

# Parallel Programming

## Introduction

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WS16/17



## Why Parallel Computing?

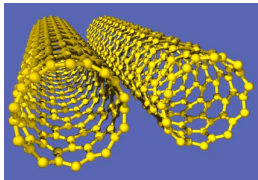
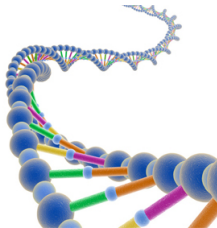
- Problems that cannot be solved fast enough sequentially
  - Real-time constraints
  - Large data sets
  - Accuracy requirements
- Main idea:
  - Decompose large problems into subproblems ...
  - ... that can be solved concurrently.

# Motivation

## Examples

### Computational science

- Genome analysis
- Drug development
- Material science
- Weather forecast
- Climate



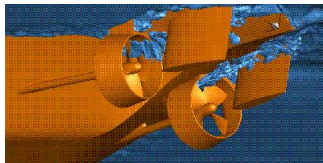
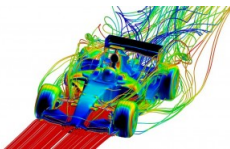
# Motivation

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## Examples

### Engineering

- Engine design
- Aerodynamics
- Fluid dynamics
- Crash simulations



# Motivation

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## Examples

### Finance

- Economics
- High-Frequency Trading



- List of the 500 fastest supercomputers in the world
- Twice per year (ISC, June, Germany - SC, November, USA)
- Computers ranked based on the LINPACK benchmark
  - Solution of linear system of equations:  $Ax = b$
  - Result measured in Flop/s<sup>1</sup> (in double precision).
- Established in 1993: 60 GFlop/s
- Latest, June 2015: 33,862,700 GFlop/s

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<sup>1</sup>Floating Point Operations per Second

# Examples of supercomputers



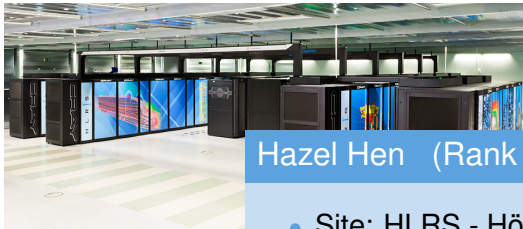
## Sunway TaihuLight.

Source: top500.org

### Sunway TaihuLight (Rank #1)

- Site: National Supercomputing Center in Wuxi, China
- 40,960 SW26010 processors, each
  - 256 processing cores
  - 4 auxiliary cores
- 10,649,600 cores
- 1,310,720 GB RAM
- 93,014.6 TFlop/s (125,435.9 TFlop/s)
- 15,371 kW

# Examples of supercomputers



## **Hazel Hen.**

Source: [hlrs.de](http://hlrs.de)

### Hazel Hen (Rank #9)

- Site: HLRS - Höchstleistungsrechenzentrum Stuttgart
- 7,712 compute nodes
  - 2 Haswell 12-core CPUs
- 185,088 cores
- 987,136 GBs RAM
- 5,640.17 TFlop/s (7,403.52 TFlop/s)
- ~3200 kW



# So...

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are parallel computers restricted to supercomputing?

Not at all!!

# Parallel Computers are everywhere!

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Source: [hp.com](http://hp.com)



Source: [indiatimes.com](http://indiatimes.com)



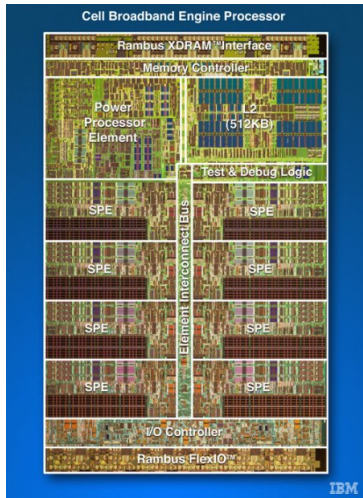
Source: [bq.com](http://bq.com)



Source: [wearabledevices.es](http://wearabledevices.es)

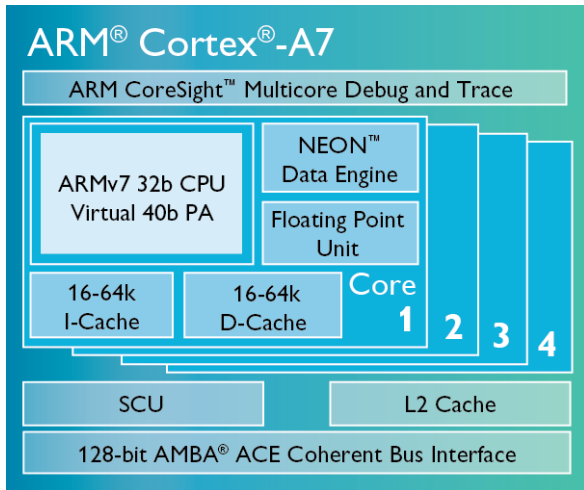
# Parallel Computers are everywhere!

## Play Station 3



# Parallel Computers are everywhere!

My cell phone



Source: arm.com

# Summarizing

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- Parallel programming is critical in science and engineering
- Not only supercomputers, but in every workstation/laptop
- Let's face it:
  - Parallel computers are here to stay
  - The burden is and will be on the programmer
  - So, let's roll up our sleeves and do our best :-)