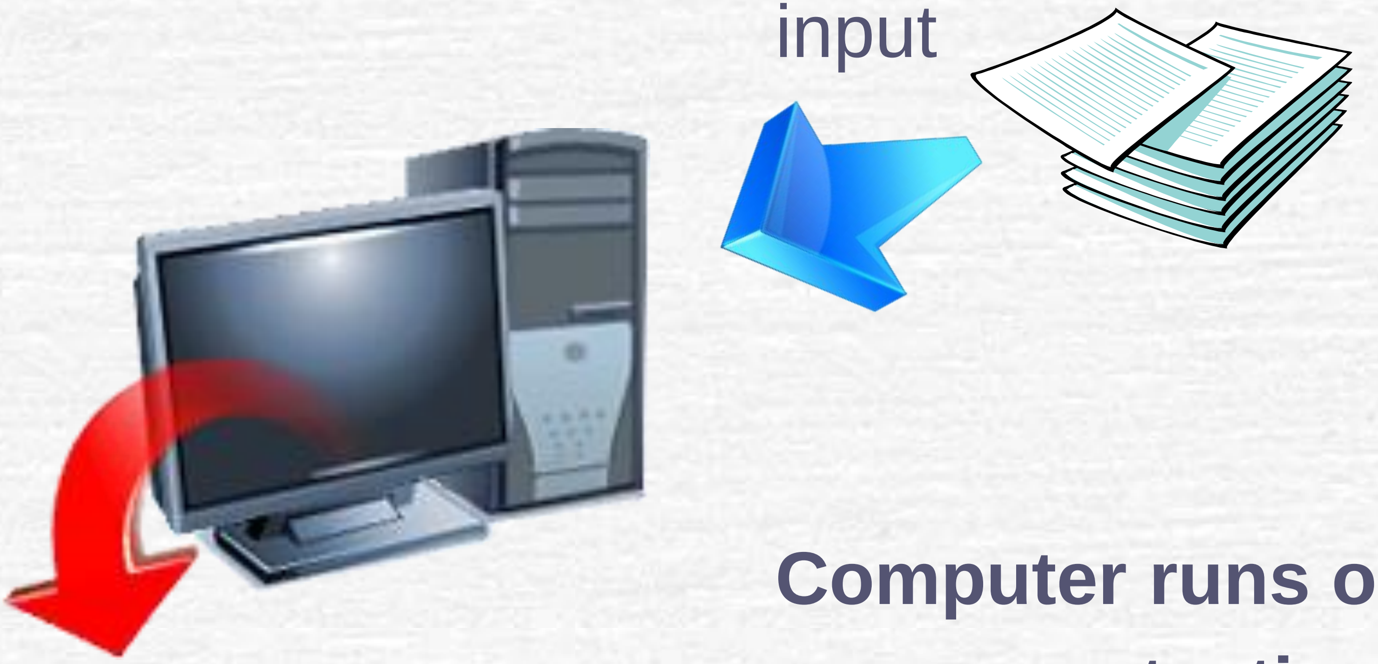
Introduction to Parallel Computing

Sofien GANNOUNI
Computer Science
E-mail: gnnosf@ksu.edu.sa ; gansof@yahoo.com

Serial hardware and software

programs

input



output

Computer runs one program at a time.

Parallelism

- **Parallel Computing:**
  - is a fundamental technique by which computations can be accelerated.
  - is a form of computation in which many calculations are carried out simultaneously.

- **Parallel Programming:**
  - Decomposing a programming problem into tasks
  - Deploy the tasks on multiple processors and run them simultaneously
  - Coordinating work and communications of those processors

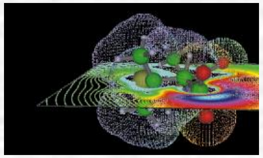
Parallel Computers

- **classified according to the level at which the hardware supports parallelism:**
  - **Multi-core** and **multi-processor (**Symmetric Multiprocessing**)** computers
    - **Multi-core** computers have multiple processing elements (cores) within a single machine.
    - **Symmetric Multiprocessing** (SMP) - multiple processors sharing a single address space, OS instance, storage, etc. All processors are treated equally by the OS
  - **Clusters** and **grids** use multiple computers to work on the same task.
    - **Cluster:** A parallel system consisting of a combination of commodity units (processors or SMPs).
    - **Grid**: is a group of networked computers that work together, only when idle, as a virtual supercomputer to perform large tasks.

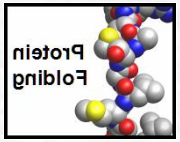
Why do we need Parallel Processing?

- Many applications need much faster machines
- Sequential machines are reaching their speed limits.
- Use multiple processors to solve large problems faster.
- Microprocessors are getting cheaper and cheaper.
- Cheap multiprocessors and multi-core CPUs bring parallel processing to the desktop.

Challenging Applications

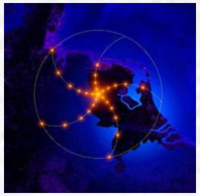


- **Modeling ozone layer, climate, ocean**
- **Quantum chemistry**



- **Protein folding**
- **General: *computational science***

- **Aircraft modeling**
- **Using volumes of data from scientific instruments**
  - astronomy
  - high-energy physics



- **Computer chess**
- **Analyzing multimedia content**

History

- 1950s: first ideas (see Gill's quote)
- 1967 first parallel computer (ILLIAC IV)
- 1970s programming methods, experimental machines
- 1980s: parallel languages (SR, Linda, Orca), commercial supercomputers
- 1990s: software standardization (MPI), clusters, large-scale machines (Blue Gene)
- 2000s: grid computing: combining resources world-wide (Globus)

Opportunities to use parallelism

- **Instruction Level Parallelism**
  - Hidden Parallelism in computer programs
- **Single computer level**
  - Multi-core computers: Chip multi-processors
    - Dual-core, Quad-core
  - Multi-processor computers: Symmetric multi-processors
    - Super-computers
- **Multiple computers level**
  - Clusters, Servers, Grid computing

☞**Need for programs that have multiple instruction streams**

Parallelism in Computer Programs

- **The main motivation for executing program instructions in parallel is to complete a computation faster.**
- **But programs are written assuming that:**
  - Instructions are executed in **sequential**.
  - Most programming languages embed sequential execution.

Instruction Level Parallelism (IPL)

- **(a+b) * (c+d)**
  - could be computed simultaneously.
- **Separation of instructions and data.**
  - Instructions and memory references execute in parallel without interfering.
- **Instruction Execution is pipelined**
- **Processors initiate more than one instruction at a time.**

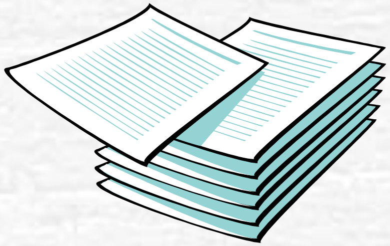
How do we write parallel programs?

- **Task parallelism**
  - Partition various tasks carried out solving the problem among the cores.
- **Data parallelism**
  - Partition the data used in solving the problem among the cores.
  - Each core carries out similar operations on it’s part of the data.

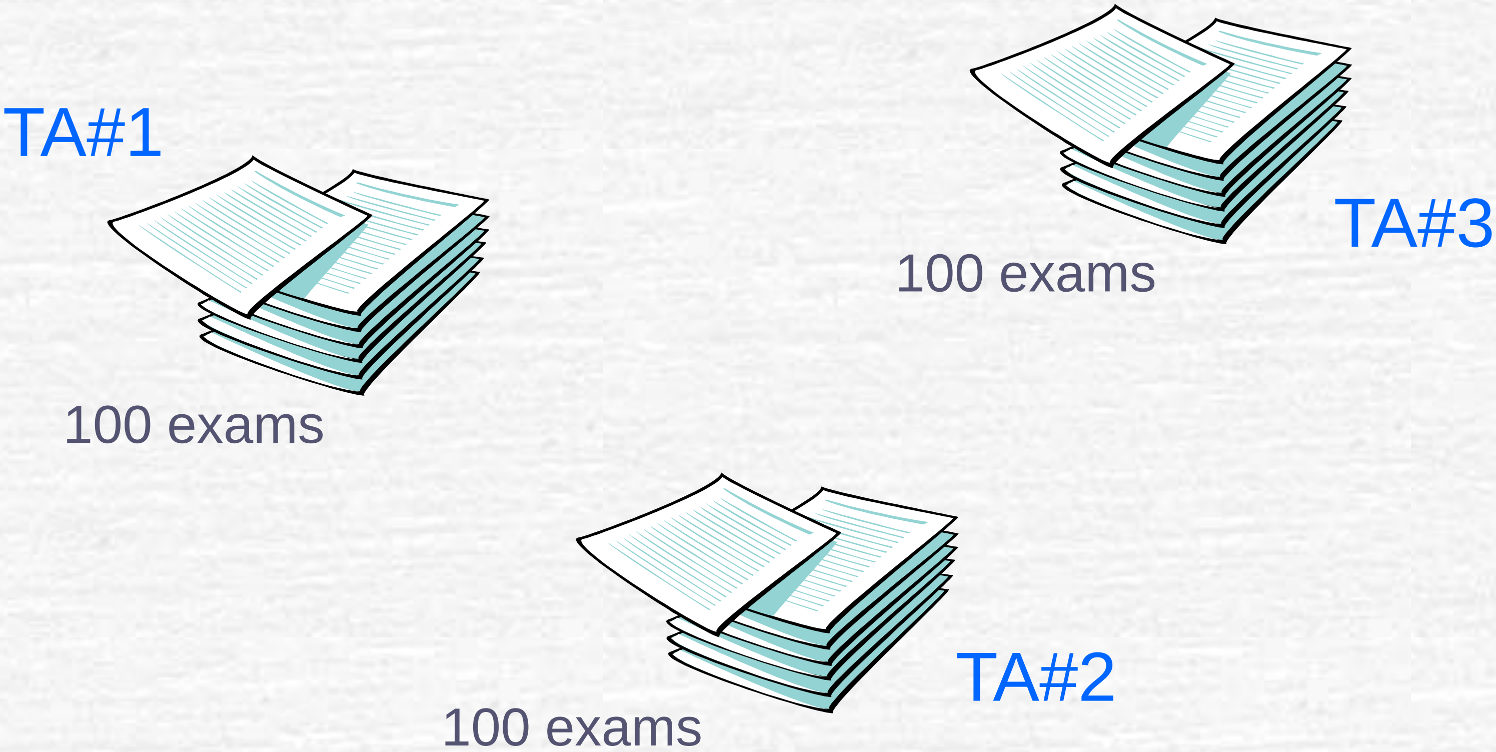
Professor P

15 questions

300 exam copies



Division of work – data parallelism



Division of work – task parallelism

TA#1

TA#3

Questions 11 - 15

or Questions 12 - 15

Questions 1 - 5

or Questions 1 - 7

TA#2

Questions 6 - 10

or Questions 8 - 11

Partitioning strategy:

- either by number
- Or by workload

Parallel Computing vs. Distributed Computing

- **Parallel computing**
  - Provides performance that a single processor can not give.
  - Interaction among processors is frequent
    - Fine grained with low overhead
    - Assumed to be reliable.
- **Distributed Computing**
  - Provides convenience:
    - Availability, Reliability
    - Physical distribution, Heterogeneity
  - Interaction is infrequent,
    - Coarse grained - heavier weight
    - Assumed to be unreliable.

Distributed Systems

What is a Distributed System?

- A distributed system is one that looks to its users like an ordinary, centralized, system but runs on multiple independent CPUs

- **Symptoms? Shroeder:**
  - Multiple, independent processing units
  - Processors communicate via a hardware interconnect
  - Processing unit failures are independent: No single point of failure
  - No global clock
  - State is shared among processors

Aspects of Parallel Computing

- **Parallel Computers Architecture**

- **Algorithms and applications**
  - Reasoning about performance
  - Designing parallel algorithms.

- **Parallel Programming**
  - Paradigms
  - Programming Models
  - Programming languages
  - Frameworks
  - Dedicated environments