Sistemi Operativi I

Corso di Laurea in Informatica

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SAPIENZA
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- All modern operating systems provide features enabling a process to contain **multiple threads** of control
- We introduce many concepts associated with multi-threaded computer systems
- We look at a number of issues related to multi-threaded programming and its effect on the design of operating systems

Threads: Overview

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- Traditional (heavyweight) processes have a single thread of control
  - There is only one program counter, and one sequence of instructions that can be carried out at any given time
- Multi-threaded applications have multiple threads within a single process, each having their own program counter, stack, and set of registers
  - But sharing common code, data, and certain structures, such as open files

Process vs. Thread

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- A thread is bound to a specific process

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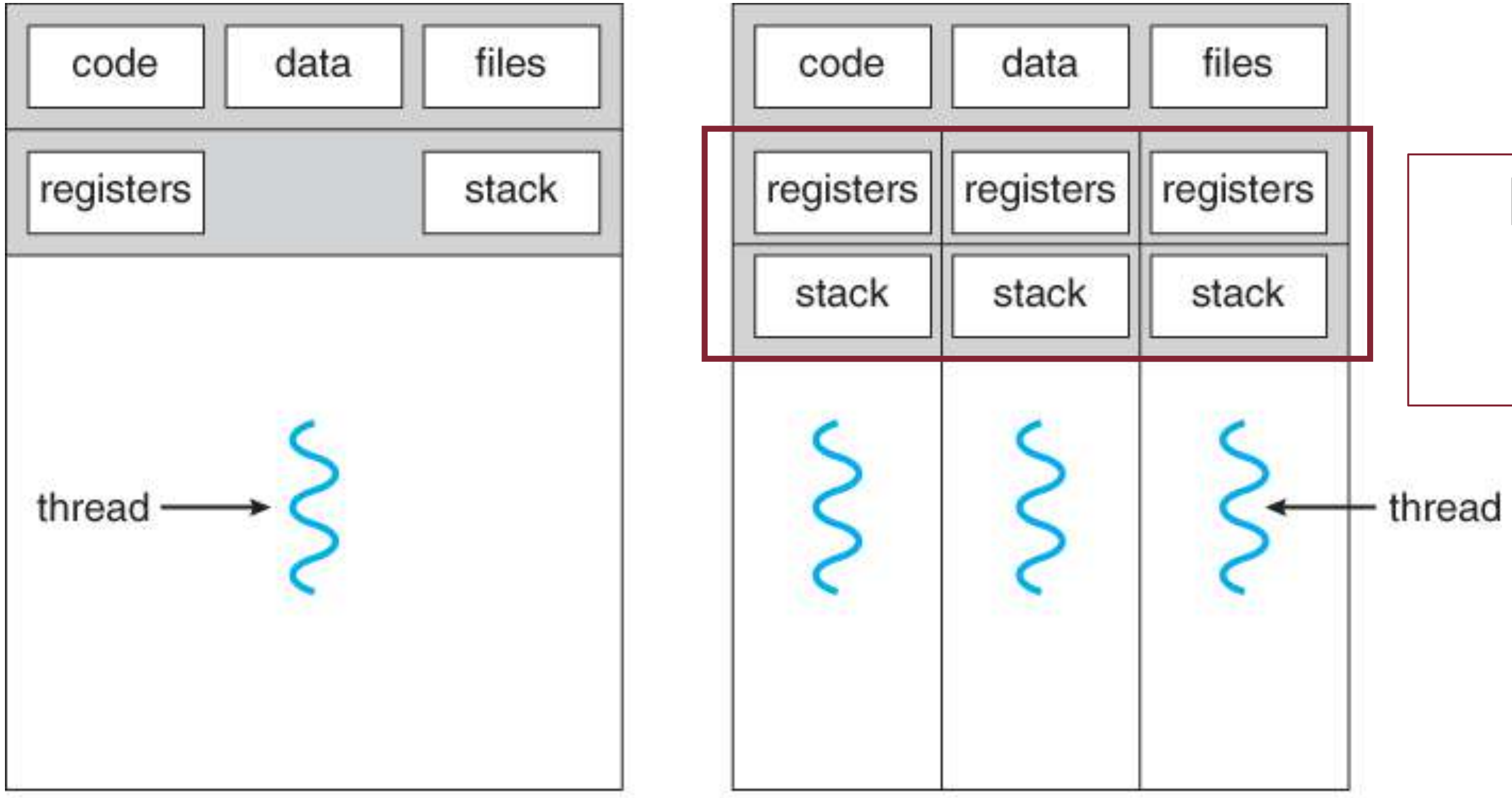
- No system calls are required for threads to cooperate with each other
- Simpler than message passing and shared memory

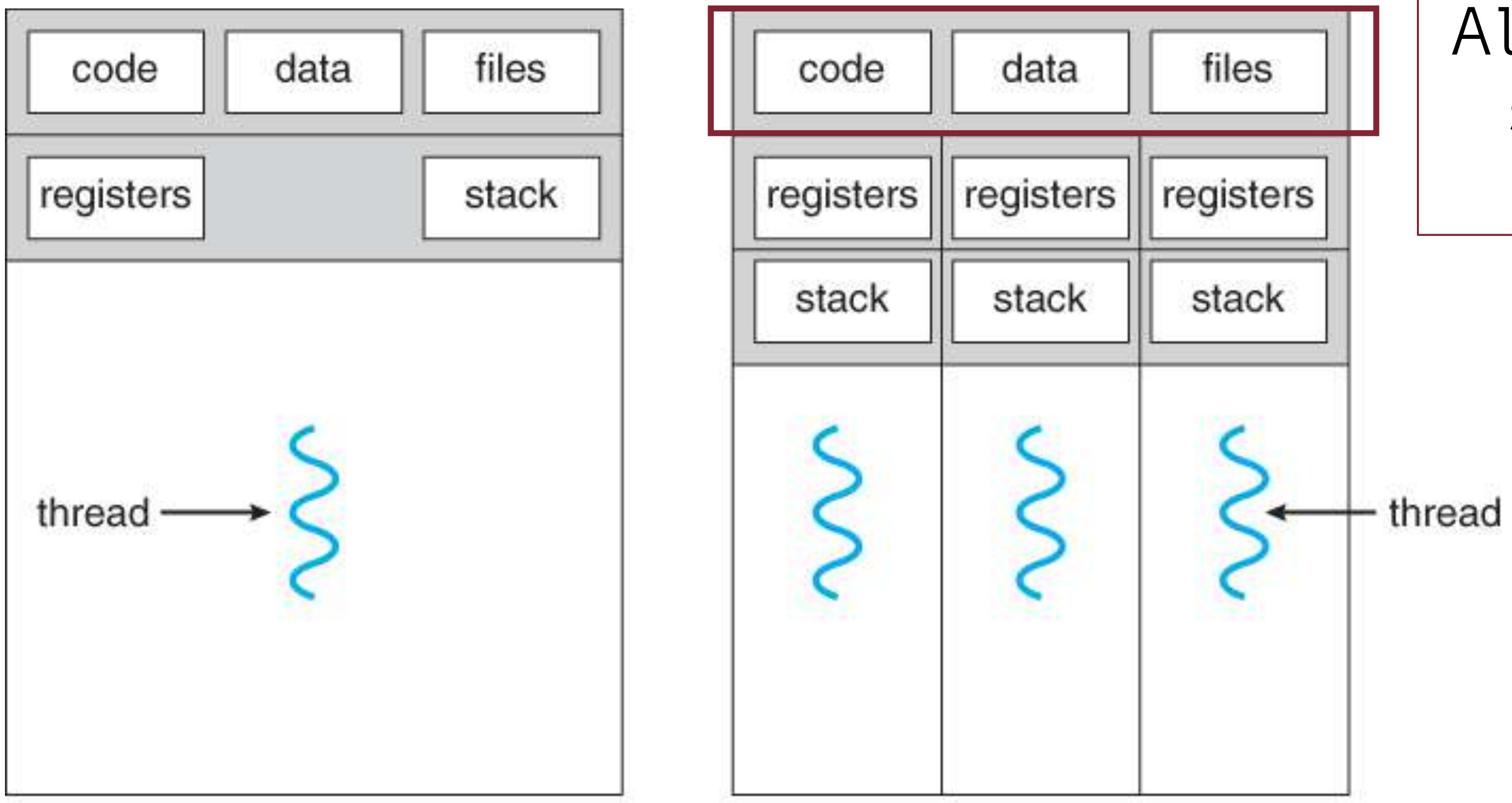
Single- vs. Multi-Threaded Process



single-threaded process
multithreaded process

Each thread has its own independent set of registers and "state"

Single- vs. Multi-Threaded Process

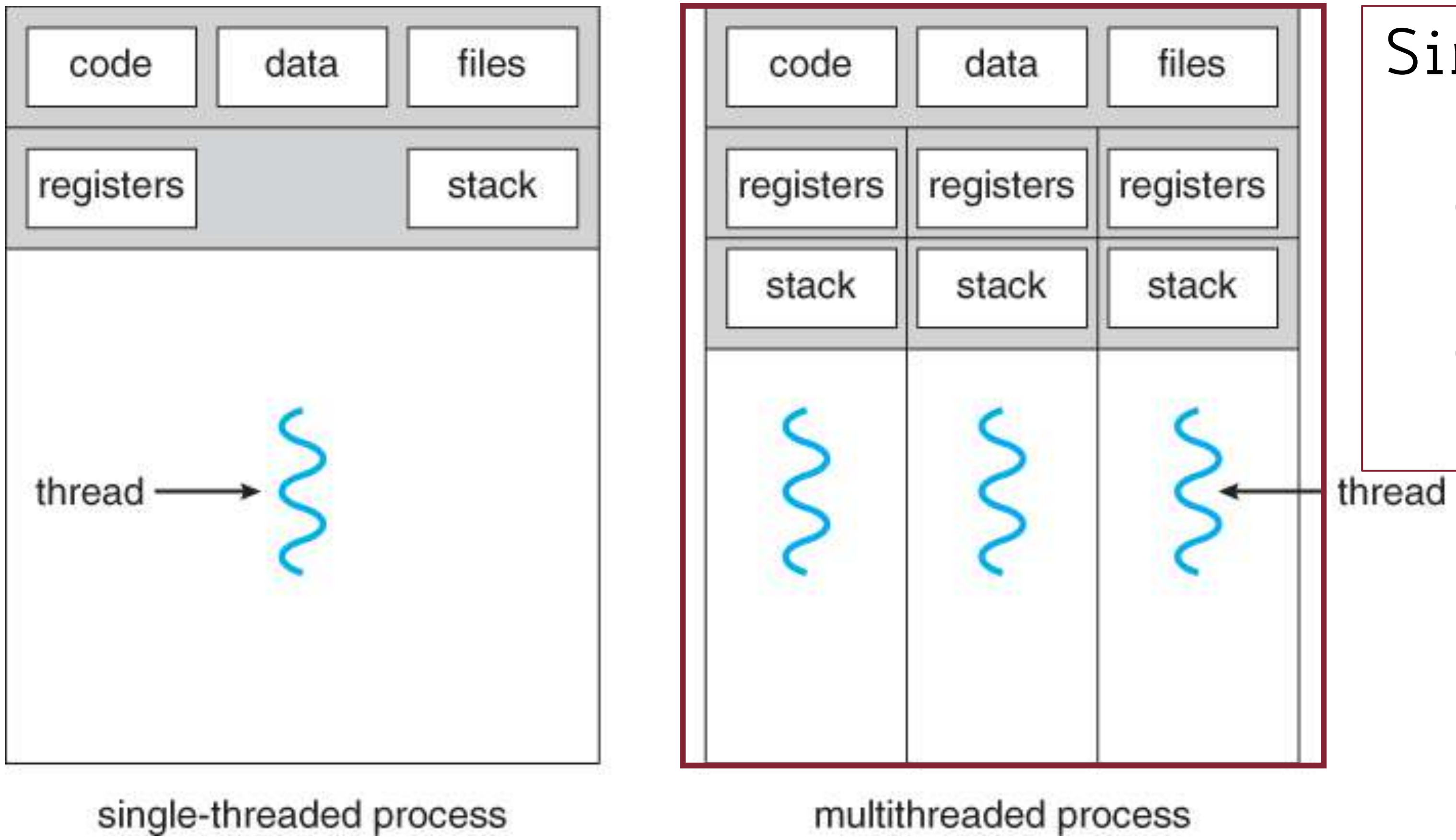


single-threaded process

multithreaded process

All the threads of a process share the same code and "global" resources

Single- vs. Multi-Threaded Process



Since all the threads live in the same address space, communication between them is easier than communication between processes

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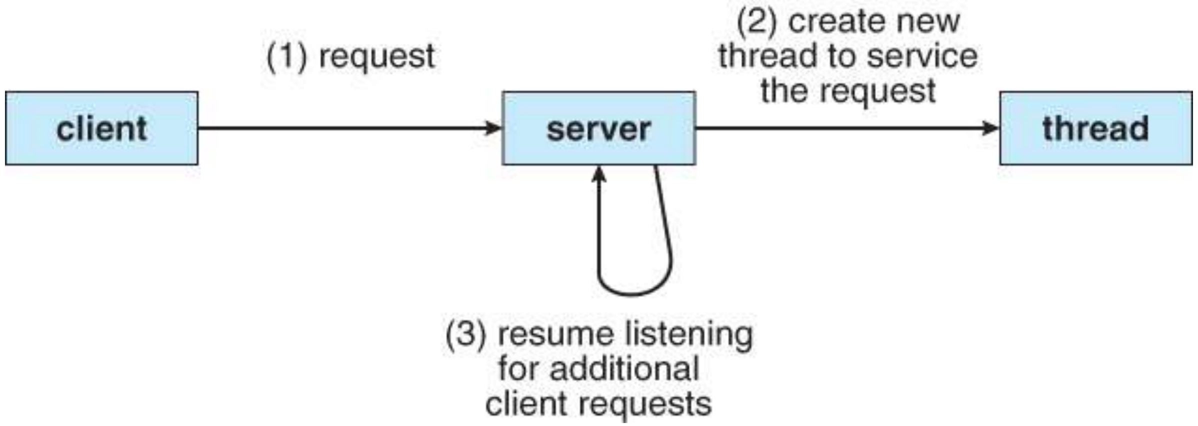
- Example: word processor
    - a thread may check grammar while another thread handles user input (keystrokes), and a third does periodic backups of the file being edited

Multi-threaded Web Server



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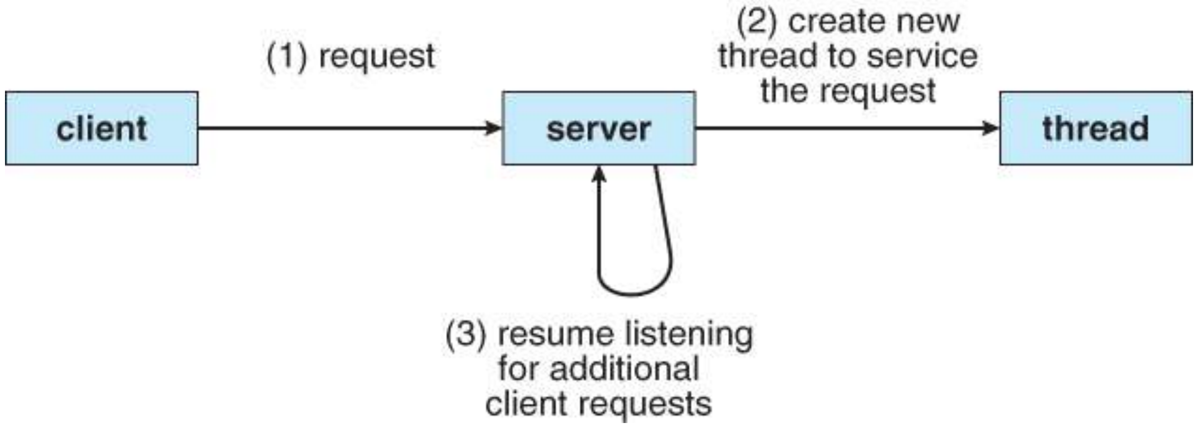

Multiple threads allow for multiple requests to be satisfied simultaneously, without having to serve requests sequentially or to fork off separate processes for every incoming request

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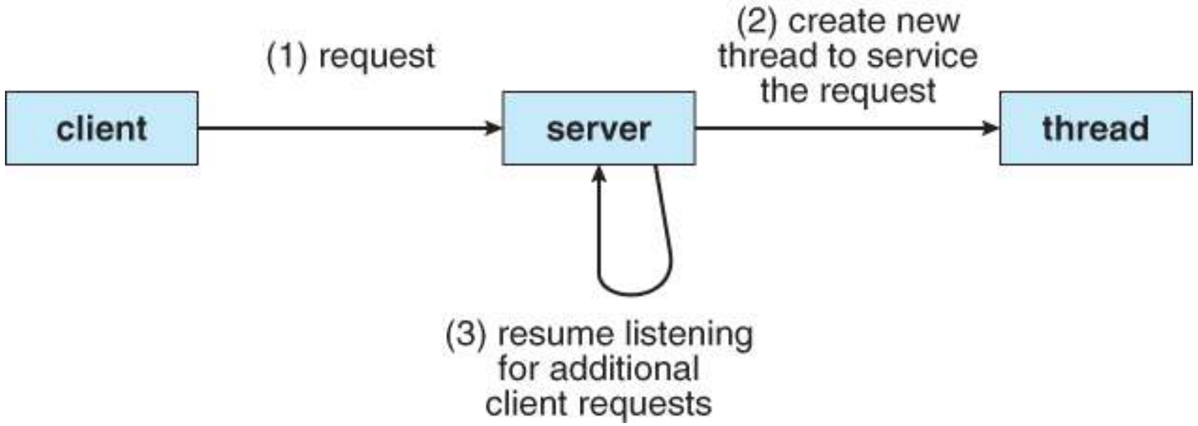

What if the server process spawns off a new process for each incoming request rather than a thread?

Multiple Processes vs. Multiple Threads

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  - Context-switches between threads is a lot faster than between processes

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  - Economy → creating and managing threads (and context switches between them) is much faster than performing the same tasks for processes
  - Scalability (multi-processor architectures) → A single threaded process can only run on one CPU, whereas a multi-threaded process may be split amongst all available processors/cores

Multi-core Programming

- A recent trend in computer architecture is to produce chips with multiple cores, or CPUs on a single chip
- A multi-threaded application running on a traditional single-core chip would have to interleave the threads
- On a multi-core chip, however, threads could be spread across the available cores, allowing **true parallel processing**!

Single- vs. Multi-core Programming

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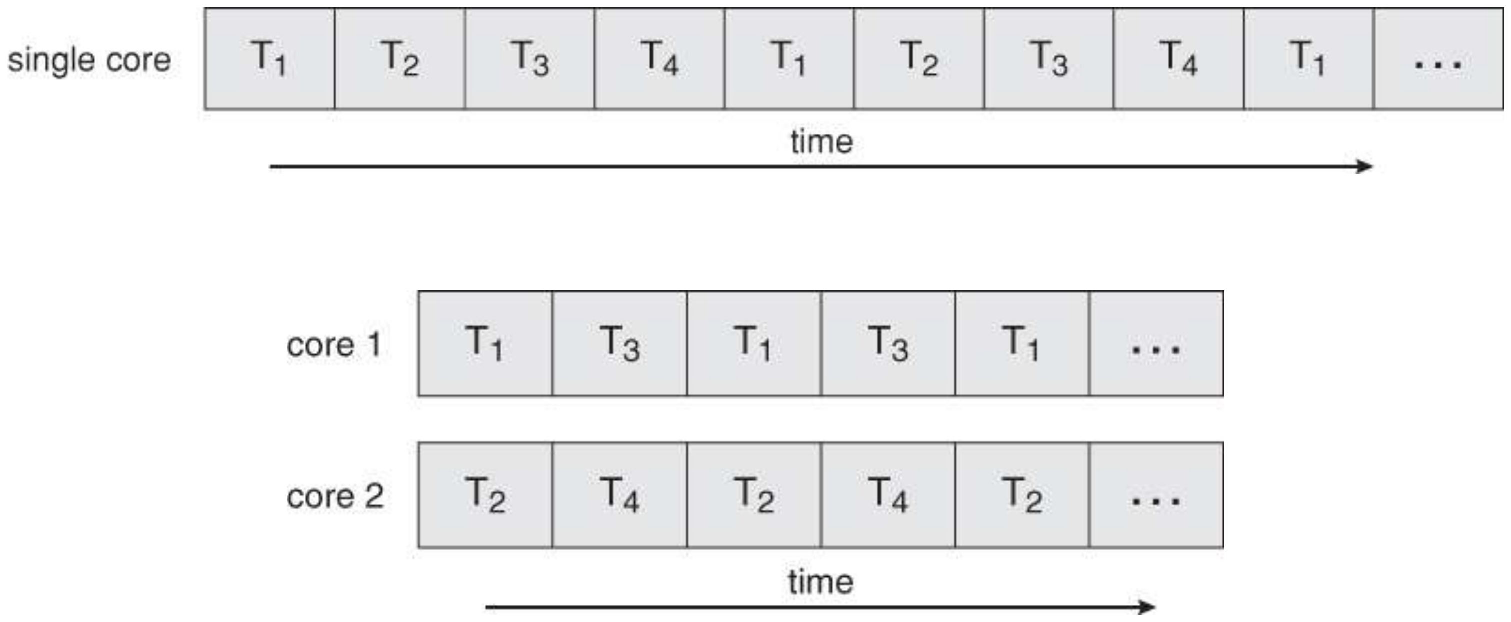

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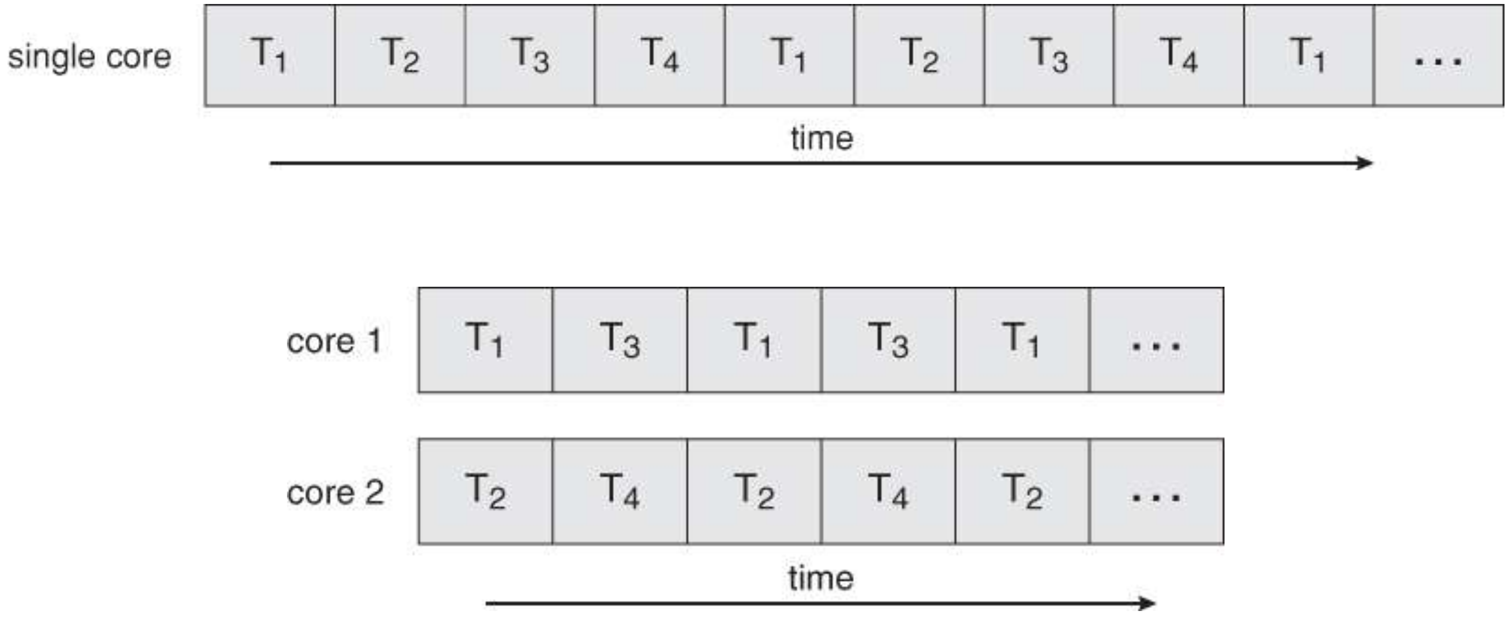

Multi-core chips require new OS scheduling algorithms to make better use of the multiple cores available

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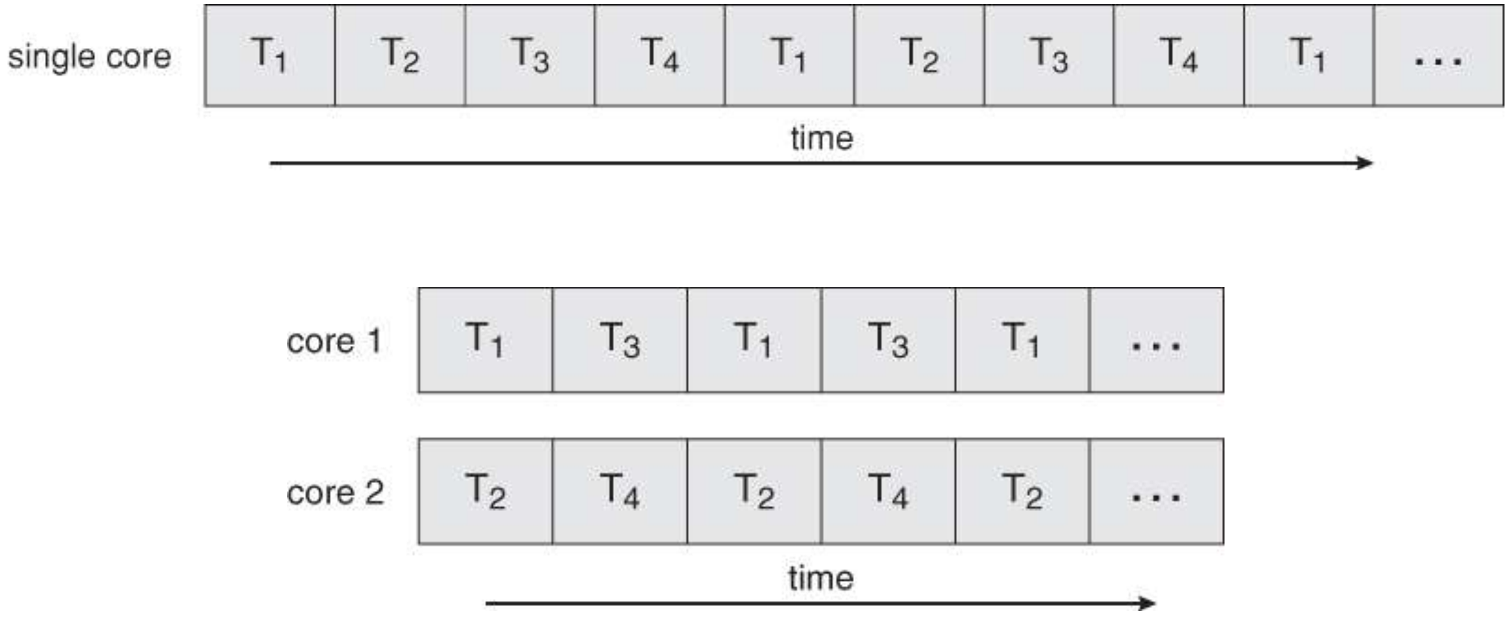

CPUs have been developed to support more simultaneous threads per core in hardware (e.g., Intel's hyper-threading)

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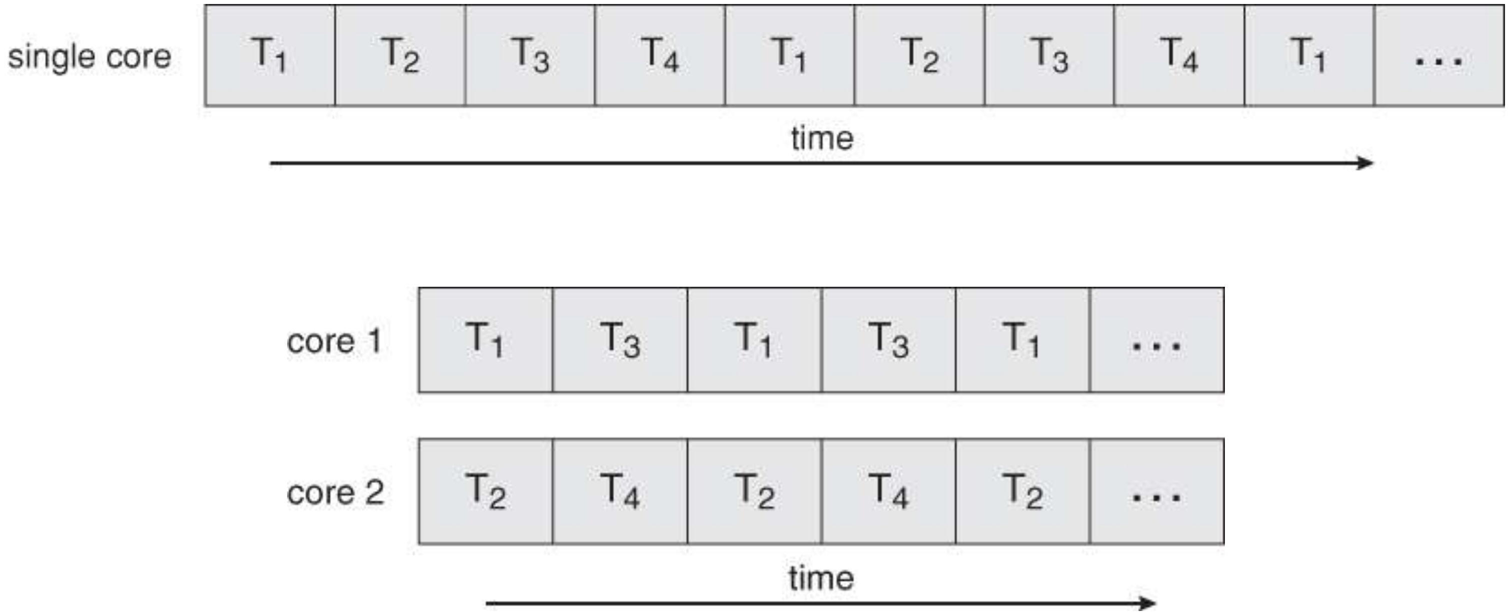

Hyper-threading

Each physical core appears as two processors to the OS, allowing concurrent scheduling of two threads per core

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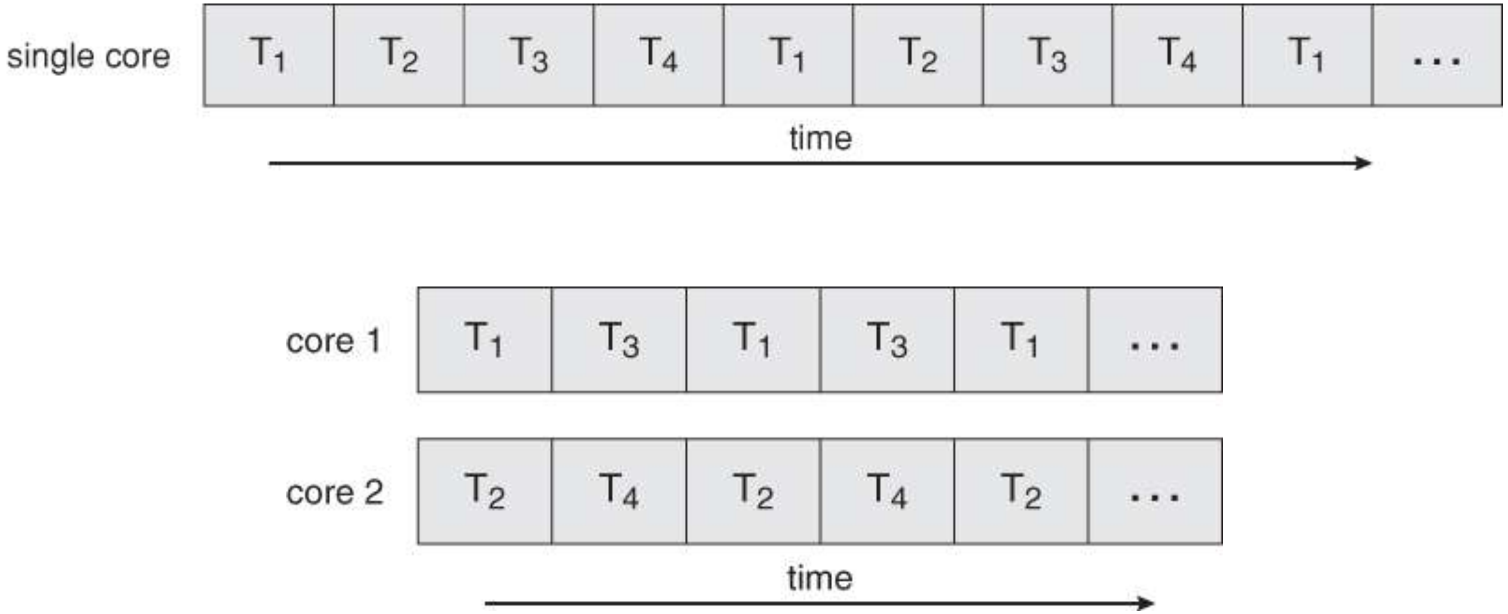

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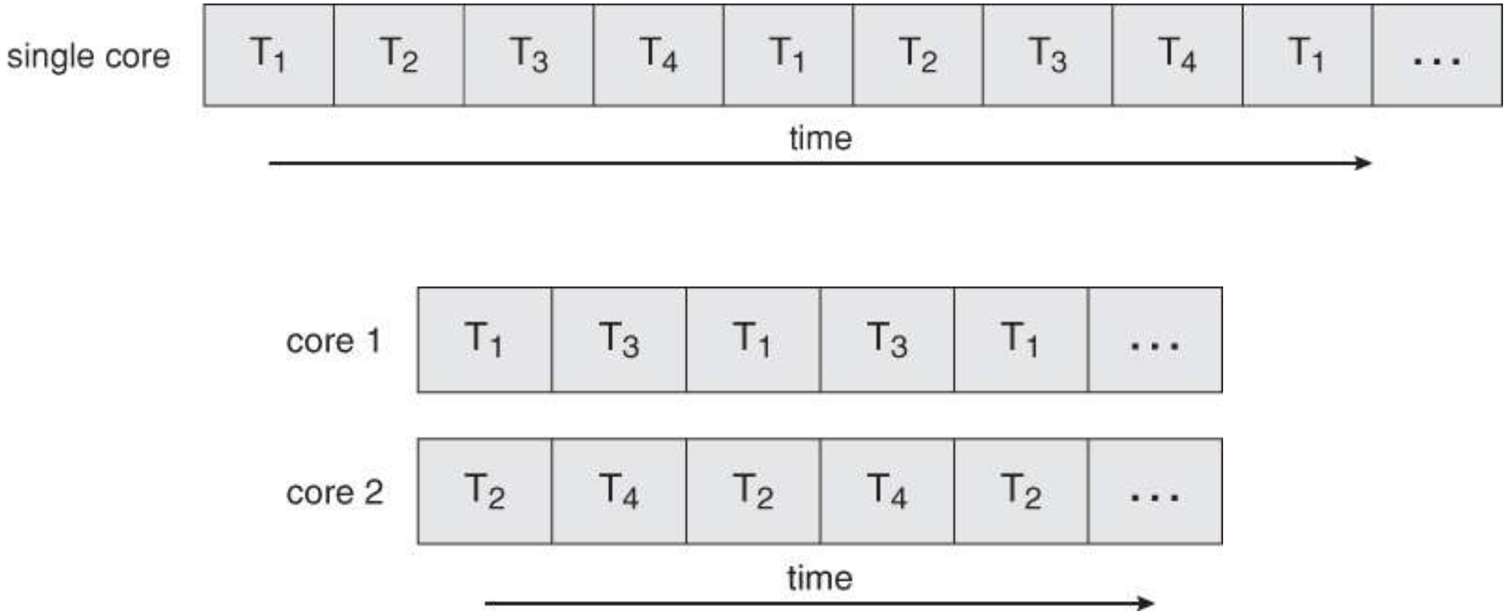

Concurrency

vs.

Parallelism

Types of Parallelism

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  - **Data parallelism:** divides the data up amongst multiple cores (threads), and performs the same task on each chunk of the data
  - **Task parallelism:** divides the different tasks to be performed among the different cores and performs them simultaneously

Example: A Pure CPU-bound Task

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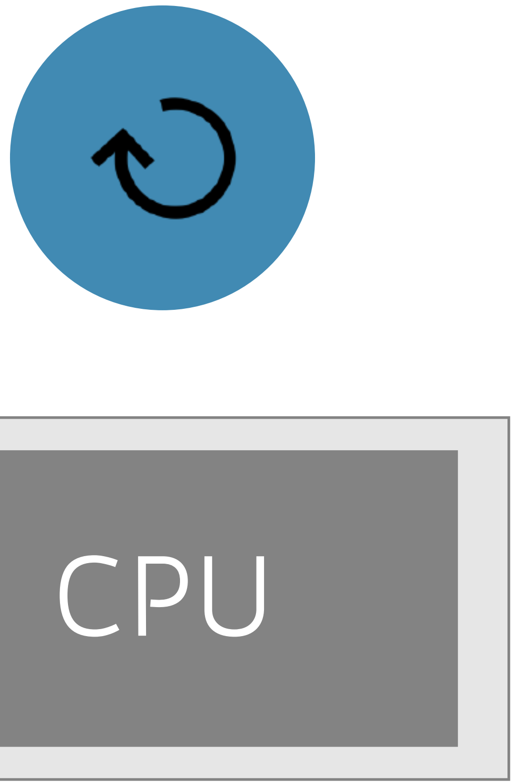
- We will consider the following setups:
  - Number of CPU cores: 1 vs. M
  - Processes/Threads: 1/1 vs. M/1 vs. 1/M

1 CPU Core, 1 Process, 1 Thread



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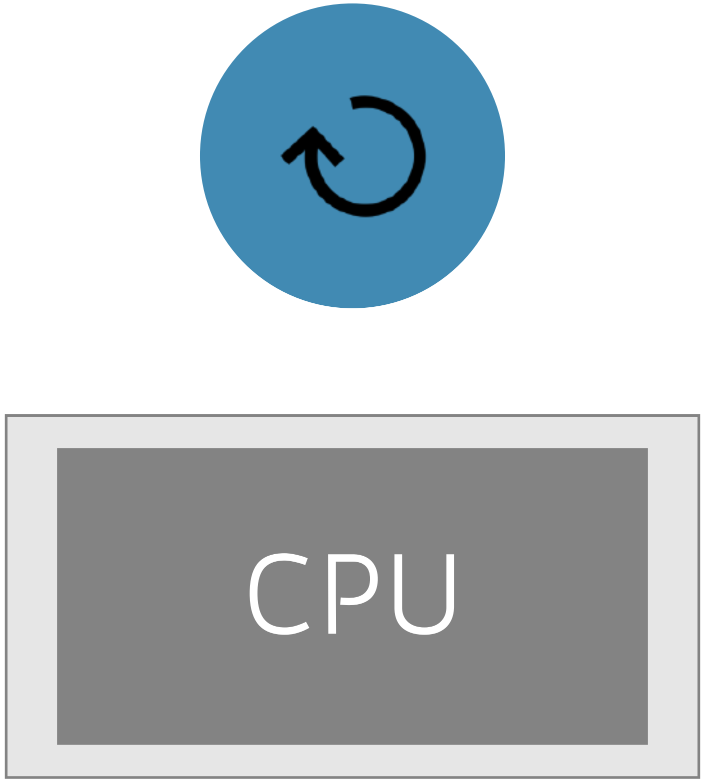
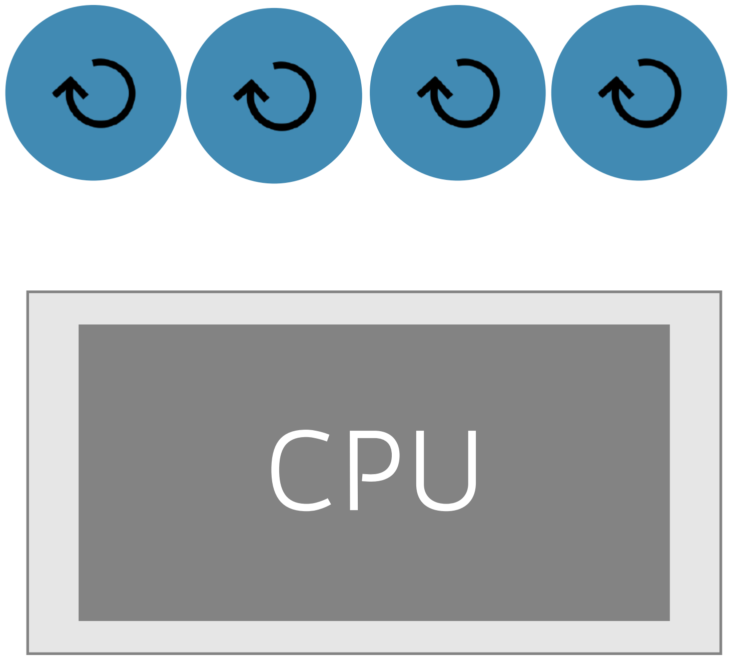


No Parallelism

No Concurrency

1 CPU Core, M Processes, 1 Thread

Divide N into M chunks: {[1, …, N/M], [(N/M)+1, … , 2N/M], …, [(M-1)(N/M)+1, …, N/M]}



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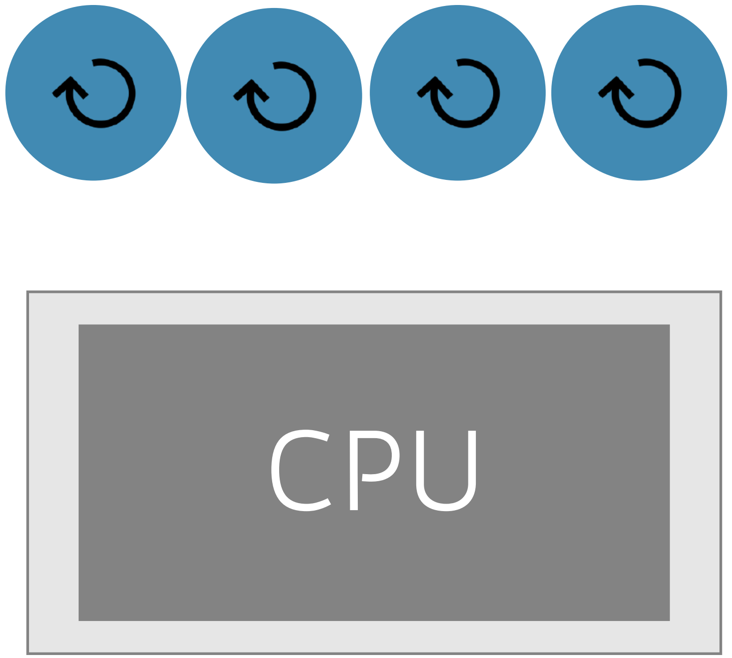
e.g., N = 1000; M=8: {[1, …, 125], [126, …, 250], …, [876, …, 1000]}



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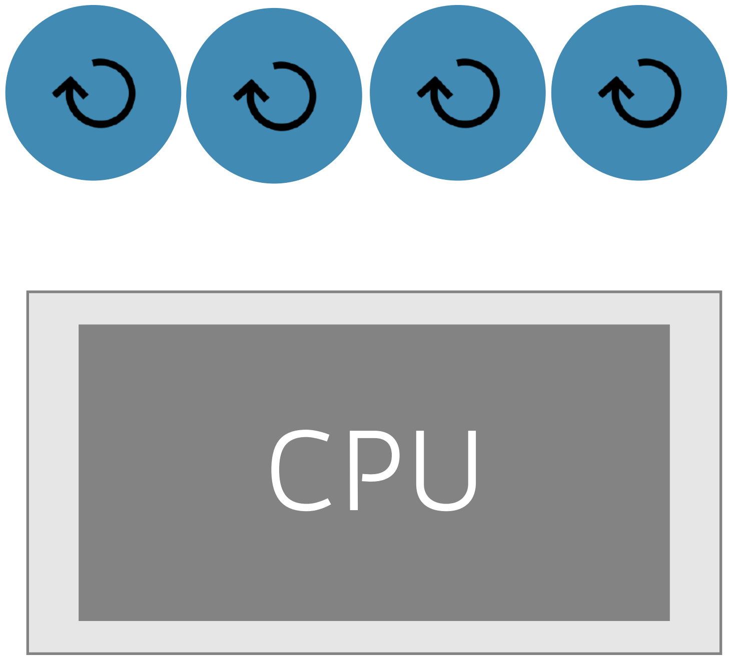

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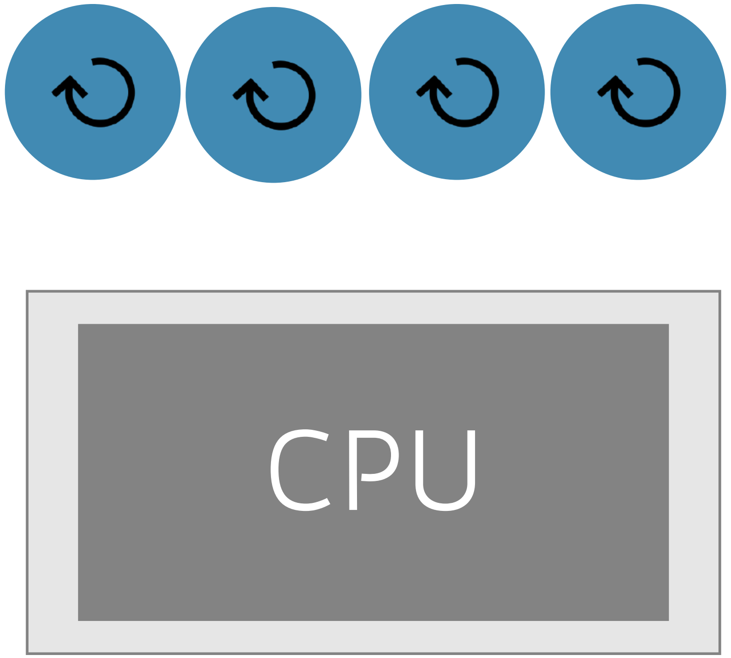

No Parallelism

Concurrency (among processes)

1 CPU Core, M Processes, 1 Thread

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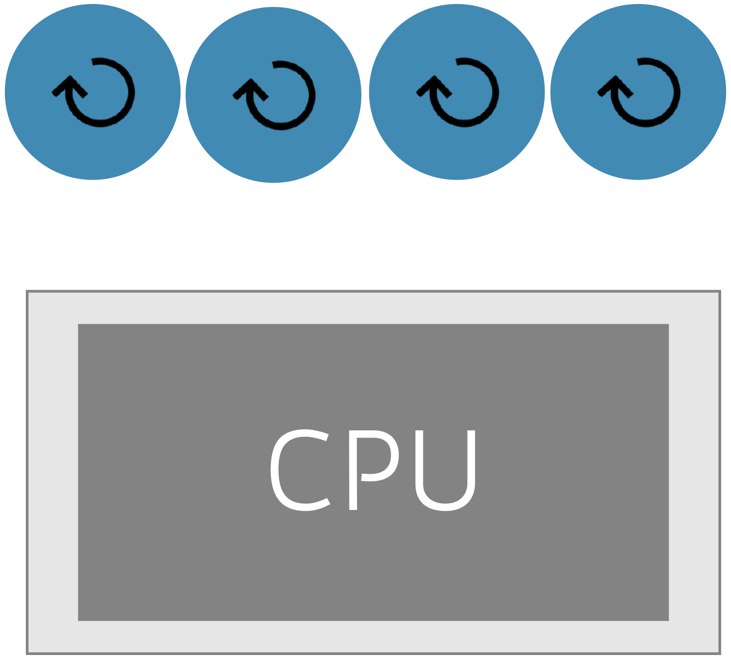

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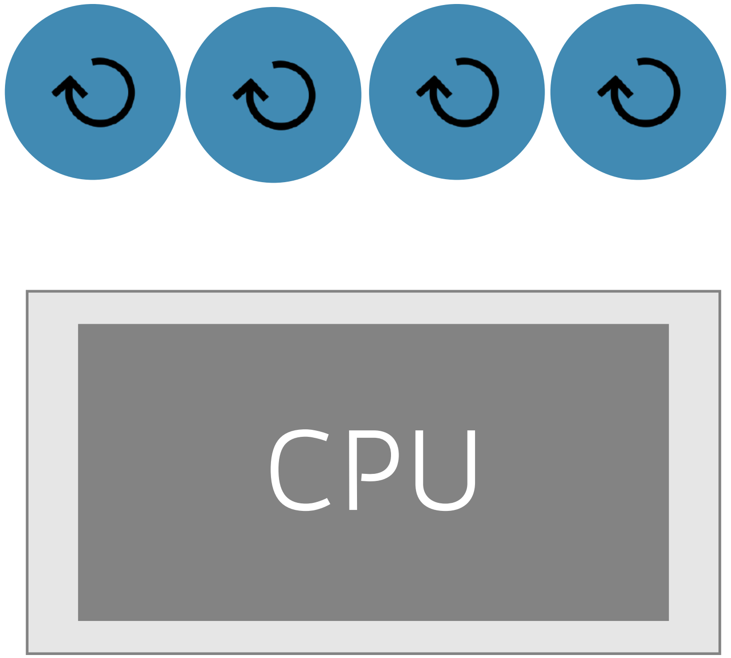

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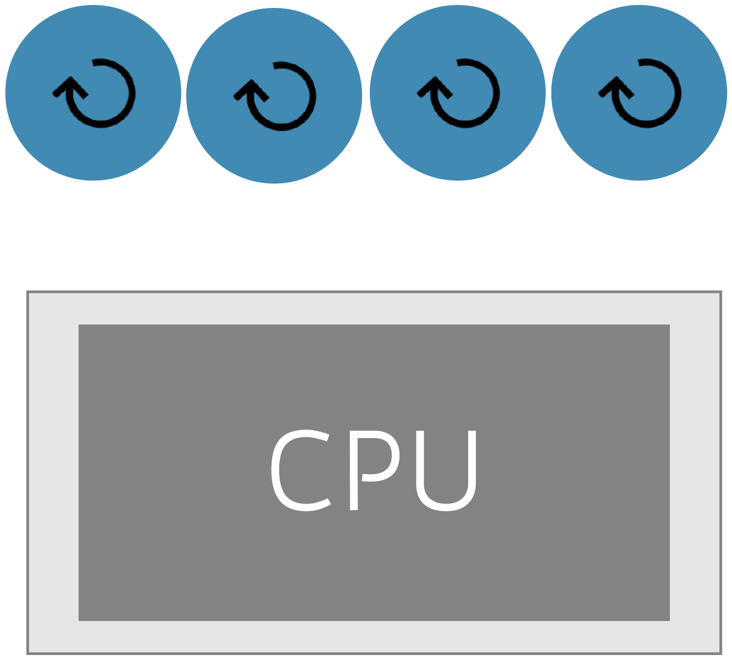

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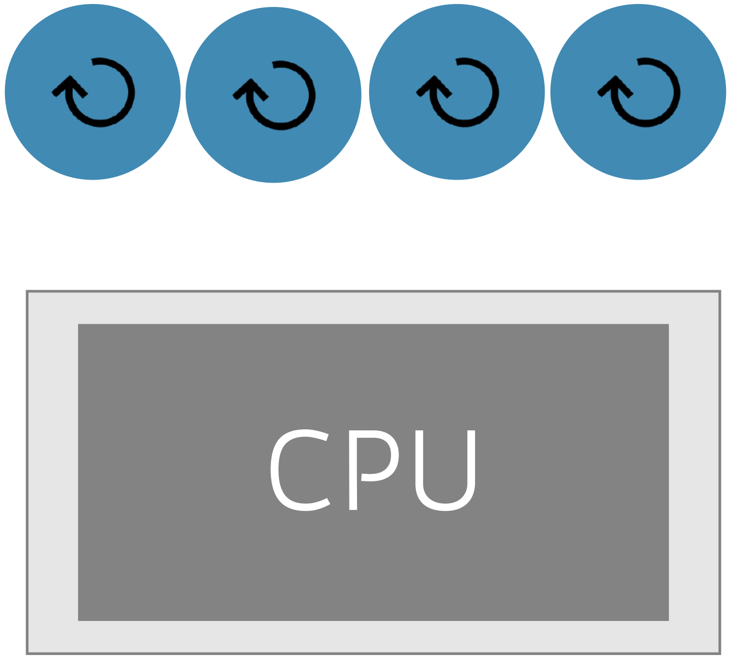

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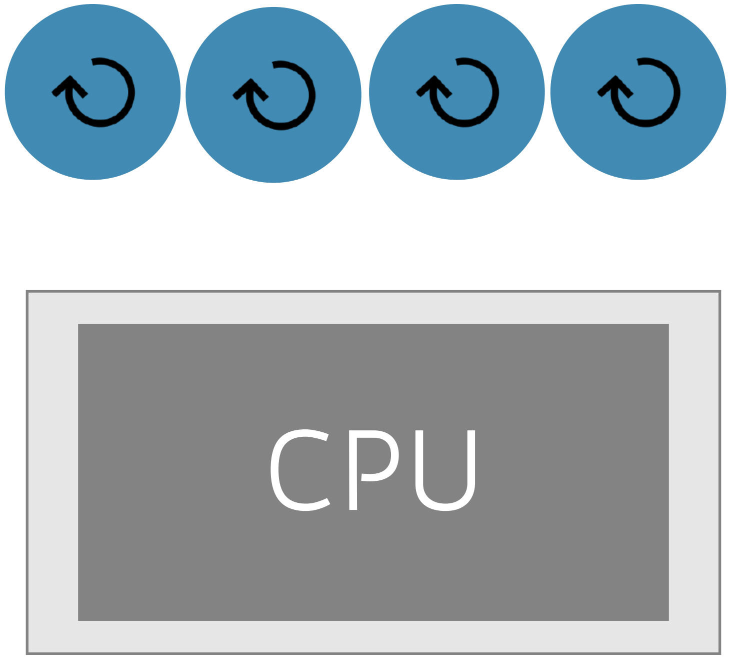

Eventually, each process must communicate its partial sum to the others

Inter-Process Communication

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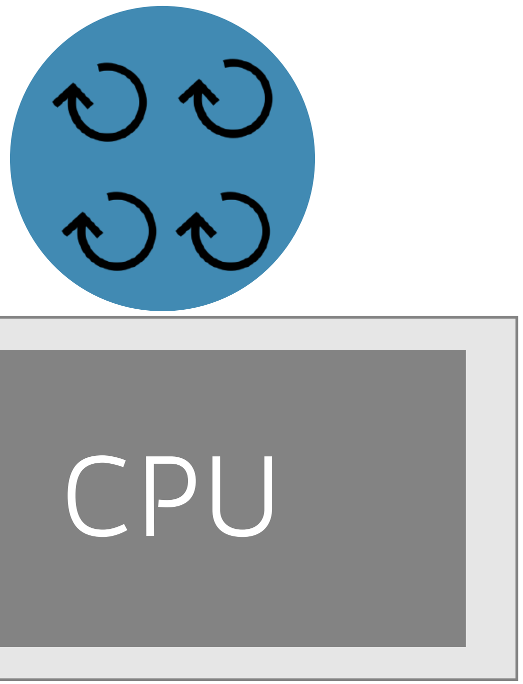

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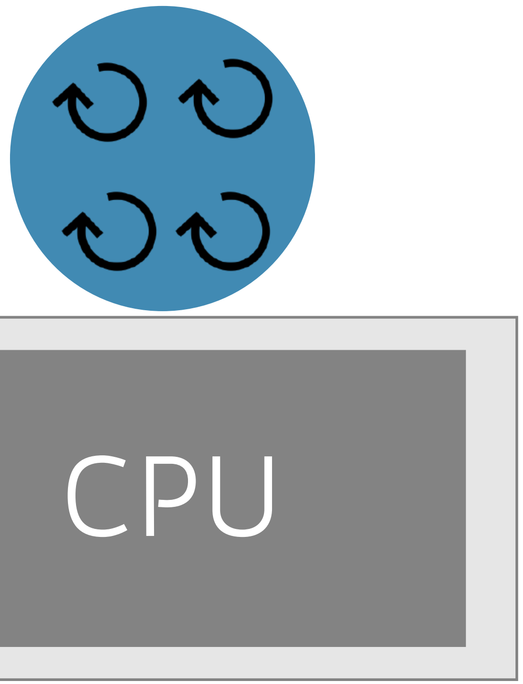

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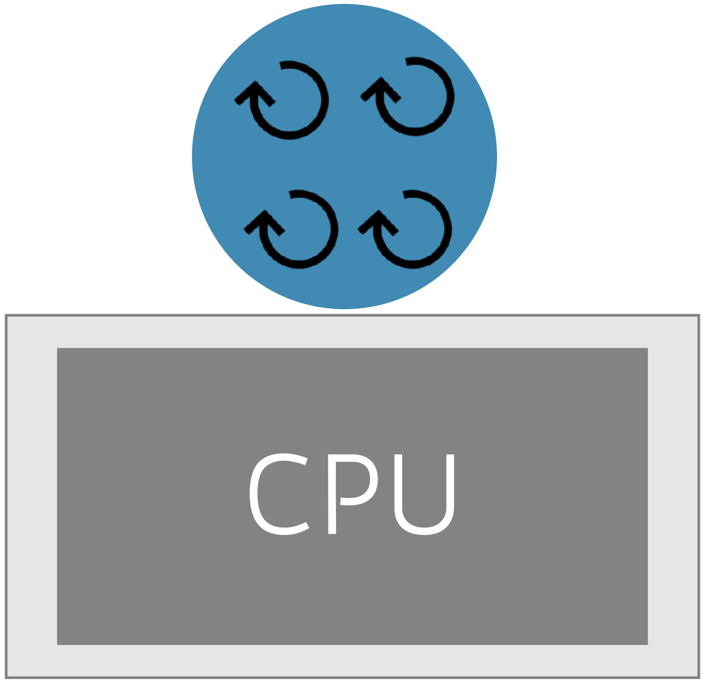

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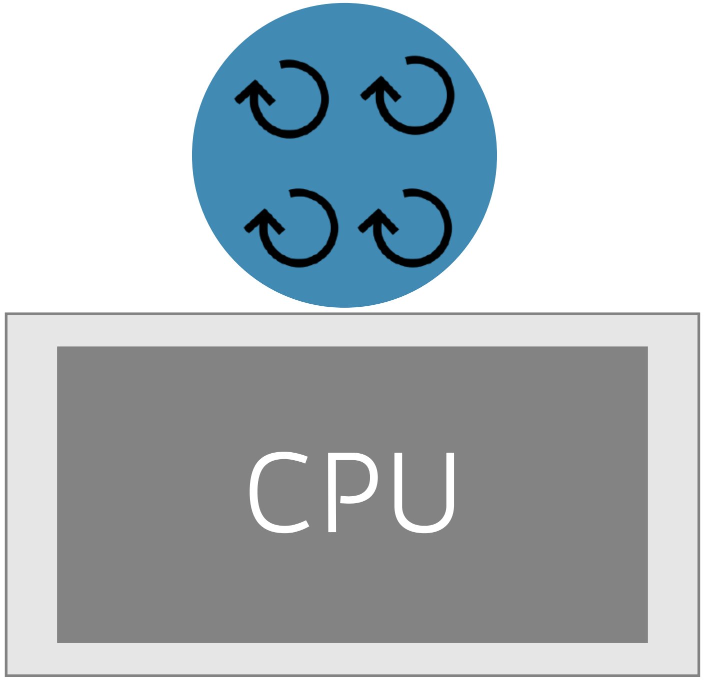

The only advantage is that each thread can easily share its partial sum with the others!

No Inter-Process Communication

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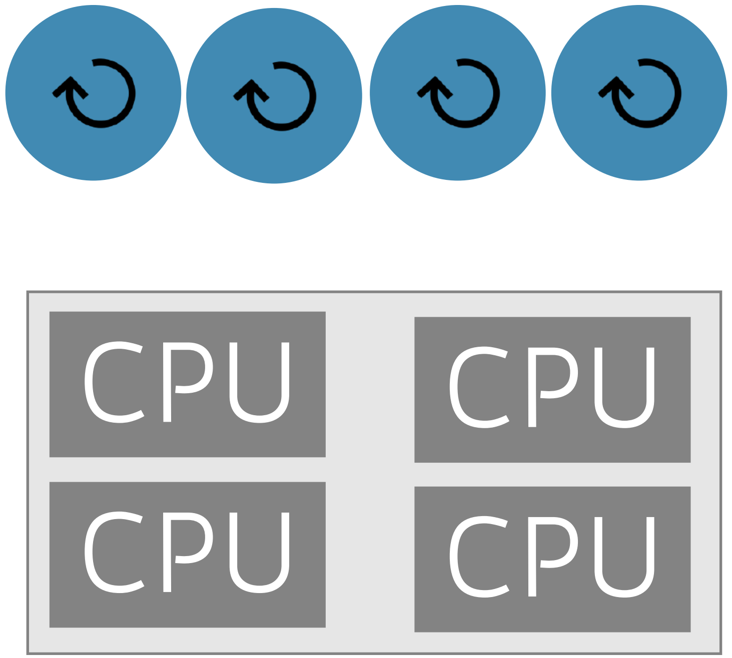

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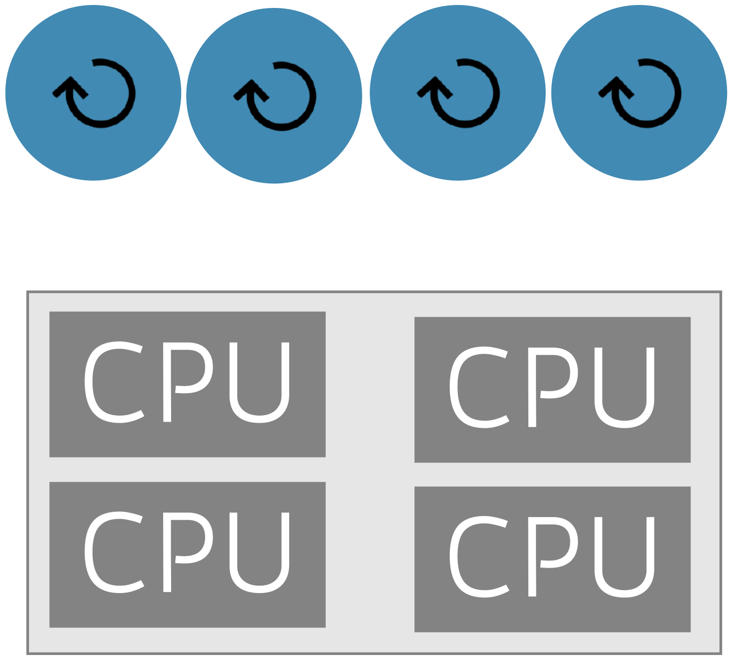

True Parallelism

Still, each process must communicate its partial sum to the others

M CPU Cores, 1 Process, M Threads

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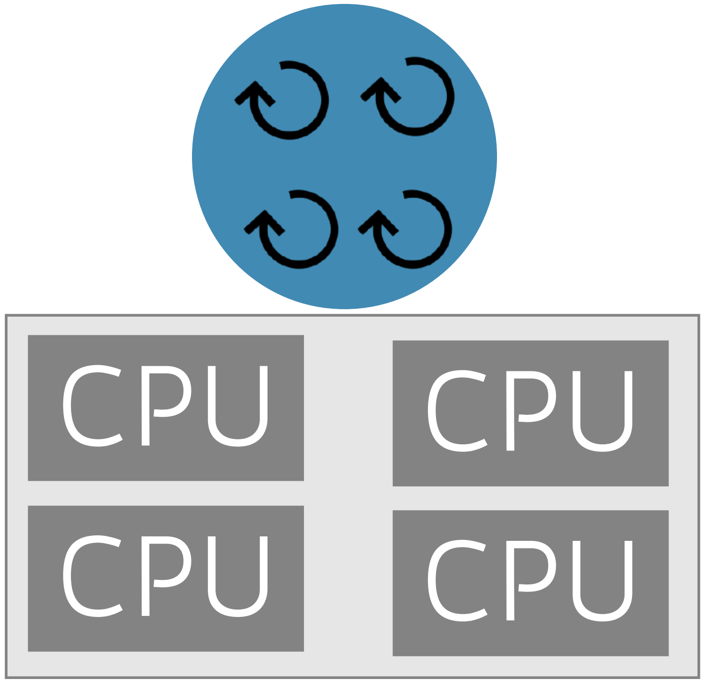

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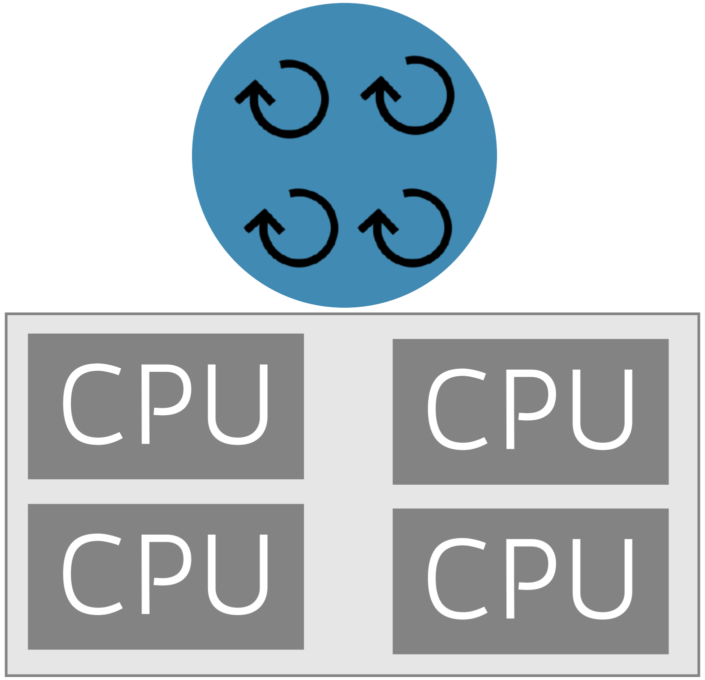

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A Mixed CPU- and IO-bound Task

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  - Compression/Decompression algorithms (side-by-side)

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- This way the CPU- and I/O-bound threads can alternate on the CPU
- This slows down the CPU-bound thread a little, but reduces or eliminates the I/O-bound gap

Classifying OSs

address space

thread

Classifying OSs

single thread

address space

thread

multiple threads

Classifying OSs

address space

thread

single address space
(uniprogramming)

multiple address spaces
(multiprogramming)

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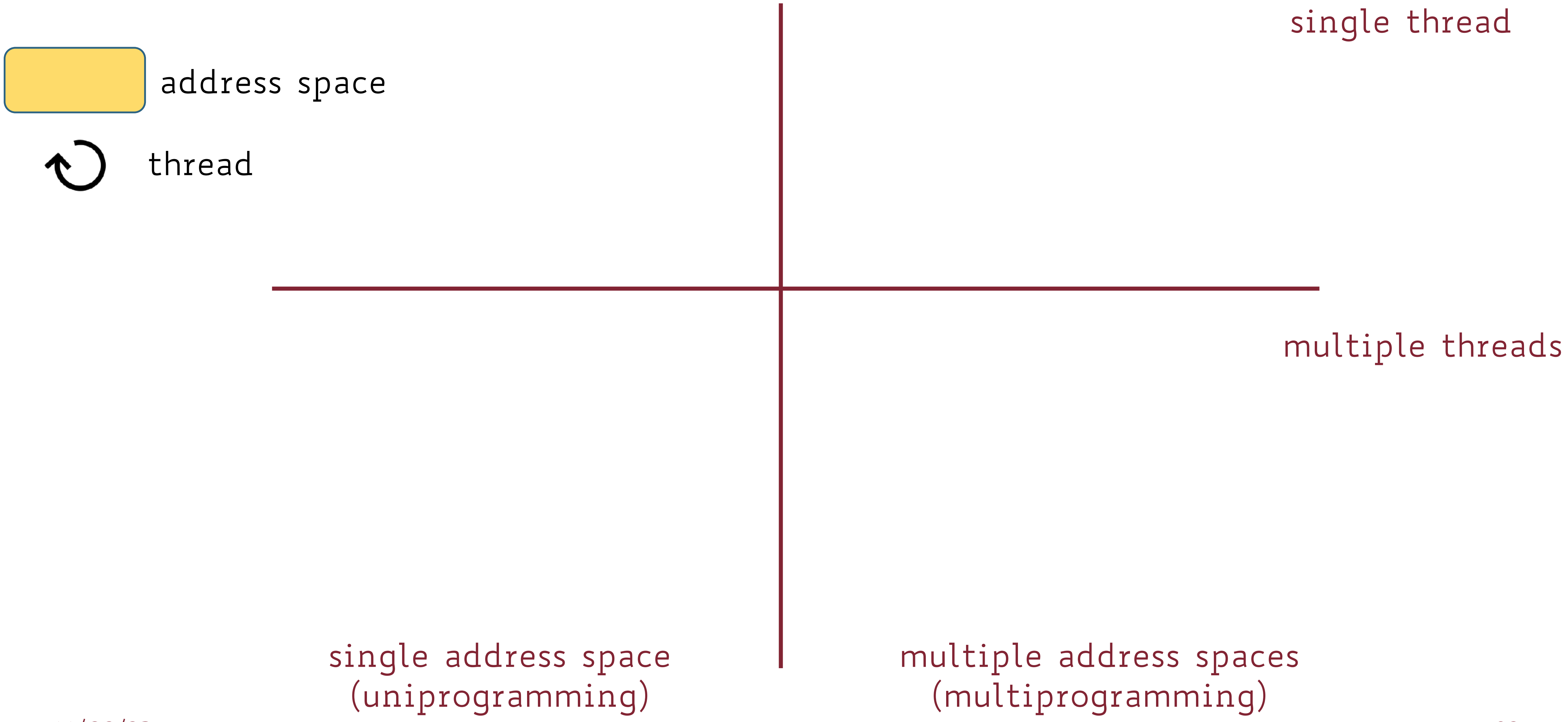

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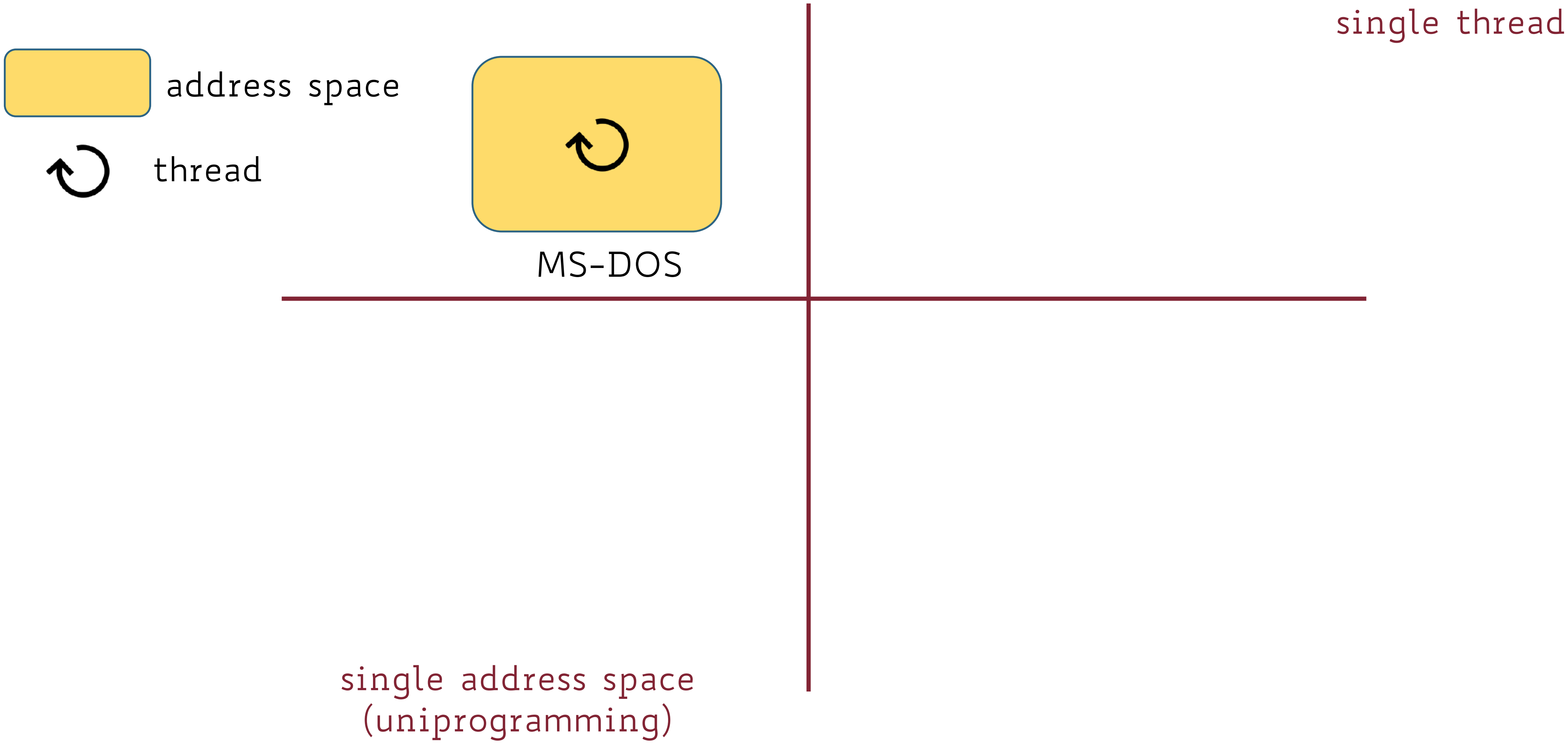

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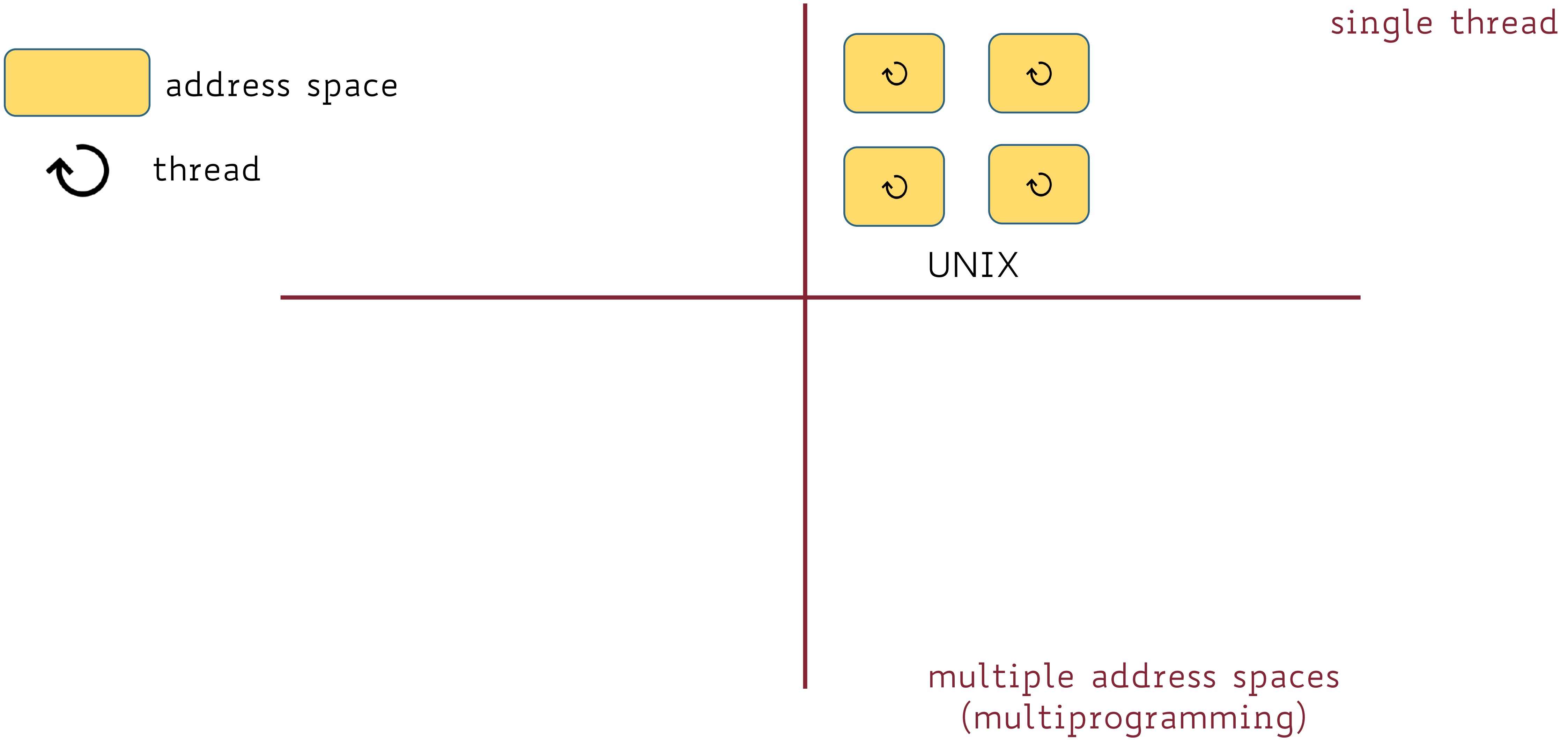

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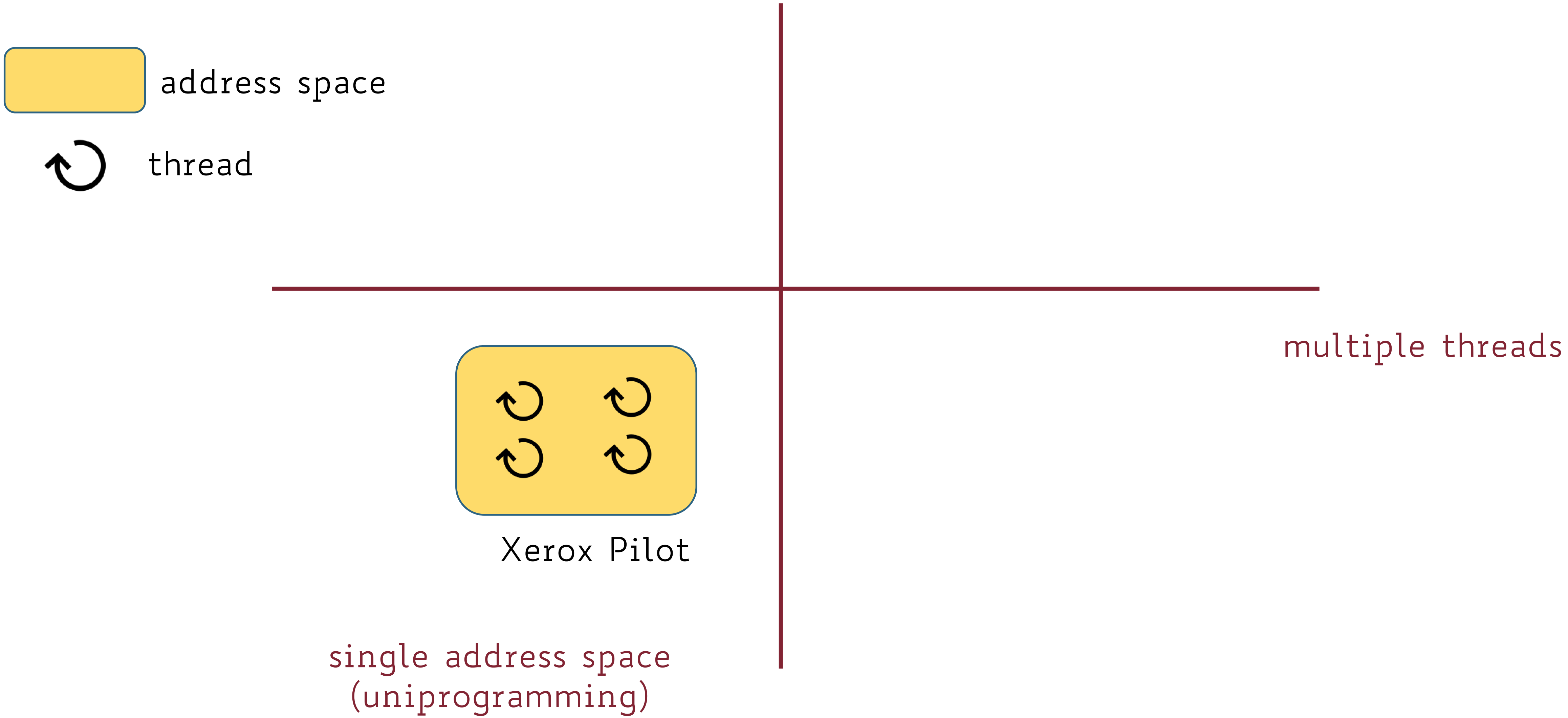

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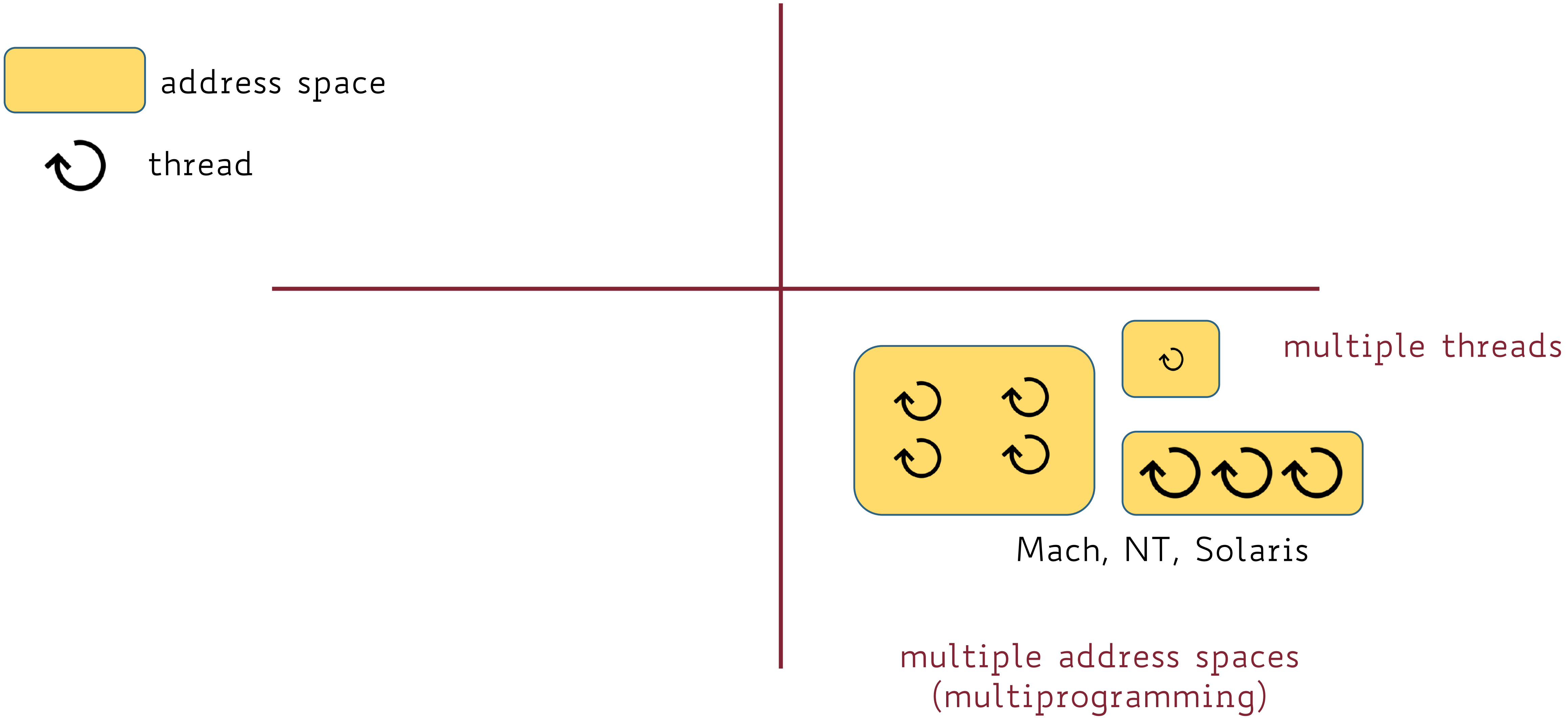
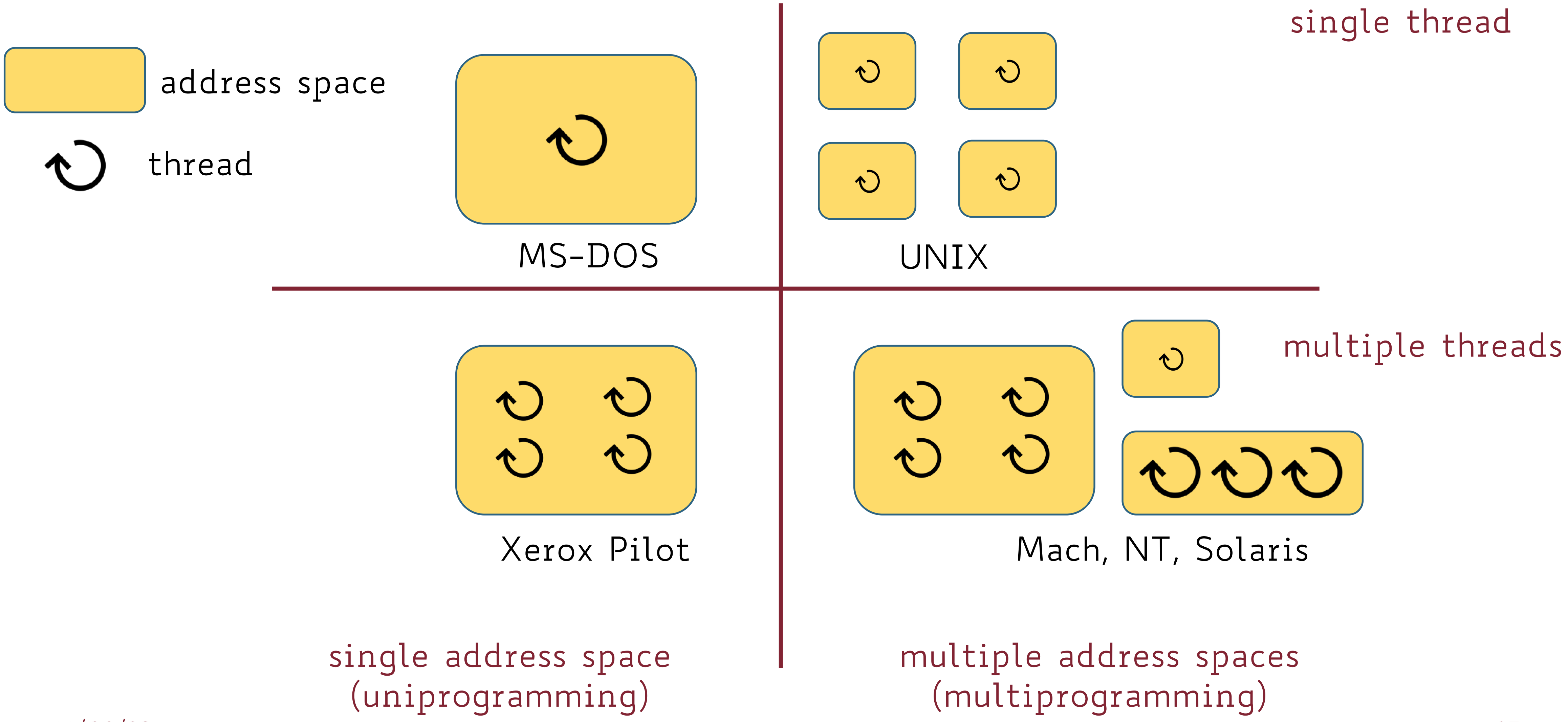


Classifying OSs



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- Thread vs. Process:
  - common vs. separate address spaces → **quicker communication**
  - lightweight vs. heavyweight → **faster context switching**
- On a single core:
  - Fully CPU-bound processes do not take advantage of multi-threading
  - Concurrency between threads in mixed CPU- and I/O-bound processes