Introduction to Parallel Computing
CS 540- High Performance Computing

Spring 2017

Computer

"A computer is a general purpose device that can be programmed to carry out a set of arithmetic or logical operations automatically"

Parts of a computer

Processor (CPU)
Main Memory
     Random Access Memory (RAM)
       Volatile
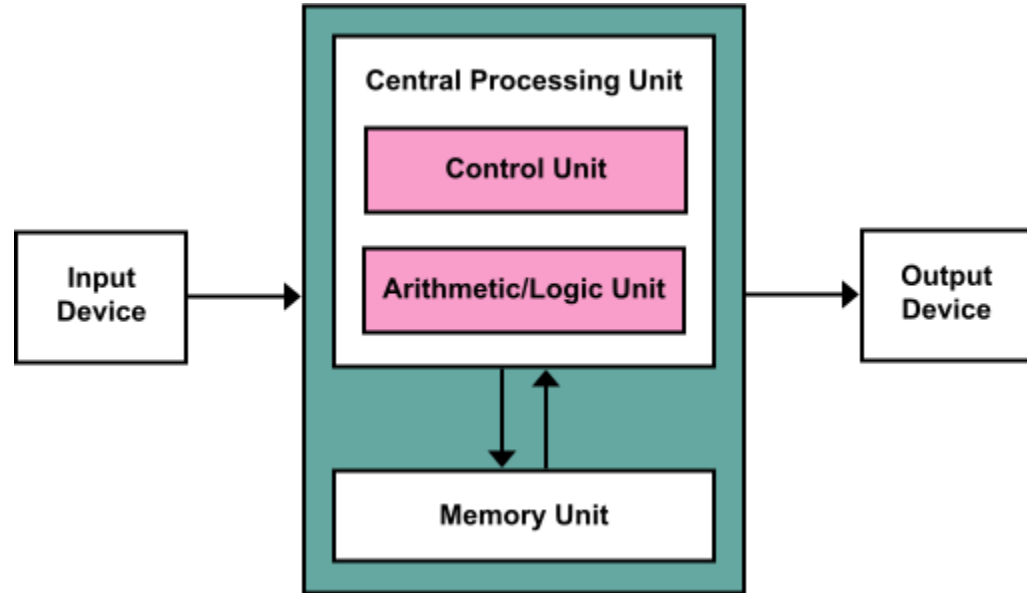Disk (Hard Drive)
     Storage device
     Non-volatile
I/O Devices
Network

Von Neumann Architecture

Instructions
1. Fetch
2. Decode
3. Execute
4. Store Result
5. Repeat

Central Processing Unit

Control Unit

Arithmetic/Logic Unit

Input Device

Output Device

Memory Unit

Serial Computing

Traditionally, software has been written for **_serial_** computation:
- A problem is broken into a discrete series of instructions
- Instructions are executed one after another (i.e. sequentially)
- Executed on a single processor
- Only one instruction may execute at any moment in time
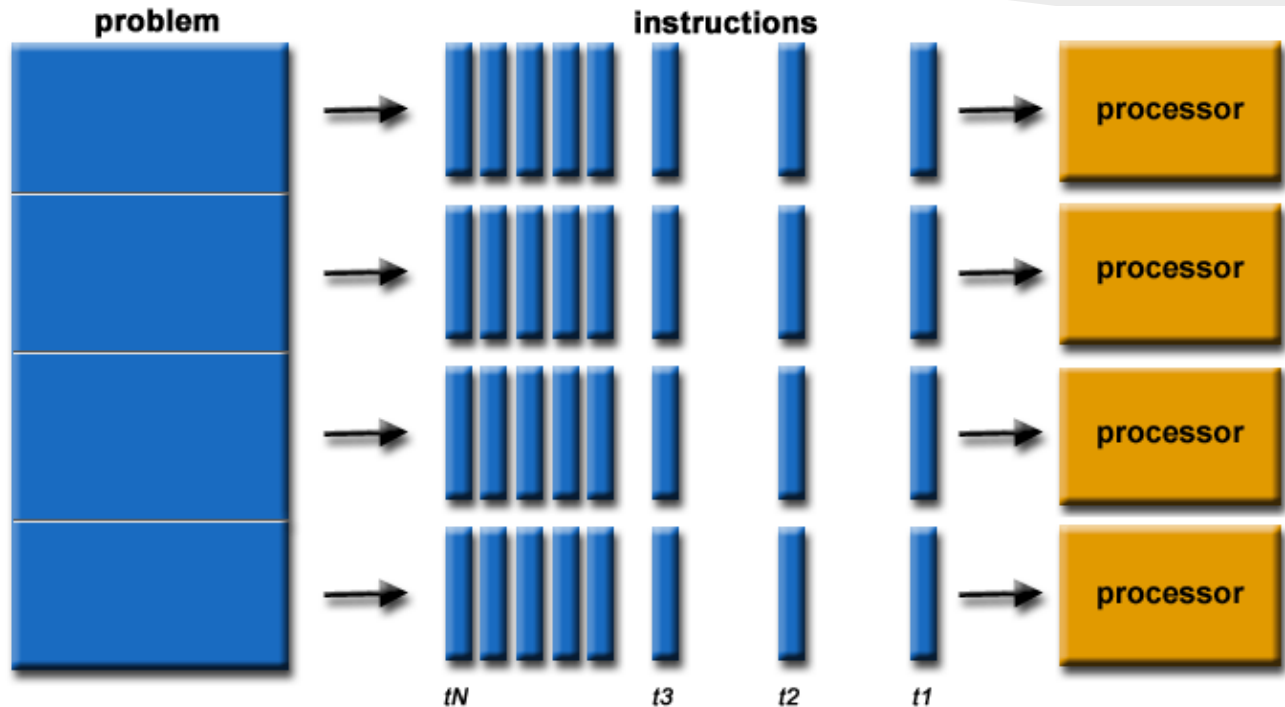
Serial Computing cont.

Source: Lawrence Livermore National Laboratory
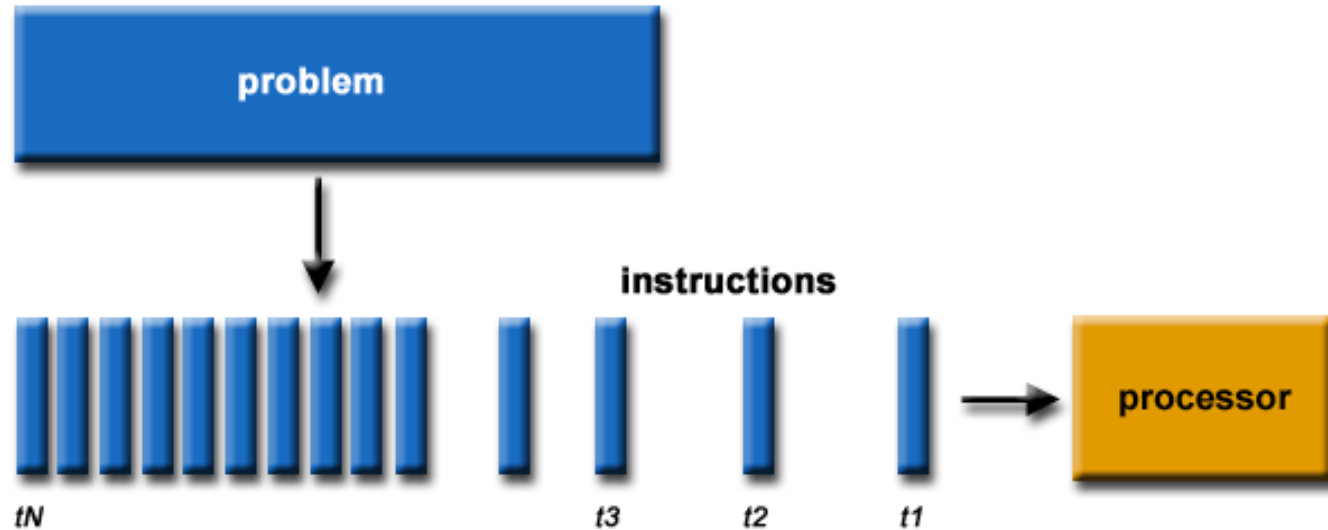
What is Parallel Computing?

parallel computing - is the simultaneous use of multiple compute resources to solve a computational problem:

- A problem is broken into discrete parts that can be solved concurrently
- Each component is further partitioned into a series of instructions
- Instructions from each component execute simultaneously on different processors
- An overall control/coordination mechanism is employed

Parallel Computing cont.

Source: Lawrence Livermore National Laboratory

Parallel Computing cont.

The problem should be able to:
- Be partitioned into discrete components of work that can be solved concurrently.
- Execute multiple instructions at any moment in time.
- Be solved in less time with multiple compute resources than with a single compute resource (i.e single core processor).
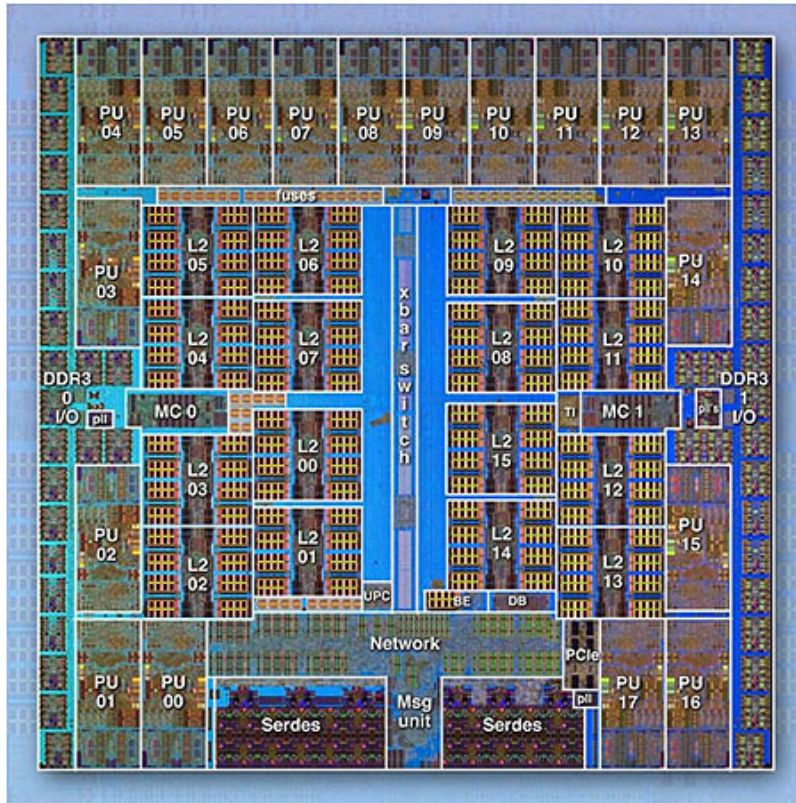
Parallel Computers

Examples of compute resources are:
- A single computer with multiple processors/cores
- An arbitrary number of such computers connected by a network

All computers today are parallel from a hardware perspective:
- Multiple functional units (L1 cache, L2 cache, graphics processing (GPU)
- Multiple execution units/cores
- Multiple hardware threads

Parallel Computers cont.

IBM BG/Q Compute Chip with 18 cores (PU) and 16 L2 Cache units (L2)

Source: Lawrence Livermore National Laboratory

Parallel Computers cont.

Networks can connect multiple stand-alone computers (nodes) to form a sizable parallel computing cluster.

Source: Lawrence Livermore National Laboratory
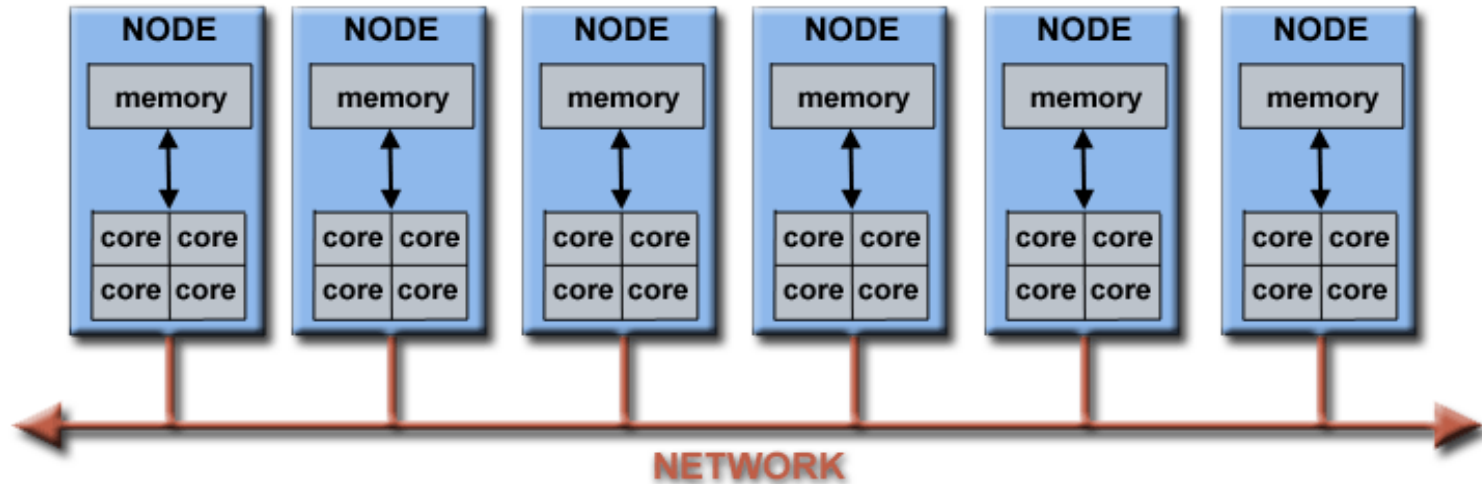
Why Parallel Computing?

- The Real World is Immensely Parallel
- Weather, Planetary Orbits, Climate Change etc.
- Compared to serial computing, parallel computing is much better suited for modeling, simulating and understanding complex, real world phenomena

Why Parallel Computing cont.?

Save time and/or money:
- Theoretically, throwing more resources at a task will shorten its time to completion, with potential cost savings.
- Parallel computers can be built from cheap, commodity components.

Why Parallel Computing cont.?

Solve larger and more complex problems:
- Many problems are so large and/or complex that it is impractical or impossible to solve them on a single computer, especially given limited computer memory.
- Examples of these larger complex problems, (en.wikipedia.org/wiki/Grand_Challenge)
- These problems require PetaFLOPS and PetaBytes of computing resources.
- Web search engines/databases processing millions of transactions every second

Why Parallel Computing cont.?

Make better use of the core parallel hardware:
- Today's computers/laptops, are parallel in architecture with multiple processors/cores.
- Parallel software is specifically intended for parallel hardware with multiple cores, threads, etc.
- In most cases, serial programs run on modern computers do not take advantage of multiple cores.

Who uses Parallel Computing?

Science & Engineering
- Traditionally, parallel computing has been considered to be "the high end of computing."
- Fields and Disciplines: Physics, Chemistry, Mechanical Engineering.

Who uses Parallel Computing?

Industrial & Commercial

- Oil discovery
- Pharmaceutical design
- Financial and economic modeling
- Web search engines, web based business services

References

1. Blaise Barney, Lawrence Livermore National Laboratory, https://computing.llnl.gov/tutorials/parallel_comp/#Overview
2. https://www.citutor.org/index.php, Parallel Computing Explained