IRA A. FULTON SCHOOLS OF engineering

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Parallel Computing and Performance Evaluation -- Amdahl's Law

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Chapter 7 Roadmap: Evaluation in Design Process

1. Amdahl's Law
2. Multi-Core and HyperThreading
3. Application of Amdahl's Law
4. Limitation of scale up

Performance Evaluation Consideration: Amdahl's Law of Speedup

Named after computer architect Gene Amdahl, born on 11/16, 1922

- What counts the most: Make the common case fast;
- Where is bottleneck of speed? Improve the bottleneck first!
- Do not ignore the uncommon cases;
- The performance enhancement of an improvement is limited by how much the improved feature is used.
- Don’t expect an enhancement proportional to how much you enhanced something.

Amdahl's Law (contd.)

Assume we have a design (e.g., a computer or a car) which does not quite meet the performance requirement (Think about the execution speed of a computer). We need to improve the design.
Assume that we redesigned the system so that
f fraction of time is enhanced by a factor of ***s***

$$Speedup = \frac{old\ (execution)\ time}{new\ (execution)\ time}$$

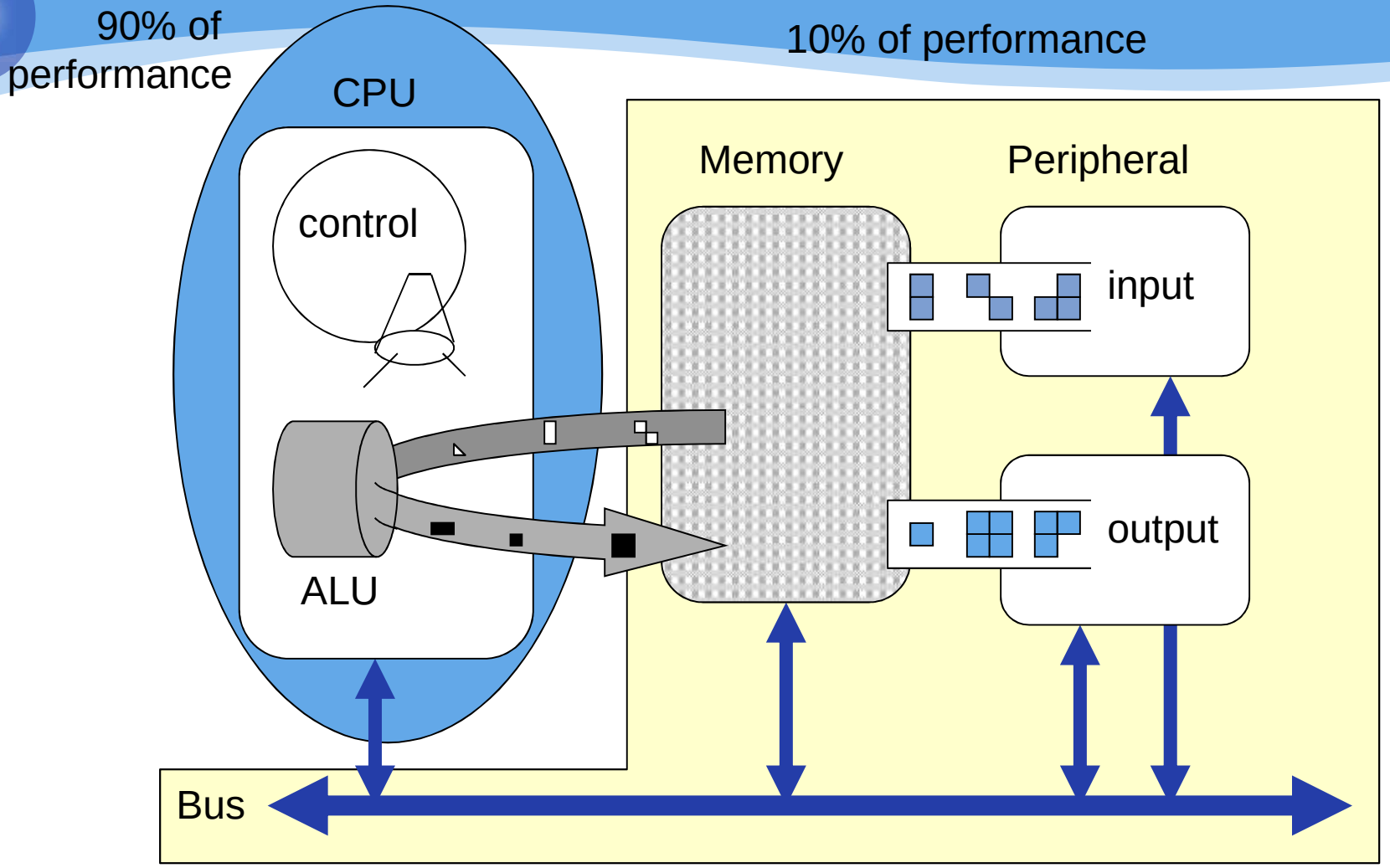
$$= \frac{old\ time}{(f \times old\ time)/s + (1 - f) \times old\ time}$$

Enhanced part

unenhanced part

$$= \frac{1}{f/s + (1 - f)}$$

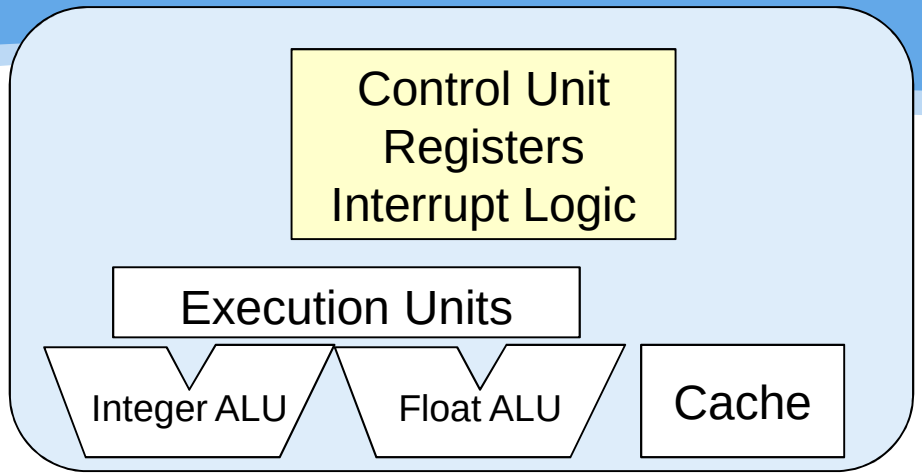
Case Study: Enhancing Performance



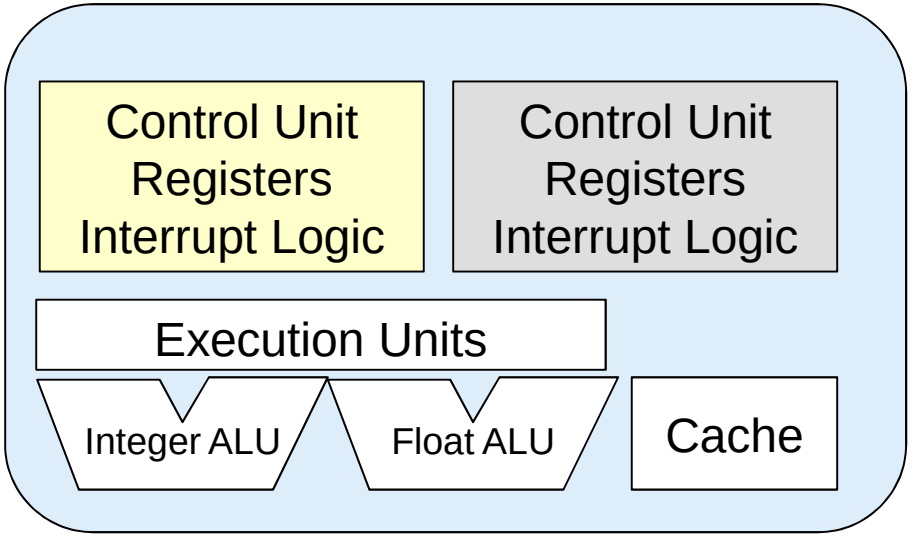
Five Components of a Computer

Single Core and HyperThreading Processor

Single Core Processor

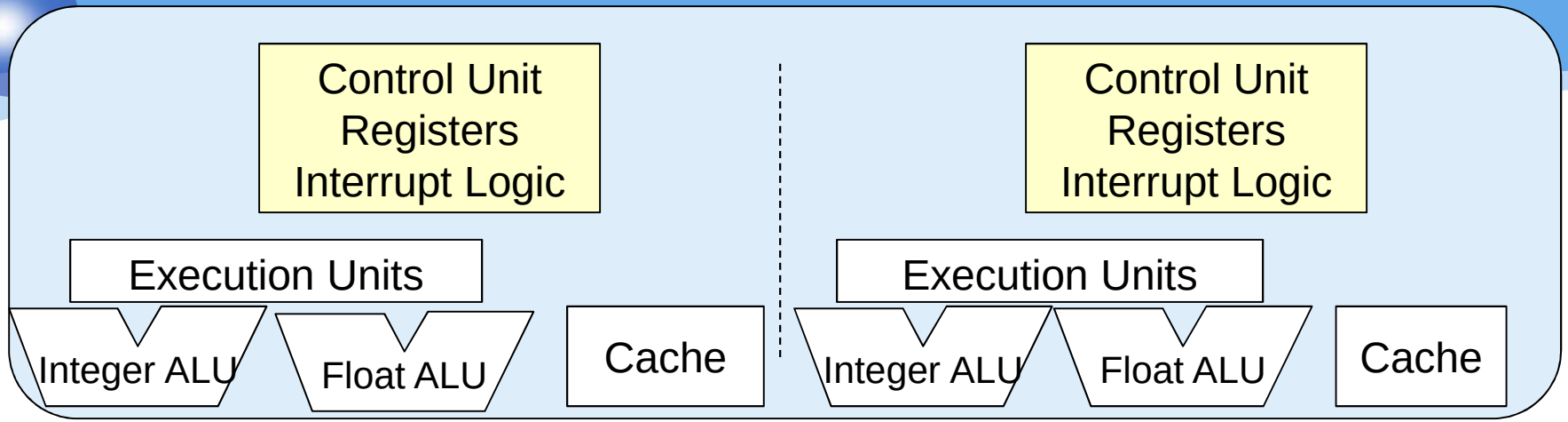


HyperThreading Processor: Allows to share the unused execution units

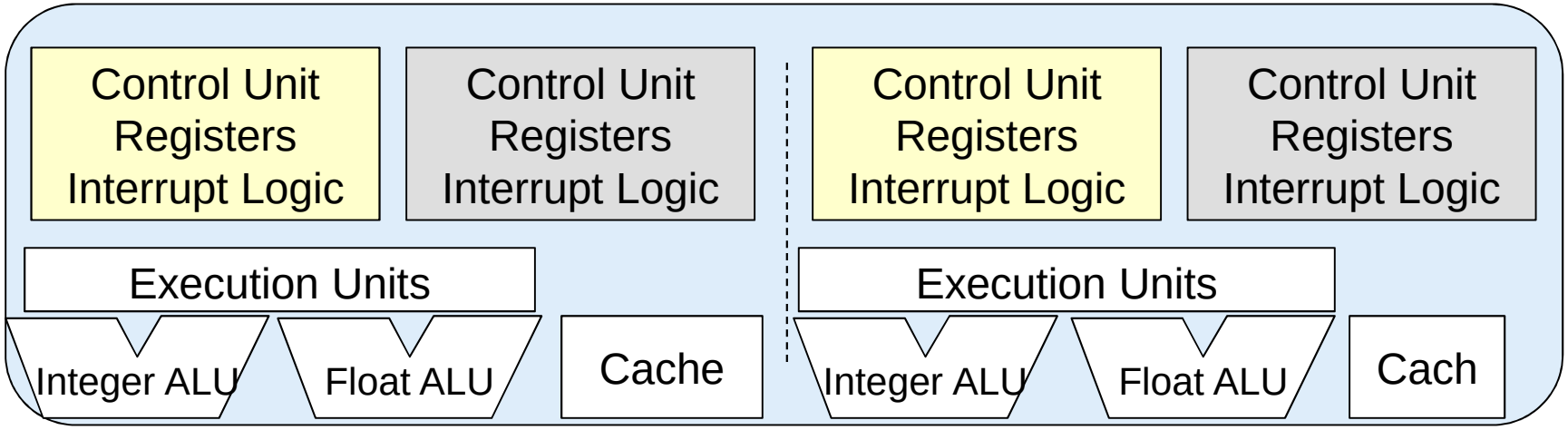


It appears to OS to have two processors, resulting two threads are assigned to the processor.
Executing two mixed threads will reduce instruction dependency for pipelined processor!

Multi-Core and HyperThreading Processor



Multi-Core

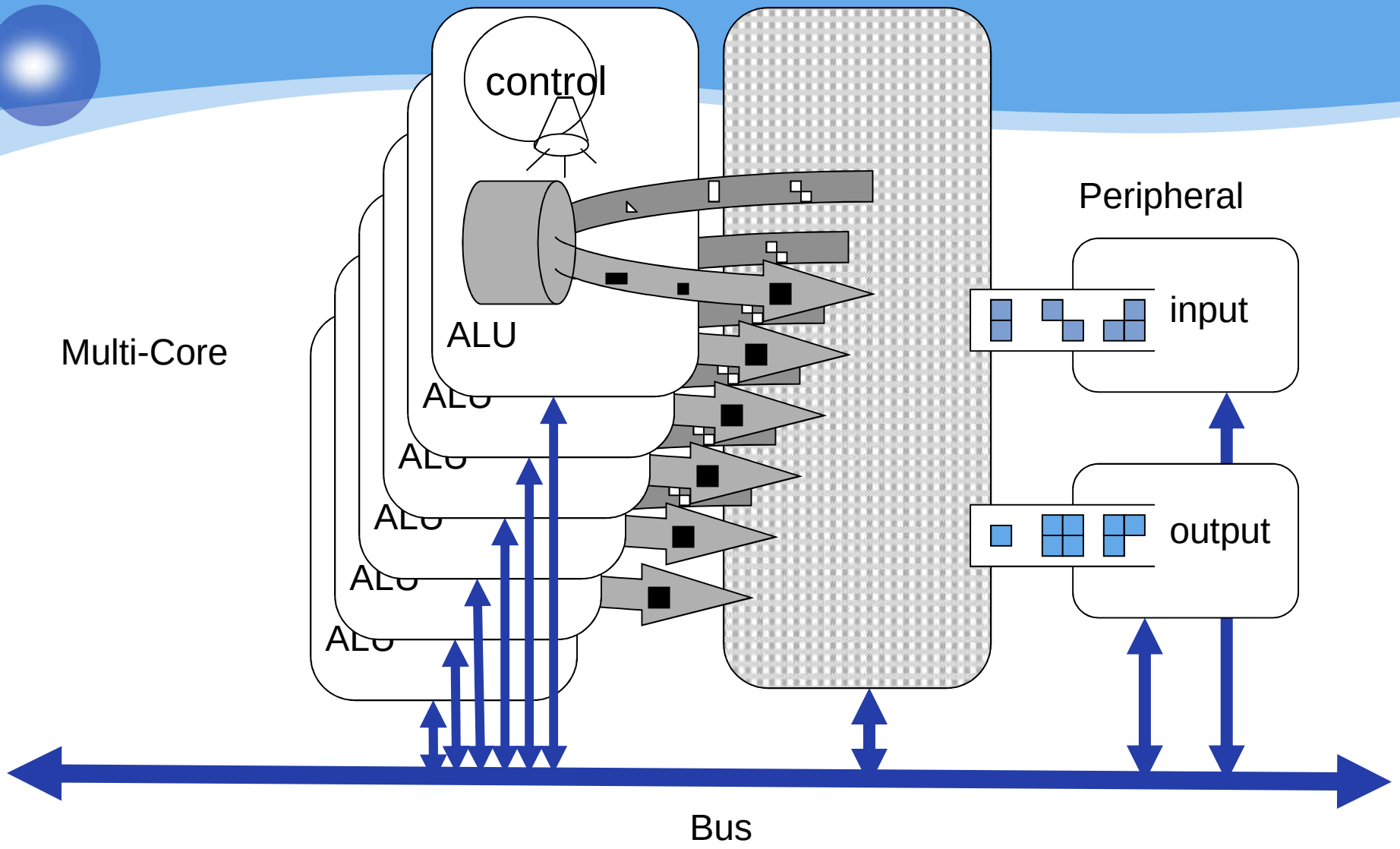


Multi-Core with HyperThreading

Intel Multi-Core HyperThreading Processors

Processor	Cache	Clock Speed	No. of Cores	Hyper Threads
i7-980X	12 MB	3.33 GHz	4	8
i7-970	12 MB	3.2 GHz	4	8
i7-950	8 MB	3.06 GHz	4	8
i7-870	8 MB	2.93 GHz	4	8
i7-860	8 MB	2.8 GHz	4	8
i5-760	8 MB	2.8 GHz	4	4
i5-750	8 MB	2.66 GHz	4	4
i5-680	4 MB	3.6 GHz	2	4
i5-670	4 MB	3.46 GHz	2	4
i5-660	4 MB	3.33 GHz	2	4
i5-650	4MB	3.2GHz	2	4
i3-550	4MB	3.2GHz	2	4
i3-540	4MB	3.06GHz	2	4
i3-540	4MB	2.93GHz	2	4

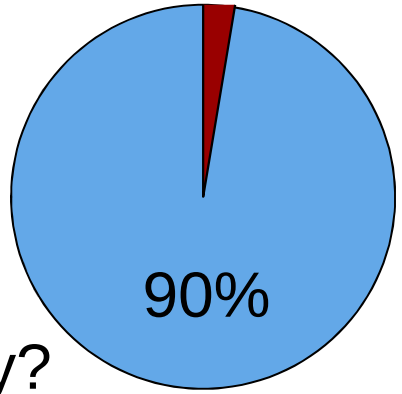
Improve CPU Performance



Pitfall

The engineers are able to make f = 90% of the system much faster. If

s = 10 times faster,
s = 100 times faster, and
s = 1000 times faster



What is the overall speed up, respectively?

9 times, 90 times, 900 times, respectively?

What is your answer?

Revolutionary New Designs and Fallacy

$$Speedup\ (f, s) = \frac{1}{f/s + (1 - f)}$$

$$Speedup\ (0.9, s) = \frac{1}{0.9/s + 0.1}$$

$$Speedup\ (0.9, s{=}10) = \frac{1}{0.9/10 + 0.1} = 5.3$$

$$Speedup\ (0.9, s = 100) = \frac{1}{0.9/100 + 0.1} = 9.1$$

$$Speedup\ (0.9, s = 1000) = 9.9$$

Limitation of Speedup

$$Speedup\ (f, s) = \frac{1}{f/s + (1 - f)}$$

When f → 0 (trying to improve little or nothing of used fraction)

Speedup → 1 (no speedup at all)

When f → 1 (improve the entire system 100%), Speedup → s

When s → 0 (no improvement), Speedup → 1

When s → ∞ (unlimited enhancement

$$\text{Speedup} \rightarrow \frac{1}{(1 - f)}$$

which is a constant, e.g., f = 0.9 → Speedup = 10

Why?

- What counts the most: Make the common case fast;
- Where is bottleneck of speed?
- Do not ignore the uncommon cases: They can become the common cases when the previous common case is addressed and a new bottleneck will occur;

Summary

- Amdahl's Speedup Law
- Reviewed the Basic Architecture: Five Component Model
- HyperThreading Architecture
- Multi-Core Architecture
- Multi-Core and HyperThreading Architecture
- Intel core architecture series
- Amdahl's Speedup Law: Improvement is limited by different factors
- Scale up and scale out