Today

- What is the difference between thread and process? Why do we need threads?
- Processes and address spaces
- Difference between thread and process
- Thread
- Multi-threaded programming
Processes and Threads

- **A full process** includes numerous things:
  - an address space (defining all the code and data pages)
  - OS resources and accounting information
  - a “thread of control”, which defines where the process is currently executing (basically, the PC and registers)

- Creating a new process is **costly**, because of all of the structures (e.g., page tables) that must be allocated

- **Communicating** between processes is costly, because most communication goes through the OS
Processes and Address Spaces

- What happens when Apache wants to run multiple concurrent computations?
Processes and Address Spaces

- Two heavyweight address spaces for two concurrent computations?

![Diagram showing process address spaces]

- Emacs
- Apache
- Mail

User

Kernel
Processes and Address Spaces

- We can eliminate duplicate address spaces and place concurrent computations in the same address space.
Threads and Processes

- Modern operating systems therefore support two entities:
  - the **process**, which defines the **address space** and general process attributes
  - the **thread**, which defines a **sequential execution stream** within a process

- **A thread is bound to a single process**. For each process, however, there may be many threads.

- Threads are the unit of scheduling; processes are **containers** in which threads execute.
Threads and Processes

single-threaded process

multi-threaded process
Thread

- Basic unit of CPU utilization.
- It comprises:
  - Thread ID
  - PC
  - Register set
  - SP
- It belongs to a process.
- It shares:
  - Code
  - Data
  - OS resources (files, etc)
  with the other threads of the same process.
Multi-threaded programming

- A programmer can create multiple threads to complete a task, to achieve:
  - Responsiveness
  - Resource sharing
  - Economy
  - Scalability
    - Multiprocessor architecture
    - Ex. Word count at many files
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