{Program}} \times \overset{\text{CPI}}{\frac{Cycles}{Instruction}} \times \overset{\text{Clock Cycle}}{\frac{Time}{Cycle}}$$

- **Common Pitfall** is to assume that we can use each metric separately to measure performance
- What about run-time issues?
  - Cache misses require more cycles
  - I/O accesses
  - Branches may impact execution rate

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Performance Benchmarks

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Synthetic Benchmarks

- A standard set of program compiled in high level language e.g. C, for different processor platform. One of the first attempts to derive a fair and reliable benchmark for CPU performances.
- Whetstone
  - Floating Point intensive
  - Trigonometric and Exponential Functions
  - Reported in Whetstone Instructions per Second
- Linpack
  - Double Precision Arithmetic
  - Linear Algebra
  - Originally developed to measure performance of Supercomputers.
- Dhrystone
  - String manipulation and Integer Operations
  - Reported in Dhrystone per second (number of times the CPU can run the program in one second).

SPEC Benchmarks

- Standard Performance Evaluation Corporation (SPEC) was formed to address the need for objective benchmarks.
- The SPEC benchmarks consist of a collection of kernel programs. These are programs that carry out the core processes involved in solving a particular problem.
- The SPEC CPU2006 benchmark consists of two parts, CINT2006, which measures integer arithmetic operations, and CFP2006, which measures floating-point processing.
- Users run the benchmarks and submit the results to SPEC for review. SPEC ensures that the results are obtained in accordance with its guidelines and publishes the results on its website.

http://www.spec.org/cpu2006/results/cpu2006.html

EEMBC Benchmarks

- Embedded Microprocessor Benchmark Consortium (EEMBC) develops benchmark for **embedded systems**.

- EEMBC organises their benchmark suites into various application domains:
  - Telecom/networking,
  - Digital media,
  - Java,
  - Automotive/industrial,
  - Consumer
  - Office equipment products.

http://www.coremark.org/benchmark/index.php?pg=benchmark