SALVATORE DI GIROLAMO <DIGIROLS@INF.ETHZ.CH>

# DPHPC: Balance Principles & SIMD

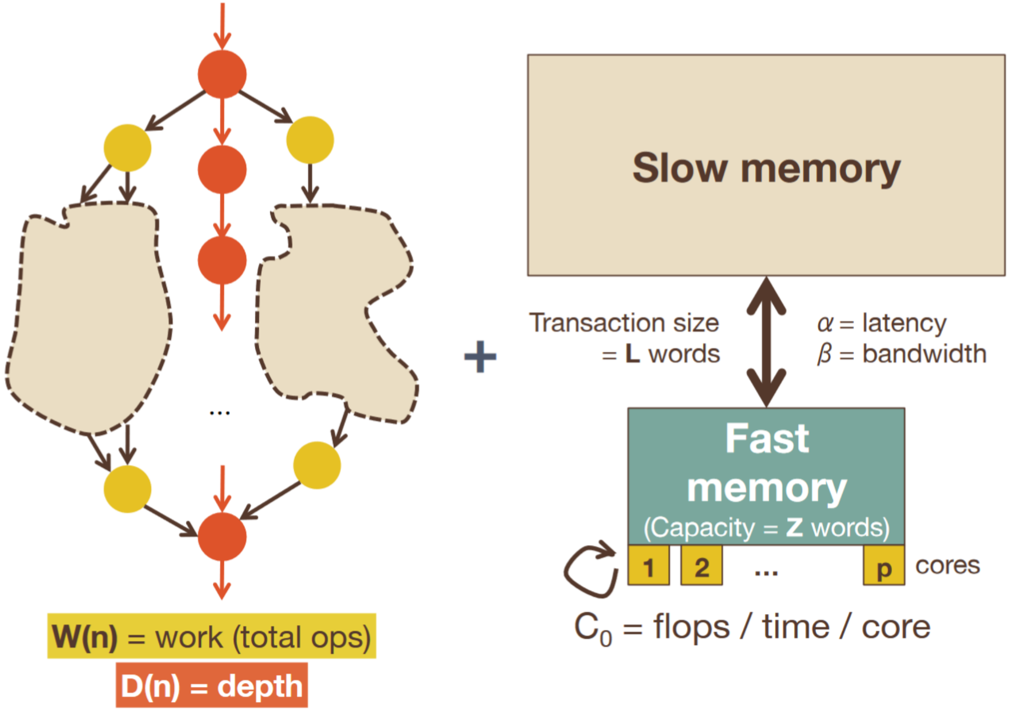
*Recitation session*

Systems@ETH zürich

# Deriving a Balance Principle

- **Concept of balance:** a computation running on some machine is efficient if the compute-time dominates the I/O time. *[Kung, 1986]*

- **Deriving a balance principle:**
  - Algorithmically analyze the parallelism
  - Algorithmically analyze the I/O behavior (i.e., number of memory transfers)
  - Combine these two analyses with a cost model for an abstract machine.




- **Goal: say precisely and analytically how**
  - Changes to the architecture might affect the scaling of a computation
  - Identify what classes of computation might execute efficiently on a given architecture

Czechowski, Kent, et al. "Balance Principles for Algorithm-Architecture Co-Design." HotPar 11 (2011): 9-9.

b) Assume a single-core system with an LRU data cache, a peak performance of $\pi = 4$ single precision floating point operations/cycle, and a memory bandwidth of $\beta = 8$ bytes/cycle.

- What is the ridge point in the roofline point of the above described system? (2pt)

- Consider the following function operating on a matrix `A` of $n^2$ floats. `A` is stored in row-major order. Assume that the cache size $\gamma$ is much smaller than $n$ ($\gamma \ll n$) and that a cache block has size equal to 8 floats (a float is 8 bytes). No elements of A are initially in cache (i.e., cold cache). What is the operational intensity of the following code? Is it compute or memory bound on this system? Justify your answer. (4pt)

```
void foo(float A[n][n]){
  for (int j=0; j<n; j++){
    for (int i=1; i<n; i++){
      A[0][j] = A[0][j] + A[i][j];
    }
  }
}
```

c) Assume a program with an operational intensity of $I = \Theta(\sqrt{\gamma})$ that is balanced with respect to a given architecture (single-core). If the peak performance ($\pi$) doubles every 2 years and the memory bandwidth ($\beta$) doubles every 4 years, with which yearly rate does the cache size need to increase in order to keep the balance? (4pt)

# Vectorizing the Vandermonde Matrix Determinant Computation

$$\begin{bmatrix} 1 & 1 & \cdots & 1 \\ x_1 & x_2 & \cdots & x_N \\ x_1^2 & x_2^2 & \cdots & x_N^2 \\ & & \cdots & \\ x_1^{N-1} & x_2^{N-1} & \cdots & x_N^{N-1} \end{bmatrix}$$

$$V_n = \prod_{1 \le i < j \le n} (x_j - x_i)$$