Recent Processor Advances Enabling Disruptive Technologies

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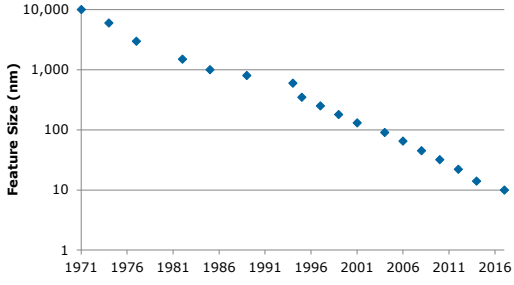
Chair, IEEE – Jordan Section

Talk in IEEE – Jordan Section Annual General Meeting, May 9, 2017

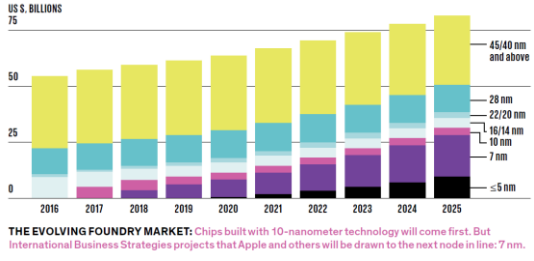
Outline

- Semiconductor Technology Advances
- Recent Processor Advances
- How Processors Achieve Higher Performance
- Example Modern Processors
- Emerging Disruptive Technologies
- Disruptions to Our Lives

Semiconductor Technology Advances



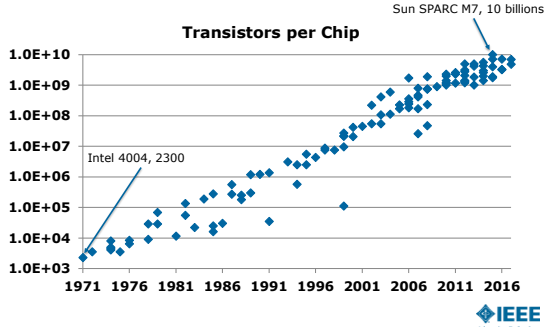
Future Feature Size



THE EVOLVING FOUNDRY MARKET: Chips built with 10-nanometer technology will come first. But International Business Strategies projects that Apple and others will be drawn to the next node in line: 7 nm.

Source: Spectrum, Jan 2017

Exponential Increase in Transistors



Semiconductor Technology Advances

- **Exponential decrease in the transistor size over time gives:**
  - Exponential increase in the number of transistors per chip
  - Exponential decrease in the transistor cost
  - Exponential increase in the switching speed
  - Exponential decrease in switching energy
- **Resulting more powerful, cheaper, smaller, power-efficient computers**

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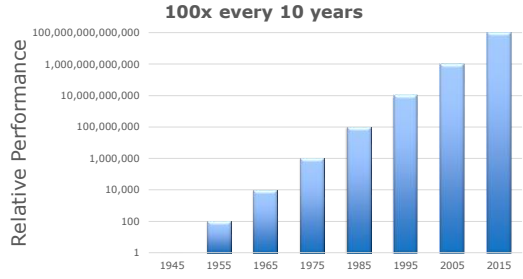
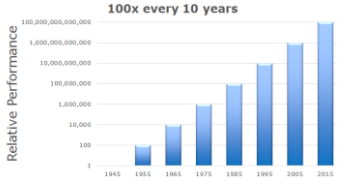
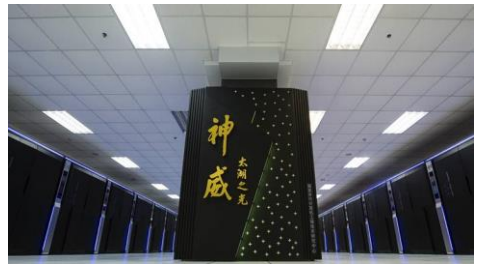
Recent Processor Advances



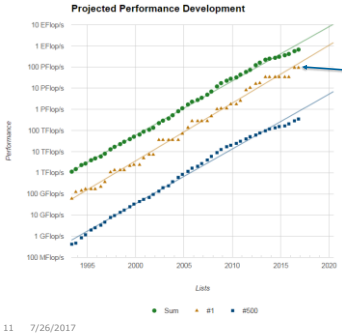
Recent Processor Advances



10 times performance improvement doubles the computer applications.



Higher Performance



www.top500.org
Nov 2016
Rank #1

Sunway TaihuLight
- 10,649,600 cores
- 93 PFlops
- 1.25 PBytes
- 15 MW

Smaller Size

Lower Power

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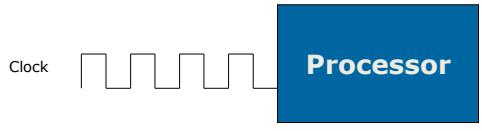
Driving Forces in Performance Improvement

1. Semiconductor Technology Advances
   - Faster transistors → Higher processor frequency
   - Larger transistor budgets
2. Architectural Innovation
   - Pipelining
   - Multiple issue
   - Multiple cores
   - Integrating fast memory and other circuits

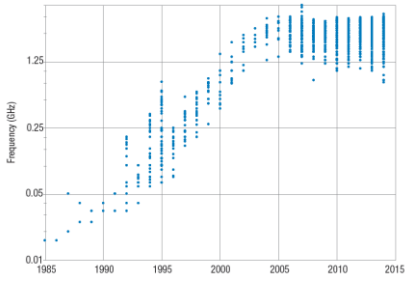
Performance Equation



Performance = Frequency * IPC

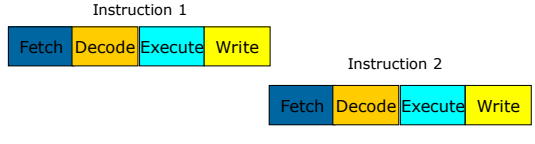
IPC: Instructions Per Cycle

Processor Frequency



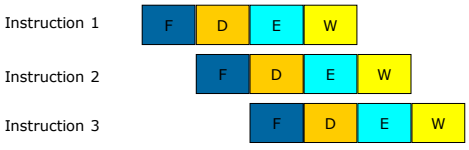
Source: Computer, Jan 2017

Conventional Processor



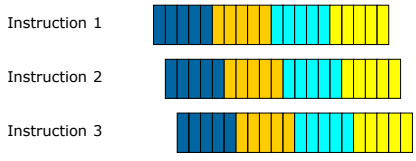
Frequency = f, IPC = ¼
Perf. = f/4

Pipelined Processor



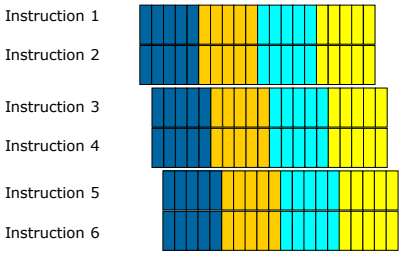
Frequency = f, IPC = 1
Perf. = f

Super-Pipelined Processor



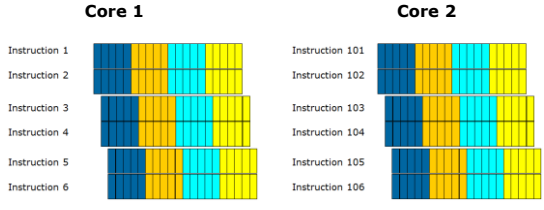
Frequency = 5f, IPC = 1
Perf. = 5f

Superscalar Processor



Frequency = 5f, IPC = 2
Perf. = 10f

Multiple Cores



Frequency = 5f, IPC = 2x2
Perf. = 20f

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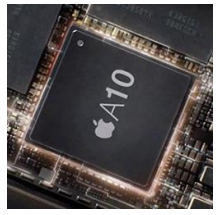
Example Modern Processors

1. Embedded Processor (microcontroller)
2. Mobile Processor
3. Desktop Processor
4. Server Processor

Embedded Processor: Intel 8051

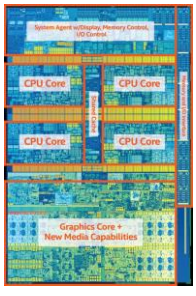
- Microchip AT89C51AC2
  - 8-bit processor
  - 20 MHz
  - 1.25 KB RAM
  - 34 KB Flash Memory
  - 2 KB EEPROM
  - Variety of I/O
  - 50 mW
  - 50 k transistors (8051)
  - $5

Mobile Processor: Apple A10



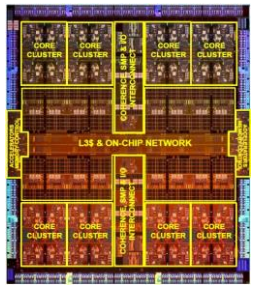
- Apple A10 Fusion
  - 2(+2) cores
  - 2.34 GHz
  - L1: 128 KB per core
  - L2: 3 MB
  - L3: 4 MB
  - Hexa-core GPU
  - Low power
  - 16 nm
  - 3.3 billion transistors
  - ~$100

Desktop Processor: Intel Core i7



- Core i7-7700K
  - 4 cores x 2 threads
  - 4.2 GHz
  - L1: 4 x 64 KB
  - L2: 4 x 256 KB
  - L3: 8 MB
  - HD Graphics 630
  - 91 W
  - 14 nm
  - Several billion transistors
  - $339

Server Processor: Sun SPARC M7



- SPARC M7
  - 8x4 cores x 8 threads
  - Up to 16 sockets
  - 4.13 GHz
  - L1: 32 x 32 KB
  - L2: 8 x 3 x 256 KB
  - L3: 64 MB
  - ~100 W
  - 20 nm
  - 10 billion transistors
  - ~$10,000 per system

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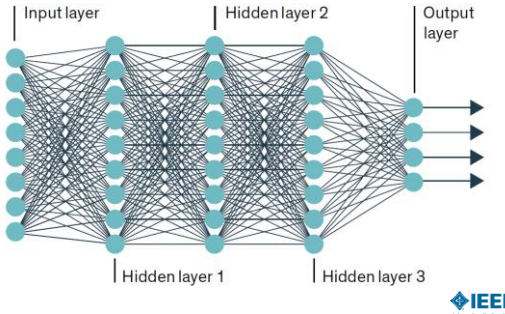
Emerging Disruptive Technologies

- Artificial Intelligence (AI)
  - Deep Neural Networks
  - Machine Learning
  - Machine Vision
- Autonomous vehicles: cars, truck, ships, drones, etc.
- Automation of jobs
  - Blue-collar jobs
  - White-collar jobs

Deep Neural Networks

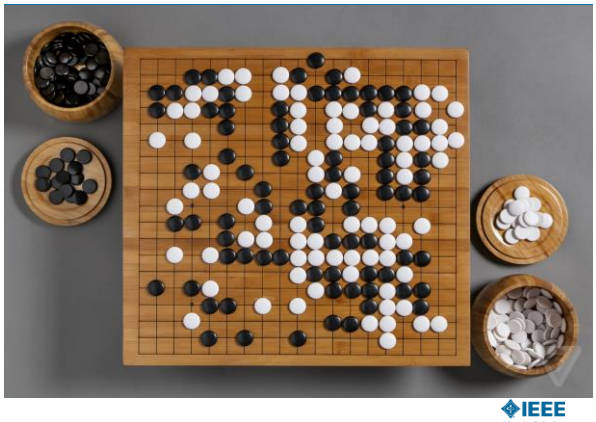


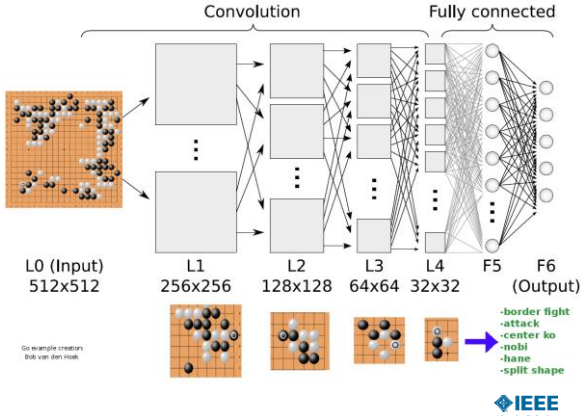
Automatic Diacritization of Arabic Text

كتب الطالب رسالة
كَتَبَ الطَّالِبُ رِسَالَةً

Systems	Error
Zitouni et al. (2006)	5.5
Habash and Rambow (2007)	4.8
Rashwan et al. (2011)	3.8
Said et al. (2013)	3.6
Abandah et al. (2015)	**2.7**

Processor/Library	Training Time
Intel i7 / RNNLIB	17 days
GPU / CURRENNT	1.25 hours





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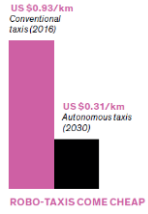
Autonomous Ships

Source: Spectrum, Feb 2017

- Safer, more efficient, and cheaper to run
- Larger cargo capacity and lower wind resistance
- Difficult to board and easier to free

Singapore's nuTonomy



Source: Spectrum, Jan 2017

Google Waymo

- Started in 2009
- 2.5 million miles
- 1 billion simulated miles
- Spectrum, Jan 2017
  - The Dawn: now-2020
  - Mixed Mode: 2020-2040
  - Autonomous Era: 2040 and beyond

Amazon's Drones

WANT IT NOW: Amazon is testing a hybrid drone that takes off and lands vertically but flies like a plane to its destination. Such drones could one day speed packages to consumers.

Source: Spectrum, Jan 2017

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Droid Drivers

Source: Spectrum, Mar 2017

Safe Robots

SAFE TO TOUCH: Sami Haddadin [left] wanted to create a factory robot that was safe to operate around people, and even be touched by them. The result is Franka Emika, which begins shipping this year.

Source: Spectrum, Jan 2017

Robots that learn: Baxter

3D Vision: Industrial Perception's Boxes robot (Acquired by Google)

Analytical Robots: Narrative Science Quill

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Disruptions to Our Lives

- Abundance of high-quality products and services
- Improved Quality of life
  - Physical and psychological health
  - Social relationships
  - Environment
- Negative effects on the individual income
- Mass elimination of jobs
- Killer robots

Conclusions

- Processor technologies continue to advance
- Enabling more computer applications
- Big disruptions are expected
- Big threats
- Big opportunities

Thank you

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