Amirkabir University of Technology
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Operating Systems

Thread Libraries & Signal handling

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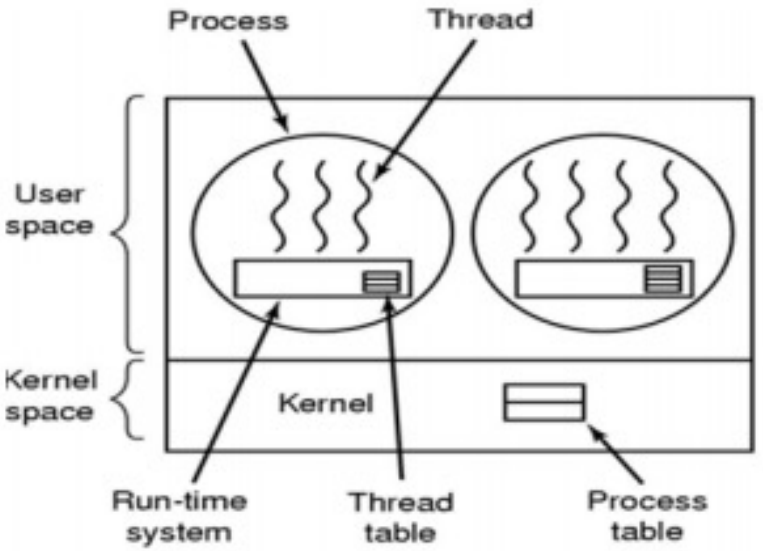
Thread Libraries

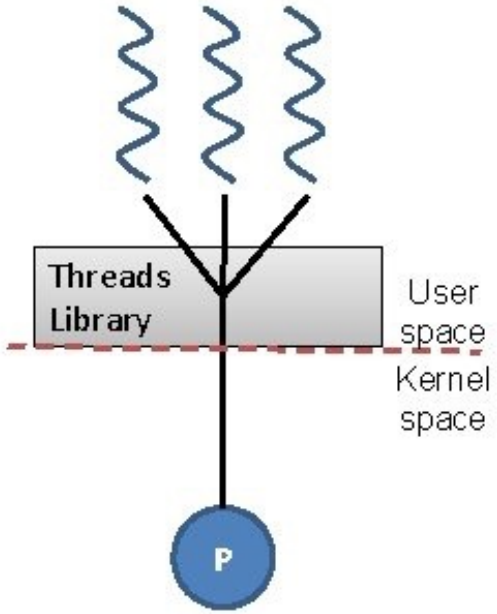
- Thread library provides programmer with API for creating and managing threads.
  - Abstract Programming Interface (API)
- Two primary ways of implementing
  - User-space library
  - Kernel-level library

https://www.tutorialspoint.com/operating_system/os_multi_threading.htm

User-Space Library

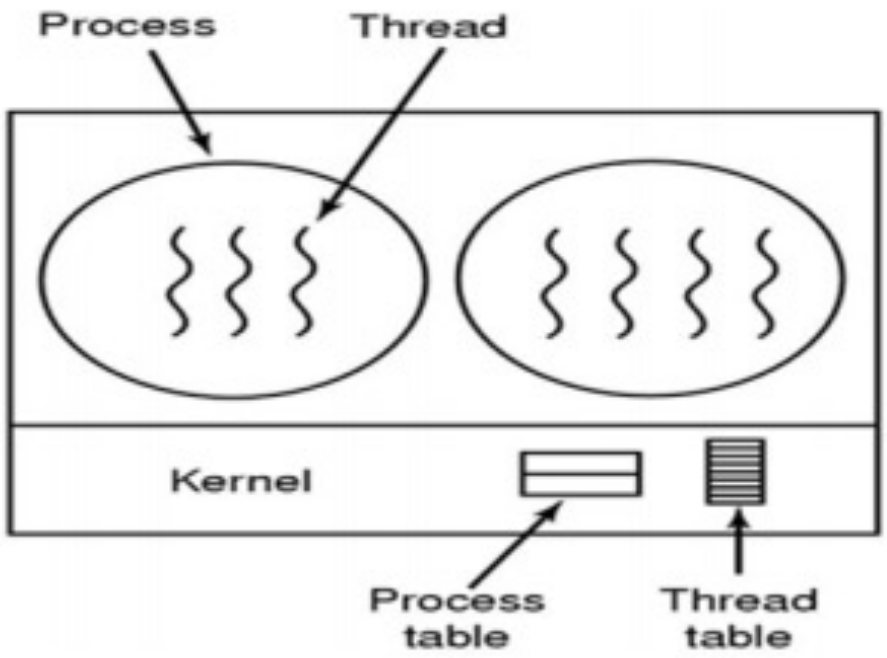
- All code and data structures for the library ***exist in user space***.
- Invoking a function in the library ***results in a local function call*** in user space and ***not a system call***.





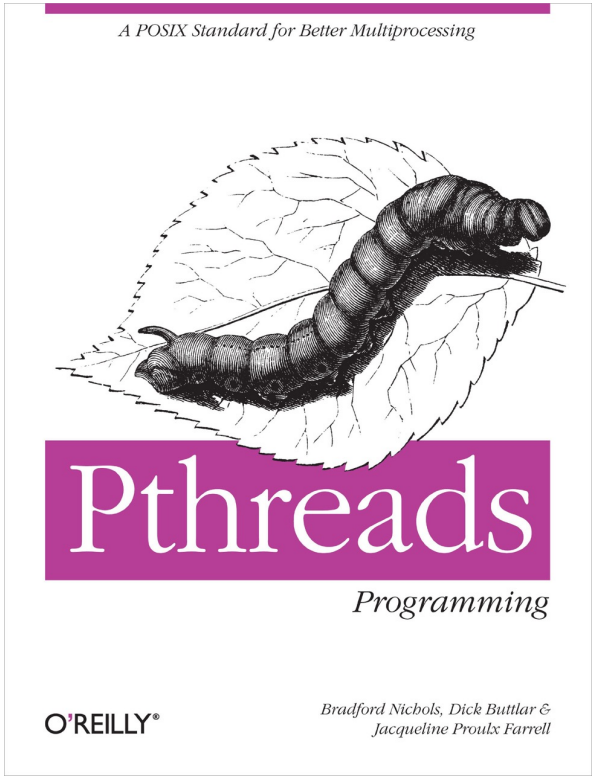
Kernel-Level Library

- Code and data structures for the library exist in kernel space.
- Invoking a function in the API for the library typically ***results in a system call*** to the kernel.



Pthreads

- May be provided either as user-level or kernel-level.
- A POSIX standard API for thread creation and synchronization.



Pthreads (cont.)

- ***Specification***, not ***implementation.***
- API specifies behavior of the thread library
  - Implementation is up to development of the library.
- Common in UNIX operating systems
  - Linux & Mac OS X

Optional reading:

https://users.cs.cf.ac.uk/Dave.Marshall/C/node30.html

https://stackoverflow.com/questions/43219214/where-is-the-value-of-the-current-stack-pointer-register-stored-before-context-s

Pthreads Example

```
#include <pthread.h>
#include <stdio.h>

#include <stdlib.h>

int sum; /* this data is shared by the thread(s) */
void *runner(void *param); /* threads call this function */

int main(int argc, char *argv[])
{
   pthread_t tid; /* the thread identifier */
   pthread_attr_t attr; /* set of thread attributes */

   /* set the default attributes of the thread */
   pthread_attr_init(&attr);
   /* create the thread */
   pthread_create(&tid, &attr, runner, argv[1]);
   /* wait for the thread to exit */
   pthread_join(tid,NULL);

   printf("sum = %d\n",sum);
}
```

Pthreads Example (Cont.)

```
/* The thread will execute in this function */
void *runner(void *param)
{
   int i, upper = atoi(param);
   sum = 0;

   for (i = 1; i <= upper; i++)
      sum += i;

   pthread_exit(0);
}
```

Pthreads Code for Joining 10 Threads

```
#define NUM_THREADS 10

/* an array of threads to be joined upon */
pthread_t workers[NUM_THREADS];

for (int i = 0; i < NUM_THREADS; i++)
   pthread_join(workers[i], NULL);
```

Threading Issues

- Semantics of **fork()** and **exec()** system calls

- Signal handling
  - Synchronous and asynchronous

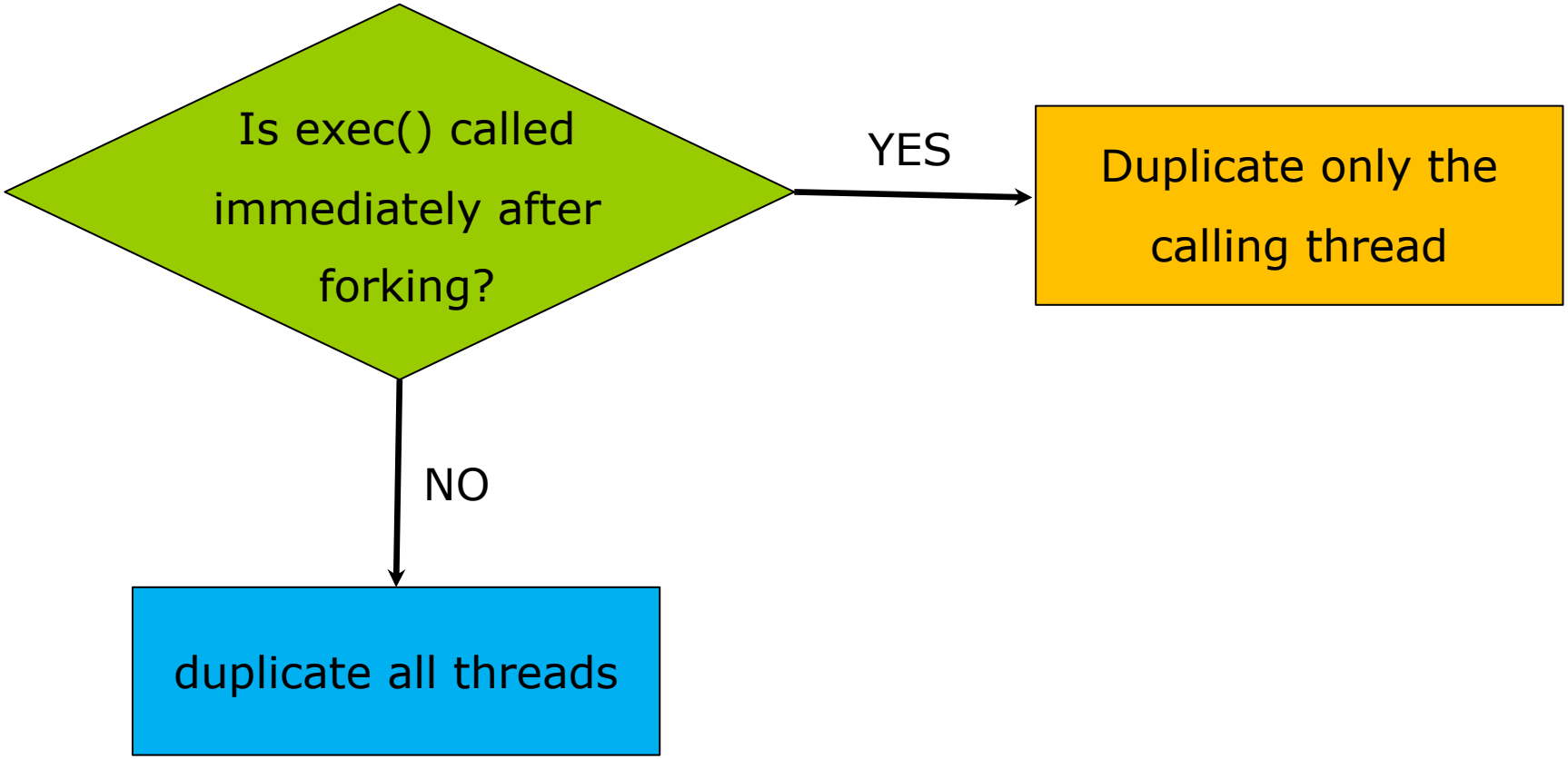
Semantics of fork() and exec()

- Does fork() duplicate only the calling thread or all threads?
  - Some UNIXes have **two versions of fork**
    - One that duplicates all threads
    - Another that duplicates only the thread that invoked the fork()

- exec() usually works as normal
  - Replace the running process including all threads.

Which Version of Fork() to use?

Depends on the application.



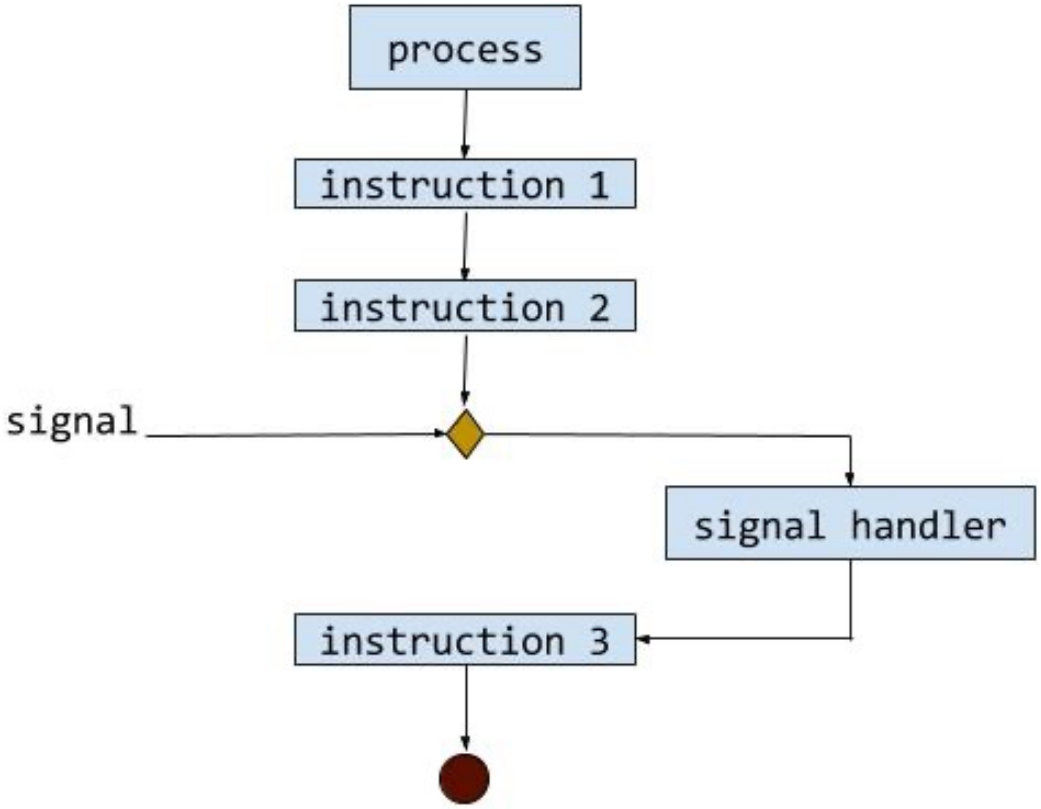
Which Version of Fork() to use?

- **If exec() is called immediately after forking**
  - Duplicating only the calling thread is appropriate.
  - Since the program specified in the parameters to exec() will replace the process.

- If the child **process does not call exec()** after forking
  - The **child process should duplicate all threads**.

Signal Handling

- **Signals** are used in UNIX systems to notify a process that a particular event has occurred.



Signal Handling

- A **signal handler** is used to process signals
  1. Signal is generated by particular event
  2. Signal is delivered to a process
  3. Signal is handled by one of two signal handlers:
     1. **default**
     2. **user-defined**

Two Types of Signals

- **Synchronous**
- **Asynchronous**

Synchronous Signals

- When a signal is generated by an event internal to a running process.
- Example:
  - Illegal memory access
  - Divide by 0
- Synchronous signals are delivered to the same process that performed the operation that caused the signal
  - That is the reason they are considered synchronous

Asynchronous Signals

- Signal is ***generated by an event external*** to a running process, that process receives the signal asynchronously.

- Example: terminating a process with specific keystrokes
  - <control><C>

- Typically, an asynchronous signal is sent to another process.

Signal Handling (Cont.)

- Every signal has default-handler that kernel runs when handling it
  - Some signals are simply ignored
    - Such as changing the size of a window
  - Others are handled by terminating the program.
    - Such as an illegal memory access
- User-defined signal handler can override default.
- For single-threaded, signal delivered to process.

Signal Handling (Cont.)

- Where should a signal be delivered for multi-threaded?
  - Deliver the signal to the thread to which the signal applies
  - Deliver the signal to every thread in the process
  - Deliver the signal to certain threads in the process
  - Assign a specific thread to receive all signals for the process
- **Which one should be used?**
  - **Depends on the type of signal generated.**

Signal Handling (cont.)

- **Synchronous *signals*** need to be delivered to the thread causing the signal and not to other threads in the process.

- However, the situation **with asynchronous signals is not as clear**.
  - Some asynchronous signals should be sent to all threads
    - Such as a signal that terminates a process (e.g., <control><C>)

Signal Handling (cont.)

- Most multithreaded versions of UNIX allow a thread to specify which signals it will accept and which it will block.
  - Therefore, in some cases, an asynchronous signal may be delivered only to those threads that are not blocking it.

- However, a signal is typically delivered only to the first thread found that is not blocking it.
  - Because signals need to **be handled only once**

Functions for Delivering Signals

- The standard UNIX function

```
kill(pid t pid, int signal)
```

  - Specifies the process to which a particular signal is to be delivered.

- POSIX Pthreads function

```
pthread_kill(pthread t tid, int signal)
```

  - Allows a signal to be delivered to a specified thread (tid)