Forms of Parallelism

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Parallel Computers - Characterization

- Different Characterizations:
  - Synchronous vs. Asynchronous
  - Custom interconnects vs. Commodity Interconnects
    - Signaling over Buses & Custom Switches vs. Data Communication over Networks

Parallel Computers – Characterizations [2]

- Custom Processors (or compute units) vs. Commodity systems
  - Custom Processors & Custom Interconnects – e.g. Cray, CM, Tera, IBM, NEC
  - Commodity Processors & Custom Interconnects – e.g. PARAM (Sparc/Pentium w. CDAC Switch), Virginia Tech. Custom supercomputer (Apple Macs w. Infiniband),

    IBM Blue Gene (PowerPC w. custom switches)
  - Commodity Systems and Commodity Interconnects –
    - Clusters (e.g. Beowulf, OpenMOSIX)

Parallel Computers – Characterizations [3]

- Shared memory vs. Message Passing
  - Systems with “Message Passing over networks” are referred to as Distributed Systems
- In shared memory systems:
  - communication and coordination happens via shared data
    - (writing and reading of values) in memory
  - coordination may be required
    - for synchronization between threads or
    - for mutual exclusion of threads in accessing shared resources / shared data
- In message passing systems:
  - synchronization happens by communication;
  - communication itself may be synchronous or asynchronous

Parallel Computers – Characterizations [4]

- Flynn's Taxonomy (of parallel architectures)
  - Two axes: Instruction (stream) vs. Data (Stream)
    - Single Instruction Single Data (SISD)
      - typical sequential processor
    - Single Instruction Multiple Data (SIMD)
    - Multiple Instruction Single Data (MISD)
    - Multiple Instruction Multiple Data (MIMD)

Flynn's Taxonomy

- Single Instruction Multiple Data (SIMD)
  - Multiple processors execute the same instruction stream in lockstep
    - They operate on different parts of the data
  - e.g. Connection Machine: CM5 - 64K processors in a hypercube
  - e.g. Vector processors: Cray supercomputers – Cray XMP/YMP

Flynn's Taxonomy [2]

- MISD: e.g. systolic array
  - typical problems: FFT, solving triangular linear systems

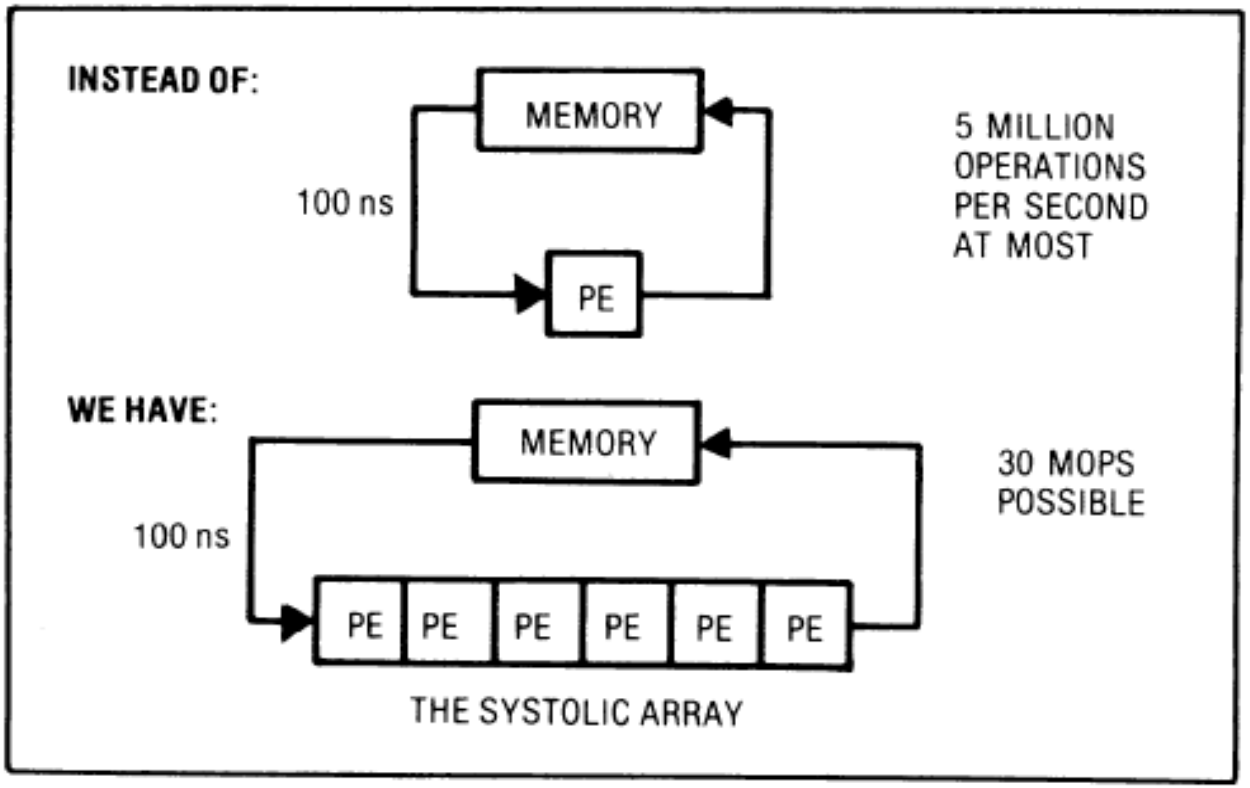

Fig. from Kung. IEEE Computer, Jan 1982

Flynn's Taxonomy [3]

- Multiple Instruction Multiple Data (MIMD)
  - Each processor executes a separate instruction stream on a separate data stream

Flynn's Taxonomy – Software Level

- Flynn's Taxonomy – morphed for software level characterization
  - Two axes: Program (instruction stream) vs. Data (Stream)
    - Single Program Single Data Stream (SPSD)
      - Single Thread
    - Single Program Multiple Data Stream (SPMD)
      - Multiple threads execute the same function on different data
      - How do you differentiate SPMD from SIMD?

Flynn's Taxonomy – Software Level [2]

- Two axes: Program (instruction stream) vs. Data (Stream)
  - Single Program Single Data Stream (SPSD)
  - Single Program Multiple Data Stream (SPMD)
  - Multiple Program Single Data Stream (MPSD)
    - Software Pipelining:

      Multiple Threads execute different functions – a single data stream flows through them.
  - Multiple Program Multiple Data Stream(MPMD)
    - Multiple Threads execute different functions on different data
      - but possibly communicating and co-ordinating.
    - How do you differentiate MPMD from MIMD?

Parallel vs. Distributed Systems

- Distributed Systems – Structural Categorization
  - Clusters
    - Homogeneous, over LAN, tightly controlled / administered
  - Grids
    - Heterogeneous, over LAN/WAN
  - Clouds
    - Virtual nodes and networks, dynamic resource allocation.

Parallel vs. Distributed System

- Lines are blurring, but broadly:
  - Tightly coupled vs. Loosely coupled
  - Shared memory vs. Message passing
  - Bus/Switch vs. Network Interconnect
  - Monolithic vs. Composite
- Clusters form the dividing line
  - Treated as Parallel or Distributed depending on context.

References

- Flynn, Michael J. (September 1972). "Some Computer Organizations and Their Effectiveness". IEEE Transactions on Computers. C-21 (9): 948–960. doi:10.1109/TC.1972.5009071.
- http://dsc.soic.indiana.edu/publications/parallelsystemsvsdistributedsystems.pdf

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Thank You