Parallel & Distibuted Computing: Lecture 6

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Concepts and Terminology

General concepts

von Neumann Computer Architecture

- Named after the Hungarian mathematician/genius John von Neumann who first authored the general requirements for an electronic computer in his 1945 papers.
- Also known as "stored-program computer" - both program instructions and data are kept in electronic memory. Differs from earlier computers which were programmed through "hard wiring".
- Since then, virtually all computers have followed this basic design

Figure 1: John von Neumann circa 1940s (Source: LANL archives)

von Neumann Computer Architecture

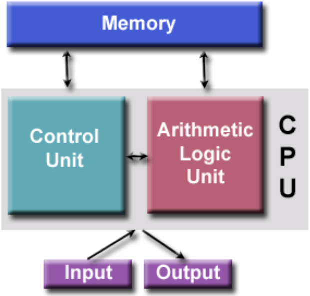

Figure 2: von Neumann Architecture

- Four main components:
  - Memory
  - Control Unit
  - Arithmetic Logic Unit
  - Input/Output
- Read/write, random access memory to store both program instructions and data
  - Program instructions are coded data which tell the computer to do something
  - Data is information to be used by the program
- Control unit fetches instructions/data from memory, decodes the instructions and then sequentially coordinates operations to accomplish the programmed task.
- Arithmetic Unit performs basic arithmetic operations
- Input/Output is the interface to the human operator

Flynn's Classical Taxonomy

- There are different ways to classify parallel computers. Examples available HERE.
- One of the more widely used classifications, in use since 1966, is called Flynn's Taxonomy.
- Flynn's taxonomy distinguishes multi-processor computer architectures according to how they can be classified along the two independent dimensions of Instruction Stream and Data Stream.
- Each dimension can have only two possible states: Single or Multiple.

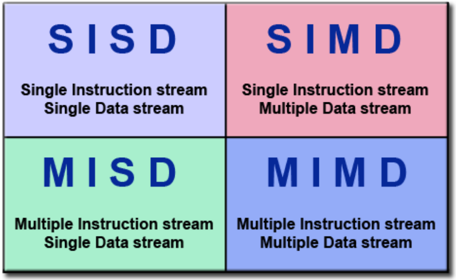

Figure 3: 4 possible classifications according to Flynn

Single Instruction, Single Data (SISD)

A serial (non-parallel) computer

- Single Instruction: Only one instruction stream is being acted on by the CPU during any one clock cycle
- Single Data: Only one data stream is being used as input during any one clock cycle
- Deterministic execution
- This is the oldest type of computer

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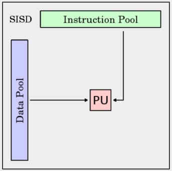
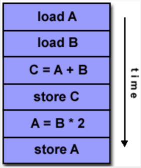
- Examples: older generation mainframes, minicomputers, workstations and single processor/core PCs.

Single Instruction, Single Data (SISD)





UNIVAC1

IBM 360

CRAY1

CDC 7600

PDP1

Dell Laptop

Single Instruction, Multiple Data (SIMD)

A type of parallel computer

- Single Instruction: All processing units execute the same instruction at any given clock cycle
- Multiple Data: Each processing unit can operate on a different data element
- Best suited for specialized problems characterized by a high degree of regularity, such as graphics/image processing.
- Synchronous (lockstep) and deterministic execution
- Two varieties: Processor Arrays and Vector Pipelines

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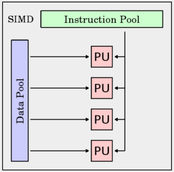
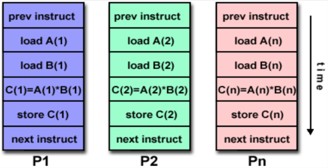
- Examples:
  - Processor Arrays: Thinking Machines CM-2, MasPar MP-1 & MP-2, ILLIAC IV
  - Vector Pipelines: IBM 9000, Cray X-MP, Y-MP & C90, Fujitsu VP, NEC SX-2, Hitachi S820, ETA10
- Most modern computers, particularly those with graphics processor units

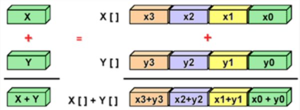
Single Instruction, Multiple Data (SIMD)





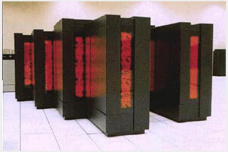

ILLIAC IV

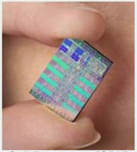

MasPar




Cray X-MP


Cray Y-MP


Thinking Machines CM-2


Cell Processor (GPU)

Multiple Instruction, Single Data (MISD)

A type of parallel computer

- Multiple Instruction: Each processing unit operates on the data independently via separate instruction streams.
- Single Data: A single data stream is fed into multiple processing units.
- Few (if any) actual examples of this class of parallel computer have ever existed.

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- Some conceivable uses might be:
  - multiple frequency filters operating on a single signal stream
  - multiple cryptography algorithms attempting to crack a single coded message.

Multiple Instruction, Single Data (MISD)

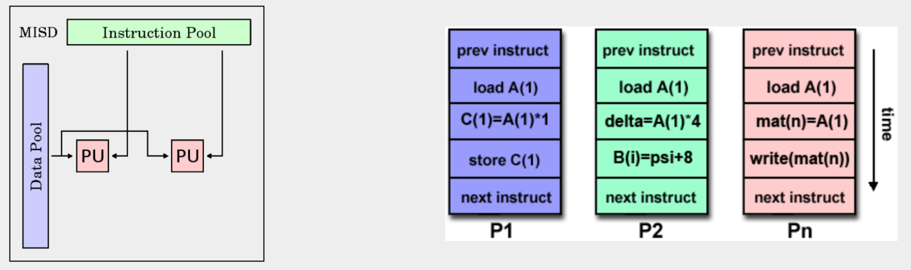

Figure 6: Multiple Instruction, Single Data (MISD)

Multiple Instruction, Multiple Data (SIMD)

A type of parallel computer

- Multiple Instruction: Every processor may be executing a different instruction stream
- Multiple Data: Every processor may be working with a different data stream
- Execution can be synchronous or asynchronous, deterministic or non-deterministic
- Currently, the most common type of parallel computer - most modern supercomputers fall into this category.

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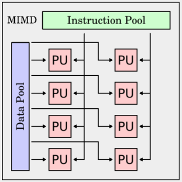
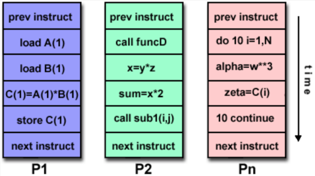
- Examples: most current supercomputers, networked parallel computer clusters and "grids", multi-processor SMP computers, multi-core PCs.
- Note: many MIMD architectures also include SIMD execution sub-components

Multiple Instruction, Multiple Data (SIMD)





IBM POWER5

HP/Compaq Alphaserver

Intel IA32

AMD Opteron

Cray XT3

IBM BG/L

Some General Parallel Terminology

- Like everything else, parallel computing has its own "jargon". Some of the more commonly used terms associated with parallel computing are listed below.
- Most of these will be discussed in more detail later.

Supercomputing / High Performance Computing (HPC) Using the world's fastest and largest computers to solve large problems.

Node A standalone "computer in a box". Usually comprised of multiple CPUs/processors/cores, memory, network interfaces, etc.
Nodes are networked together to produce a supercomputer.

Some General Parallel Terminology

CPU / Socket / Processor / Core This varies, depending upon who you talk to.

In the past, a CPU (Central Processing Unit) was a singular execution component for a computer.

Then, multiple CPUs were incorporated into a node.

Then, individual CPUs were subdivided into multiple "cores", each being a unique execution unit. CPUs with multiple cores are sometimes called "sockets" - vendor dependent.

The result is a node with multiple CPUs, each containing multiple cores. The nomenclature is confused at times. Wonder why?

Some General Parallel Terminology

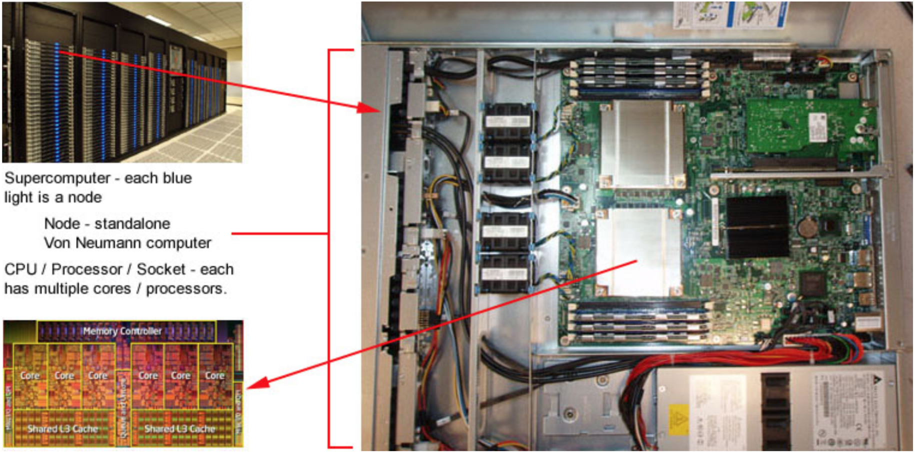


Figure 8: CPU / Socket / Processor / Core

Some General Parallel Terminology

Task A logically discrete section of computational work.
A task is typically a program or program-like set of instructions that is executed by a processor. A parallel program consists of multiple tasks running on multiple processors.

Pipelining Breaking a task into steps performed by different processor units, with inputs streaming through, much like an assembly line; a type of parallel computing.

Some General Parallel Terminology

Shared Memory From a strictly hardware point of view, describes a computer architecture where all processors have direct (usually bus based) access to common physical memory. In a programming sense, it describes a model where parallel tasks all have the same "picture" of memory and can directly address and access the same logical memory locations regardless of where the physical memory actually exists.

Symmetric Multi-Processor (SMP) Shared memory hardware architecture where multiple processors share a single address space and have equal access to all resources.

Some General Parallel Terminology

Distributed Memory In hardware, refers to network based memory access for physical memory that is not common.
As a programming model, tasks can only logically "see" local machine memory and must use communications to access memory on other machines where other tasks are executing.

Communications Parallel tasks typically need to exchange data.
There are several ways this can be accomplished, such as through a shared memory bus or over a network, however the actual event of data exchange is commonly referred to as communications regardless of the method employed.