Lecture 26: Parallelism I

CS 62

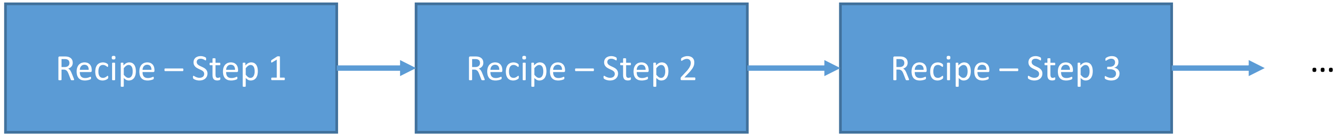
Fall 2018

Alexandra Papoutsaki & William Devanny

Some slides based on those fom Dan Grossman, U. of Washington

The story so far assumed…

- *Sequential programming*: everything is part of one sequence and happens one thing at a time
  - E.g., in Java start at `main()` , one assignment/call/return/arithmetic operation at a time



Recipe – Step 1

Recipe – Step 2

Recipe – Step 3

…

Multi-threaded programming

In *multi-threaded programming* we need to rethink:

- Programming: work is divided among threads of execution that need to be coordinated (*synchronized*)
- Algorithms: parallelism increases the work done per unit time (*throughput*)
- Data Structures: need to provide *concurrent* access if multiple threads access the same data

A simplified view of history

- Writing correct and efficient multithreaded code is often much more difficult than sequential code
  - Especially in common languages like Java and C
  - So typically stay sequential if possible
- From roughly 1980-2005, desktop computers got twice as fast every couple years at running sequential programs
- But nobody knows how to continue this
  - Increasing clock rate generates too much heat
  - Relative cost of memory access is too high
  - But we can keep making "wires exponentially smaller" (Moore's "Law"), so put multiple processors on the same chip ("multicore")

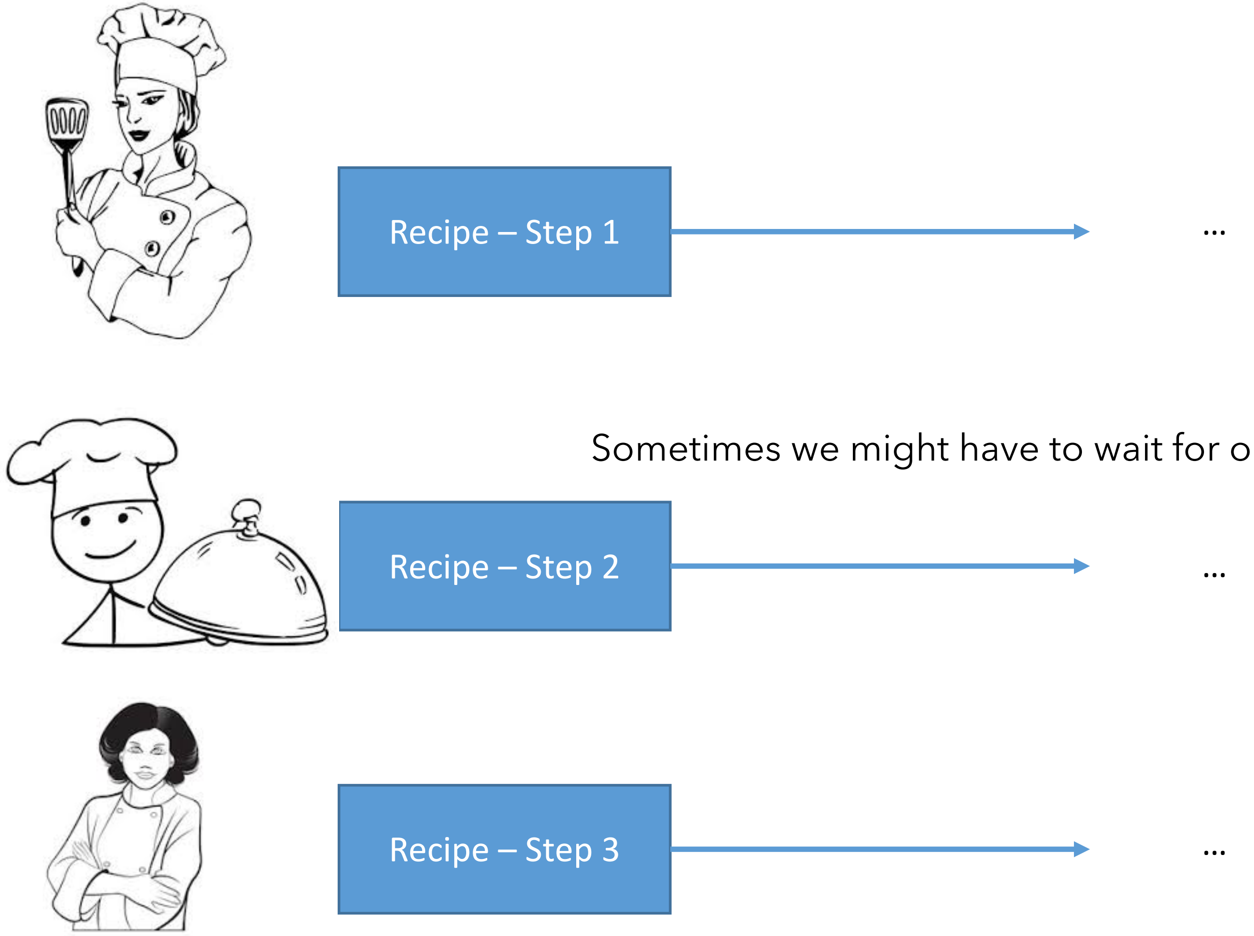
What can we do with multiple cores?

- Run multiple totally different programs at the same time
  - Already doing that, but with *time-slicing*
- Do multiple things at once in one program
  - Our focus – more difficult
  - Requires rethinking everything from asymptotic complexity to how to implement data-structure operations

Parallelism vs Concurrency – Separate Terms

- **Parallelism**: Use extra resources to solve a problem faster
- **Concurrency**: Correctly and efficiently manage shared resources
- Common ground:
  - They both use threads
  - If parallel computations need access to shared resources, then the concurrency needs to be managed

Parallelism



Recipe – Step 1

…

Sometimes we might have to wait for one cook to finish their step

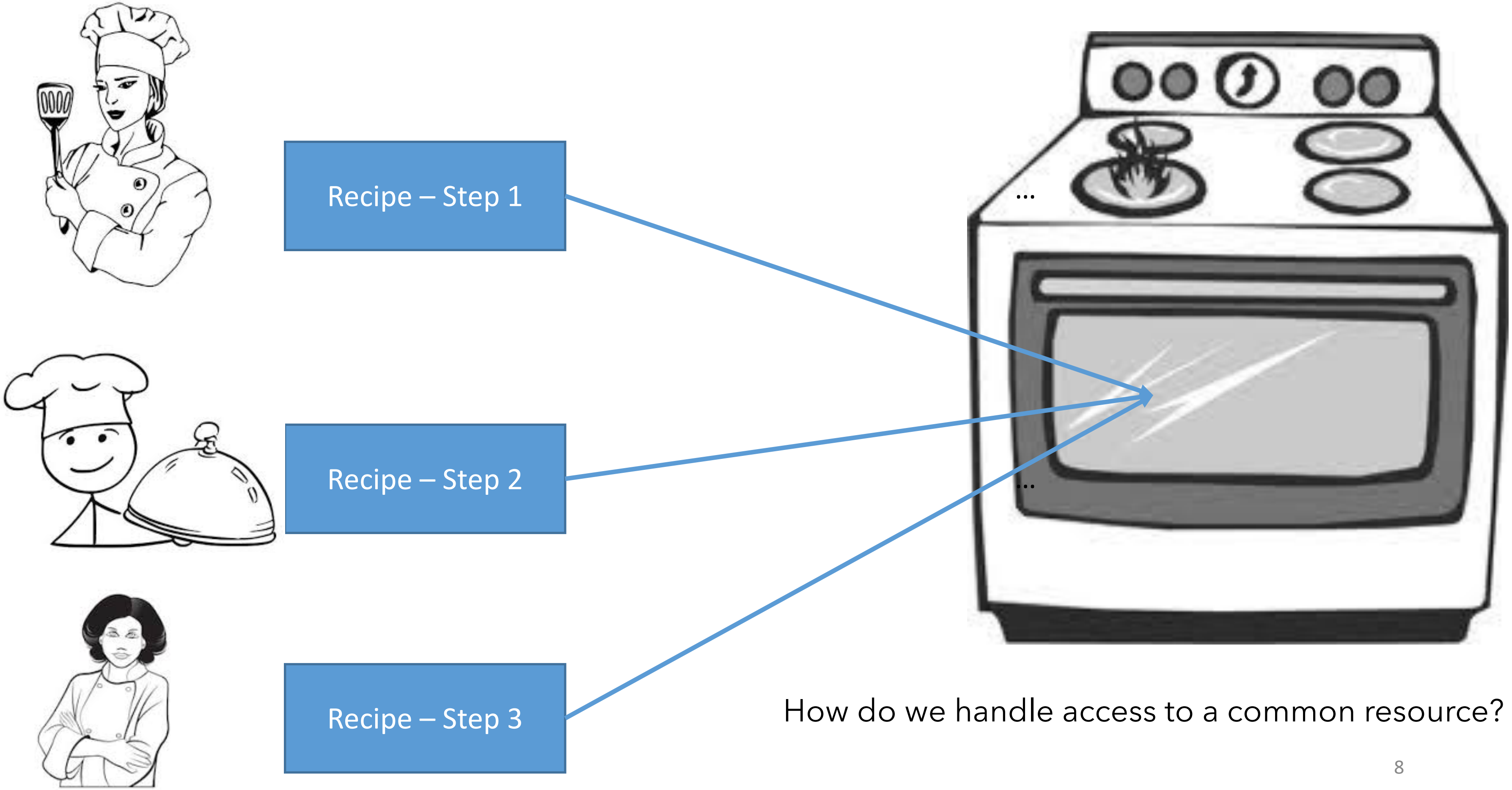
Recipe – Step 2

…

Recipe – Step 3

…

Concurrency



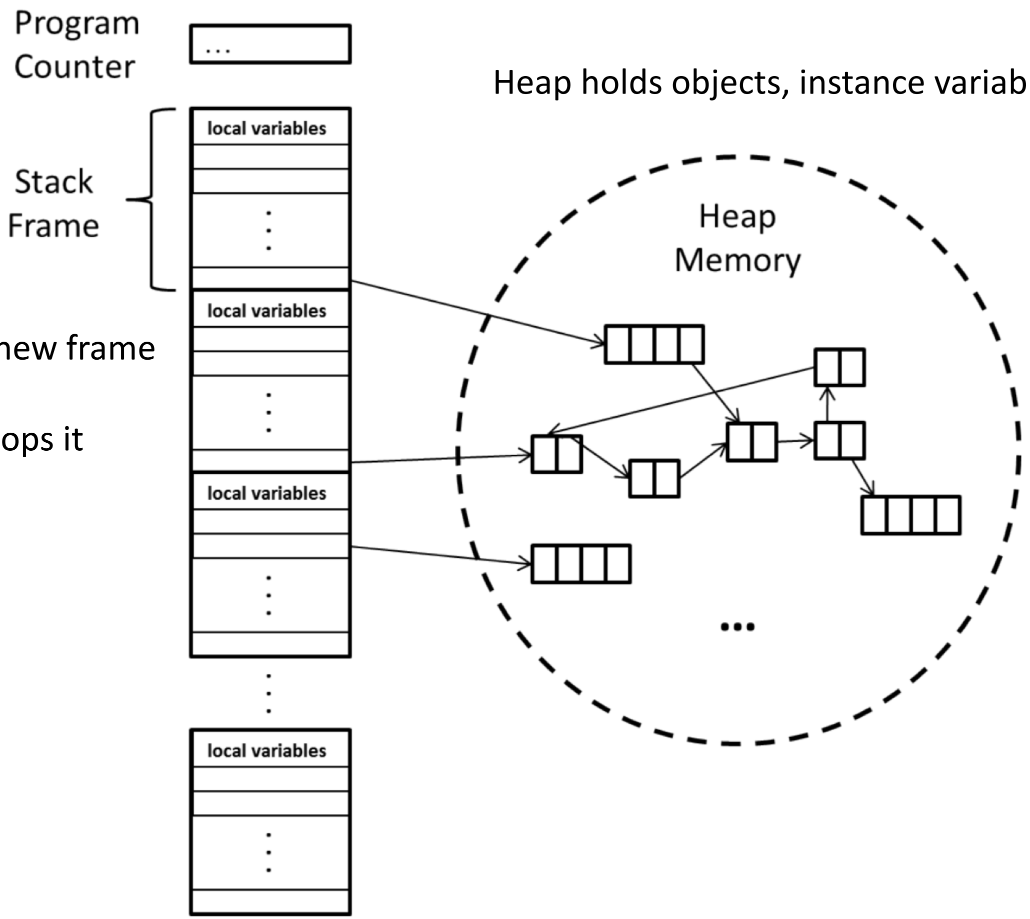
Recipe – Step 1

Recipe – Step 2

Recipe – Step 3

How do we handle access to a common resource?

Program state in sequential programming



Heap holds objects, instance variables, and static variables

Calling a method pushes a new frame

Returning from a method pops it

Multiple Threads/Processors Model

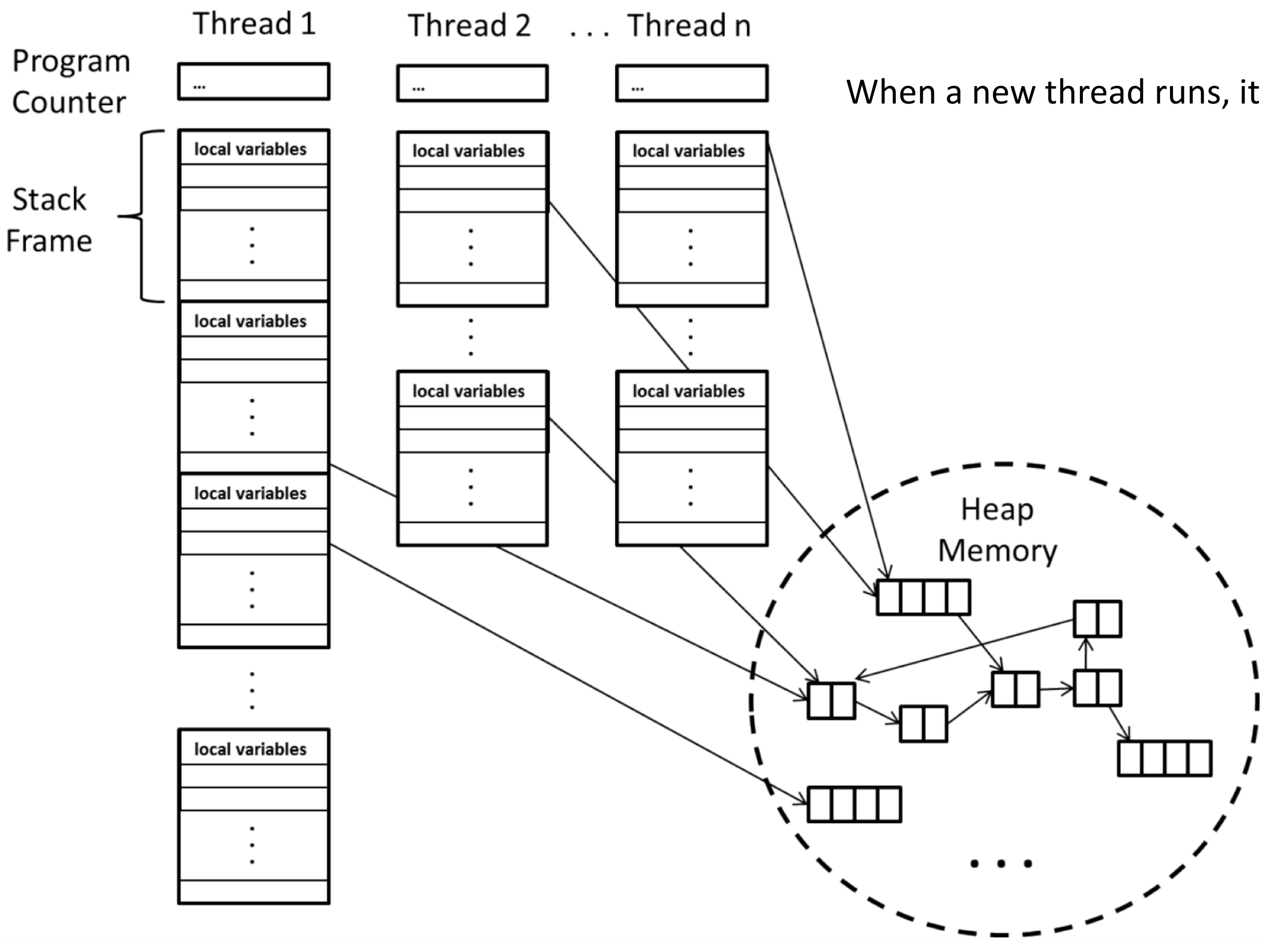
- A set of threads, each with its own call stack & program counter
- No access to another thread’s local variables
- Threads can (implicitly) share static fields / objects
- To communicate, write somewhere another thread reads

Shared memory

Threads, each with own unshared call stack & current statement

- (pc for "program counter")
- local variables are primitives, `null`, or heap references

Program state in parallel programming



When a new thread runs, it has its own call stack