Algorithm Engineering

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Theoretical Limits

Theoretical and Effective Performance

- Theoretical Performance
  - Number of nodes: 1
  - Number of CPUs: 1
  - Number of Cores: 1
  - CPU frequency: 2.66 GHz
  - Number of operations per cycle: 4 FLOP/cycle (single precision)

  Theoretical (peak) performance

$$2.66\,\mathrm{GHz} \cdot 4\,\mathrm{FLOP/cycle} \approx 10.6\,\mathrm{GFLOP/s}$$

- Effective performance determines the number of operations per time

Theoretical and Effective Bandwidth

- Theoretical bandwidth
  - Memory clock: 1066 MHz
  - Type of memory: DDR2 (double data rate)
  - Number of channels: 2
  - Memory bus: 64 bit

  $1066\,\text{MHz} \cdot 2 \cdot 2 \cdot 64\,\text{bit}/8 = 34\,112\,\text{MB/s} \approx 34.1\,\text{GB/s}$

- Effective bandwidth

$$(B_r + B_w)/t,$$

  where B_r is the number of bytes read, B_w number of bytes written and t the spent time.

System Information

- CPU

  ```
  $ lshw -C cpu
  ```

- Memory

  ```
  $ lshw -short -C memory
  ```

IO bound vs Compute bound

- Average #operations per in-/output

$$\frac{\text{number of operations}}{\text{size of in- and output}}$$

- Number of operations needed to avoid CPU stalls (due to memory accesses)

Amdahl's Law

Fraction x of program optimized by a factor s, then

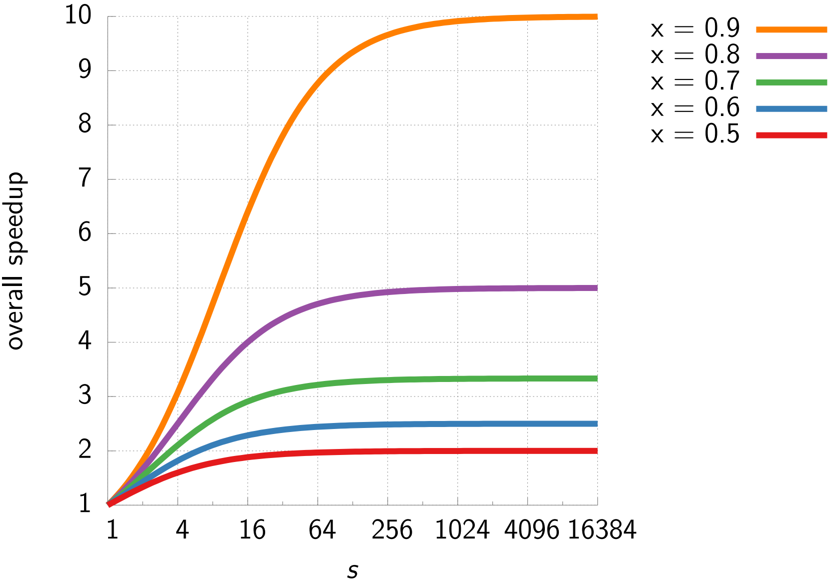
$$T_s = \underbrace{(1-x)}_{\text{unoptimized}} + \underbrace{\frac{x}{s}}_{\text{optimized}}$$

Assume $T = 1$ (unoptimized program's running time), then overall speedup is

$$\frac{T}{T_s} = \frac{1}{(1-x) + \frac{x}{s}}$$

- $x = 1$ yields overall speed up of s
- Strong scaling
  Overall speed up for fixed input size

Amdahl's Law (cont.)



Gustafson's Law

Embarrassingly parallel fraction x of program, then

$$T = (1 - x) + p \cdot x$$

Parallel running time is

$$T_p = (1 - x) + x = 1$$

Hence, speed up is

$$\frac{T}{T_p} = (1 - x) + p \cdot x = 1 + (p - 1) \cdot x$$

- Parallel part grows linear with the number of processors
- Input sizes increase
- Weak scaling
  Overall speed up for increasing input size

Gustafson's Law (cont.)