Craig Shaffer

Dr. Swami Ponpondi

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Homework Three

**1. Explain the difference between the concepts of parallelism and pipelining using an example. [10]**

The concepts are similar in the fact that many things are processed by multiple units. However, how they handle this is different. For the concept of parallelism, performance is increased by performing operations simultaneously or parallel to each other. Functionally, it splits the overall load over several processors to increase the performance. The concept of pipelining is used to complete repetitive tasks by breaking down the task into smaller stages that are performed in a sequence.

**Explaining the difference with an example**: Tasked with making 100 peanut butter and jelly sandwiches. Parallelism will divide the load and pipelining will divide the task into smaller tasks.

- Parallelism example: Have 4 people build 25 sandwiches each to finish the task faster
- Pipelining example: Break the process into stages like an assembly line,
  - Stage 1 - person 1 - pass two bread slices to person 2
  - Stage 2 - person 2 - puts peanut butter on one slice
  - Stage 3 - person 3 - puts jelly on the other slice
  - Stage 4 - person 4 - puts the two slices together completing the sandwich

**2. Textbook problem 1.2, Page 54. [10]**

**Match 8 great ideas to similar ideas from other fields**

a. Assembly lines in automobile manufacturing
    i. **Performance via pipelining**
b. Suspension bridge cables - (multiple cables to keep the bridge up if one breaks)
    i. **Dependability via redundancy**
c. Aircraft and marine navigation systems that incorporate wind information
    i. **Performance via prediction**
d. Express elevators in buildings - (spreads load of people across many elevators)
    i. **Performance via parallelism**
e. Library reserve desk - (makes frequently used materials readily available)
    i. **Make the common case fast**
f. Increasing the gate area on a CMOS transistor to decrease its switching time
    i. **Hierarchy of memories**
g. Adding electromagnetic aircraft catapults (which are electrically powered as opposed to current steam-powered models), allowed by the increased power generation offered by the new reactor technology
    i. **Design for Moore's law**
h. Building self-driving cars whose control systems partially rely on existing sensor systems already installed into the base vehicle, such as lane departure and smart cruise control systems
    i. **Use abstraction to simplify design**

**3. Textbook problem 1.5, Page 55 [10]**

| | **Instruction count** | **CPI** | **Frequency (clock rate)** |
|---|---|---|---|
| P 1 | x | 1.5 | 3 GHz |
| P 2 | x | 1 | 2.5 GHz |
| P 3 | x | 2.2 | 4 GHz |

a. **Which processor has the highest performance expressed in instructions per second?**

**Note:** CPI = clock cycles/instructions, Clock Rate = clock cycles/second

----> IPS = 1/CPI * clock rate = ClockRate/CPI

P1 - IPS = 3/1.5= 2 instructions per nanosecond = 2 billion instructions per second

P2 - IPS =2.5/1= 2.5 instructions per nanosecond = 2.5 billion instructions per second

P3 - IPS =4/2.2≈ 1.82 instructions per nanosecond ≈ 1.82 billion instructions per second

<u>P2 has the highest performance expressed in instructions per second</u>

b. **If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions.**

| | **Number of Instructions**<br>10× (inst per sec) | **Number of Cycles**<br>CPI×Number of instructions |
|---|---|---|
| P 1 | 20 billion instructions | 30 billion cycles |
| P 2 | 25 billion instructions | 25 billion cycles |
| P 3 | 18.2 billion instructions | 40 billion cycles (not rounded)<br>(40.04 billion using rounded calculation) |

**c. We are trying to reduce the execution time by 30% but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction**

0.7×Execution time = Instructions × (1.2 × CPI) / New Clock Rate

instr = $\frac{ExecutionTime \times ClockRate}{CPI}$

Number of instructions is constant so:

$$\frac{OldExecutionTime \times OldClockRate}{OldCPI} = \frac{NewExecutionTime \times NewClockRate}{NewCPI}$$

$NewExecutionTime\ = .70 \times\ OldExecutionTime$, $NewCPI = 1.2 \times\ OldCPI$

Then $NewClockRate = 1.2/0.7 \times\ OldClockRate \approx 1.714 \times\ OldClockRate$

So the new clock rate should increase by 71.4%

| | **Old Clock Rate (Frequency)** | **New Clock Rate (Frequency)**<br>1.714 × Old Clock Rate |
|---|---|---|
| P 1 | 3 GHz | 5.142 GHz |
| P 2 | 2.5 GHz | 4.285 GHz |
| P 3 | 4 GHz | 6.856 GHz |

**4. Textbook problem 1.6, Page 55 [10]**

| | **Instructions** | **Clock Rate** | **Class A CPI** | **Class B CPI** | **Class C CPI** | **Class D CPI** | **Global CPI** (Weighted Avg) |
|---|---|---|---|---|---|---|---|
| P 1 | 1 million | 2.5 GHz | 1 | 2 | 3 | 3 | 2.6 |
| P 2 | 1 million | 3 GHz | 2 | 2 | 2 | 2 | 2 |

1.0E6 instructions = 1 million instructions, 10% class A, 20% class B, 50% class C, 20% class D

a. **What is the global CPI for each implementation?**

P1 Avg CPI = 2,600,000/1,000,000 = 2.6

1 x 100,000 -> 100,000

2 x 200,000 -> 400,000

3 x 500,000 -> 1,500,000

3 x 200,000 -> 600,000

P1 Global CPI = 2.6

P2 Avg CPI = 2,000,000/1,000,000 = 2

2 x 100,000 -> 200,000

2 x 200,000 -> 400,000

2 x 500,000 -> 1,000,000

2 x 200,000 -> 400,000

P2 Global CPI = 2

b. **Find the clock cycles required in both cases**

clock cycles = # of instructions x CPI

P1 clock cycles = 2.6 x 1 million = 2.6 million clock cycles

P2 clock cycles = 2 x 1 million = 2 million clock cycles

**Which is faster P1 or P2?**

CPU time = instr num x cpi x frequency

P1 CPU time = 1,000,000 x 2.6 /2.5ns = 1,040,000 ns = .00104 seconds

P2 CPU time = 1,000,000 x 2 /3ns = 666,666.67ns = .00067 seconds

P2 is faster than P1