Threads

Topics

- How can two “threads of execution” share the same memory space?
- How can we start and work with threads?

What’s a Thread

- What is a Thread?
  ..
  - Similar to a process but it's lighter weight.
  - Sometimes called..
- Main Thread
  - A process always has at least one thread, called main thread: from main()

Details

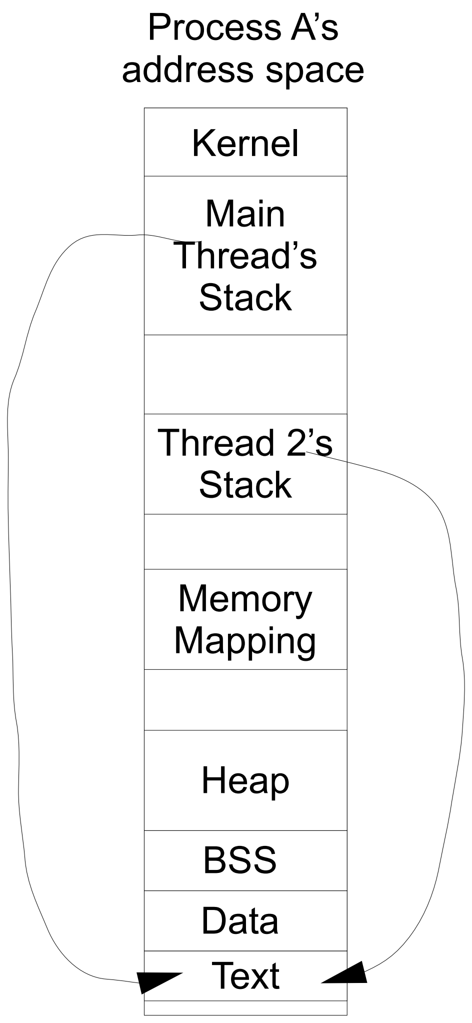
- Can find more info in OSTEP book
  (more depth than we require)
  - Chapter 26 Concurrency: An Introduction
    https://pages.cs.wisc.edu/~remzi/OSTEP/threads-intro.pdf
  - Chapter 27 Interlude: Thread API
    https://pages.cs.wisc.edu/~remzi/OSTEP/threads-api.pdf

Threads vs Processes

Thread vs Process

- If threads and processes execute in parallel on different cores, then what are the difference?
  - ..

    fork() creates a child process with its own address space.
  - ..
    text, data, bss, and heap segments.
- Each thread gets its own:
  - stack
  - registers
  - program counter (running different function).
  - errno



Benefits on Threads & Processes

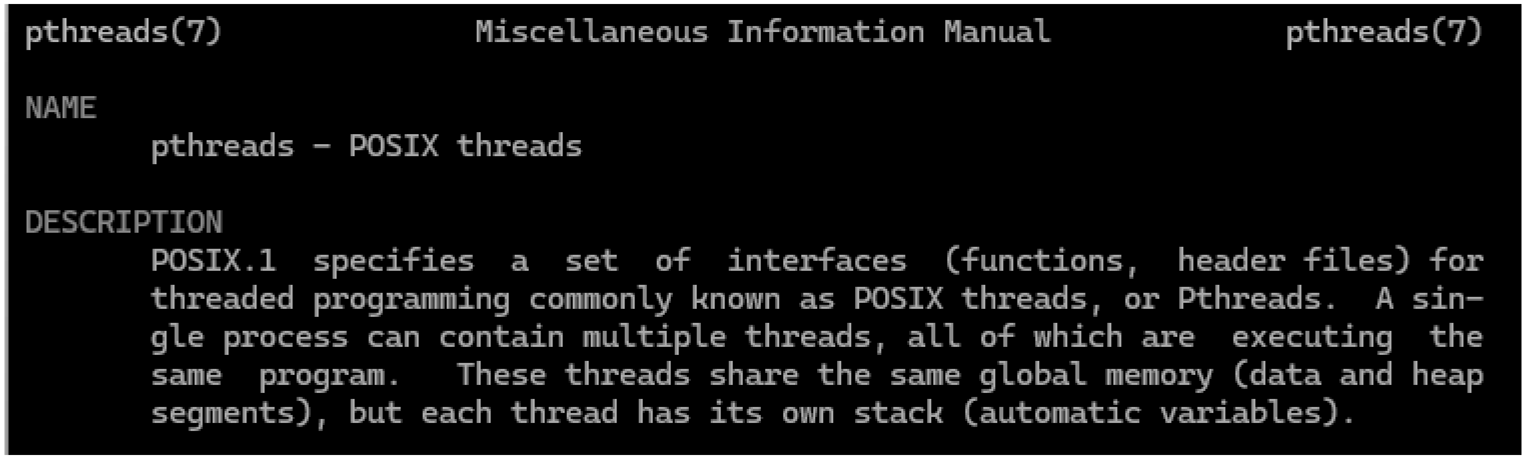
- Benefit of a thread
  - Threads in a process share the same addresses

    ..
  - E.g., any thread can read from or write to a global variable.

    Can pass pointers between them.
  - ..
- Benefit of a process
  - ..

POSIX Threads

man pthreads



```
pthreads(7)             Miscellaneous Information Manual            pthreads(7)

NAME
       pthreads - POSIX threads

DESCRIPTION
       POSIX.1  specifies  a  set  of  interfaces  (functions,  header files) for
       threaded programming commonly known as POSIX threads, or Pthreads.  A sin-
       gle process can contain multiple threads, all of which are  executing  the
       same  program.   These threads share the same global memory (data and heap
       segments), but each thread has its own stack (automatic variables).
```

- man pthreads
  Review sections:
  - Description: What’s shared & not
  - Return value & errno
  - Thread ID
  - Thread safe Functions

Common Functions

- pthread_create()
  - Check man page
  - pthread_t: this is the type used for thread IDs.
  - ..
    (that will run as a thread).
  - void *arg, passed in.
    - void* can be cast to any pointer.
      Use a struct to pass multiple arguments.
  - pthread_attr_t specifies various attributes of the new thread.
- pthread_exit() terminates the calling thread.
  - Done implicitly when returning from thread function
    return 0;   // Leaving thread function!

Common Functions

- pthread_self()
  - Returns the caller's id.
- pthread_join()
  - ..
  - Thread return value with `void **retval`.
- pthread_detach()
  - Lets the calling thread just run.
  - You can use this when you don't need to return anything.

ABCD: PThread

- Each thread gets its own...

  a) `Stack`

  b) `Heap`

  c) `Text / Code`

  d) `stdout`

ABCD: pthread_create()

- Which of the following is true about pthread_create()?

  a) It creates a new process running the provided thread start function.

  b) It passes nothing to the function (void).

  c) It waits until the spawned thread finishes.

  d) It stores the thread_id for later user.

Pthread Activity

- [15 min] Write a program where:
  - Main thread will:
    - create another thread.
    - print out the new thread's ID,
    - wait until thread terminates,
    - print out the return value.
  - New thread accept a string as its argument,
    - print out this string and its own ID,
    - return the length of the received string.

      Note: a thread start function can cast return type to integer types (e.g., `long`).
  - When compiling a program that uses pthreads, you need to use `-pthread` as a compiler option, e.g., `clang -pthread example.c`.

Start simple!
Make a thread
and print “hi”!

Data Race

Data Race Activity

- [10 min] Activity:
  write a program that has two additional threads.
  - Create global variable:
    int cnt = 0;
  - Each new thread adds 1 to `cnt` 10 million times.
  - Main thread waits for new threads, and prints `cnt`.
- Run multiple times; see output!

Deterministic

- Deterministic:
  - ..

    Usually, this is what we want!
  - Note that the “behaviour” might not be the same each time: the order that threads get scheduled will be different each time.
  - However, non-deterministic behaviour does not lead to non-deterministic output unless you have a race case.

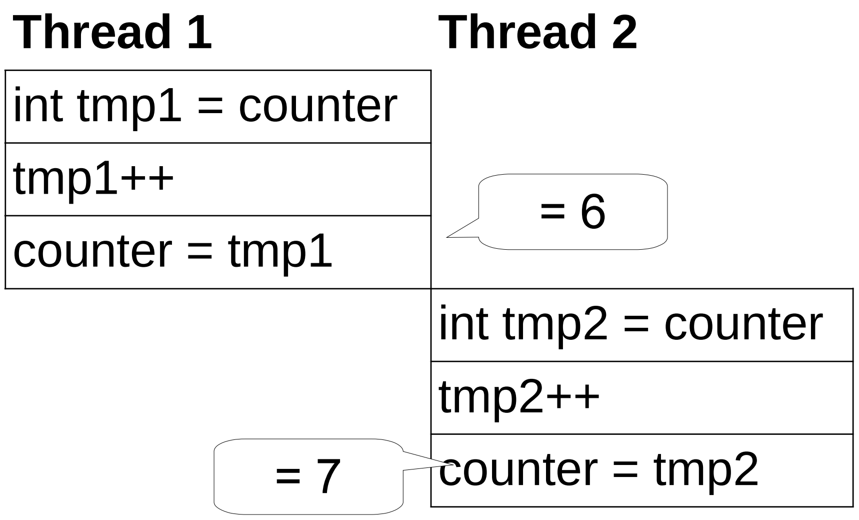
    Usually, what we want to avoid!

Data Race Problem

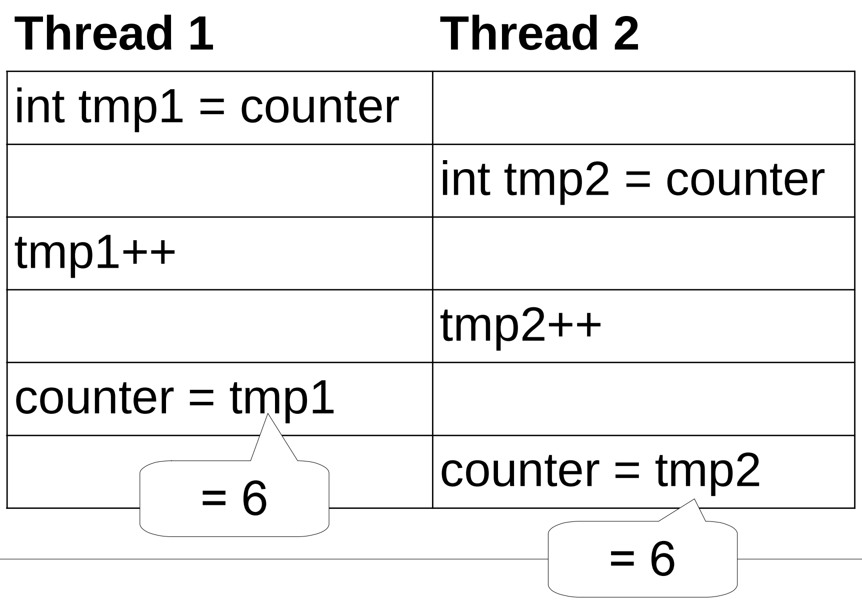
- Consider the statement counter++
  - It seems like `counter++` is one operation.
  - ..

```
int tmpRegister = counter;      // Load from memory
tmpRegister++;                  // Charge value
counter = tmpRegister;          // Store value to memory
```

- What happen if this runs on 2 threads? (assume counter = 5)



Thread 1	Thread 2
int tmp1 = counter	
tmp1++	
counter = tmp1	
	int tmp2 = counter
	tmp2++
	counter = tmp2



Thread 1	Thread 2
int tmp1 = counter	
	int tmp2 = counter
tmp1++	
	tmp2++
counter = tmp1	
	counter = tmp2

Race Condition

- Data Race
  - This is called the data race problem:
    ..
- Race Condition
  - More generally, a race condition is a condition in which
    ..
- Difference between a Data Race and a Race Condition
  - Very similar and related ideas.
  - We’ll not get into details. For more info: https://blog.regehr.org/archives/490

Summary

- Threads
  - Lightweight processes that share a memory space.
  - Always have main thread
- PThread
  - POSIX library / API for threads
  - pthread_create(), pthread_join(), ...
- Data Race
  - When two threads may access the same data at the same time.