Today

- Threads
- Difference between threads and processes
- Multi-threaded programming
The cost of processes

• **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
The cost of processes

- What happens when Apache wants to run multiple concurrent computations?
The cost of processes

- Two heavyweight address spaces for two concurrent computations?
Eliminating the cost by threads!

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

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.
Processes and Threads

- **Single-threaded process**
  - Code
  - Data
  - Files
  - Registers
  - Stack

- **Multi-threaded process**
  - Code
  - Data
  - Files
  - Registers
  - Registers
  - Registers
  - Stack
  - Stack
  - Stack
Thread

- Basic unit of CPU utilization.
- It consists of:
  - 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 of many files
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