Programming Interface

Main Points

- Creating and managing processes
  - fork, exec, wait
- Performing I/O
  - open, read, write, close
- Communicating between processes
  - pipe, dup, select, connect
- Example: implementing a shell

Shells

- A shell is a job control system
  - Allows programmer to create and manage a set of programs to do some task
  - Windows, MacOS, Linux all have shells
    - Desktop vs. Shell?

- Example: to compile a C program

```
$ cc -c sourcefile1.c
$ cc -c sourcefile2.c
$ ln -o program sourcefile1.o sourcefile2.o
```

Questions

- If the compiler (cc) crashes, does the shell crash?
- If the shell crashes, does the compiler run to completion?

Basic Shell Operation

- Shells implement some commands, but primarily they launch new processes
  - cc –c sourcefile1.c
    Starts a new process that (a) executes "cc" and (b) is passed [-c, sourcefile1.c] as arguments.
- What system call(s) are required to create a new process running some executable?

Windows: `CreateProcess`

- System call to create a new process to run a program
  - Create and initialize the process control block (PCB) in the kernel
  - Create and initialize a new address space
  - Load the program into the address space
  - Copy arguments into memory in the address space
  - Initialize the hardware context to start execution at ``start''
  - Inform the scheduler that the new process is ready to run

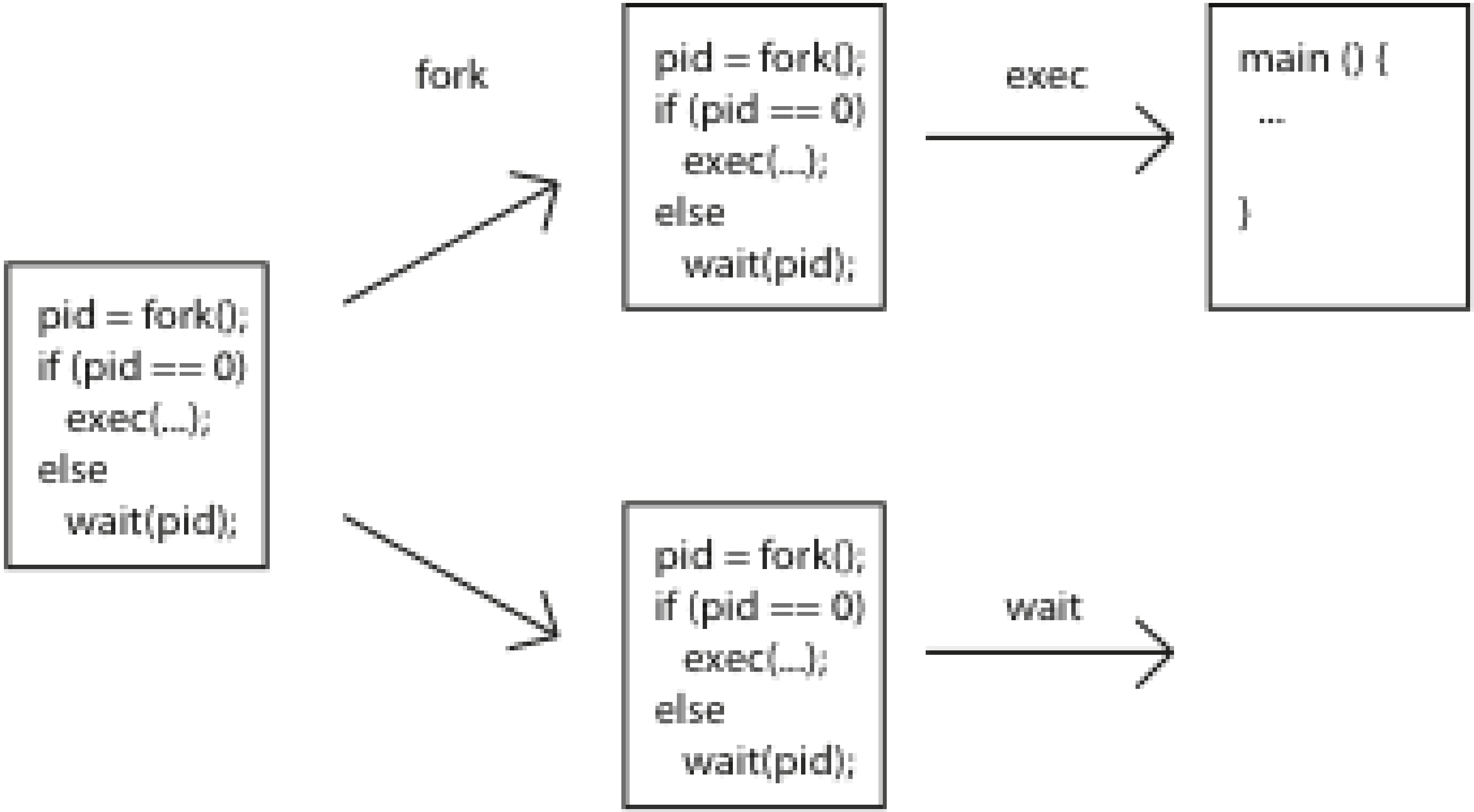
Windows `CreateProcess` API (simplified)

```
if (!CreateProcess(
    NULL,          // No module name (use command line arg)
    argv[1],       // Command line
    NULL,          // Process handle not inheritable
    NULL,          // Thread handle not inheritable
    FALSE,         // Set handle inheritance to FALSE
    0,             // No creation flags
    NULL,          // Use parent's environment block
    NULL,          // Use parent's starting directory
    &si,           // Pointer to STARTUPINFO structure
    &pi )          // Pointer to PROCESS_INFORMATION structure
)  { // success
```

UNIX Process Management

- `fork` – system call to create a copy of the current process, and start it running
  - No arguments!
- `exec` – system call to change the program being run by the current process
- `wait` – system call to wait for a process to finish
- `signal/kill` – system calls to register a handler for a signal and to send a signal to another process

UNIX Process Management



```
pid = fork();
if (pid == 0)
  exec(...);
else
  wait(pid);
```

```
pid = fork();
if (pid == 0)
  exec(...);
else
  wait(pid);
```

```
main () {
  ...

}
```

```
pid = fork();
if (pid == 0)
  exec(...);
else
  wait(pid);
```

Question: What does this code print?

```
int child_pid = fork();
if (child_pid == 0) {           // I'm the child process
    printf("I am process #%d\n", getpid());
    return 0;
} else {                        // I'm the parent process
    printf("I am parent of process #%d\n", child_pid);
    return 0;
}
```

Questions

- Can UNIX fork() return an error? Why?
- Can UNIX exec() return an error? Why?
- Can UNIX wait() ever return immediately? Why?

Implementing UNIX `fork`

Steps to implement UNIX `fork`

- Create and initialize the process control block (PCB) in the kernel
- Create a new address space
- Initialize the address space with a copy of the entire contents of the address space of the parent
- Inherit the execution context of the parent (e.g., any open files)
- Inform the scheduler that the new process is ready to run

Implementing UNIX `exec`

- Steps to implement UNIX `exec`
  - Load the executable into the current address space (overwriting what's already there)
  - Copy arguments into the address space
  - Initialize the hardware context to start execution at ``start''

UNIX I/O

- Uniformity
  - All operations on all files, devices use the same set of system calls: `open, close, read, write`
- Open before use
  - Open returns a handle (file descriptor) for use in later calls on the file
- Byte-oriented
- Kernel-buffered read/write
- Explicit close
  - To garbage collect the open file descriptor

UNIX File System Interface

- UNIX file `open` is a Swiss Army knife:
  - Open the file, return file descriptor (an int)
  - Options:
    - if file doesn’t exist, return an error
    - If file doesn’t exist, create file and open it
    - If file does exist, return an error
    - If file does exist, open file
    - If file exists but isn’t empty, nix it then open
    - If file exists but isn’t empty, return an error
    - …

Interface Design Question

- Why not separate syscalls for open/create/exists?

```
if (!exists(name))
    create(name);   // can create fail?
fd = open(name);   // does the file exist?
```

Implementing a Shell

```
char *prog, **args;
int child_pid;

// Read and parse the input a line at a time
while (readAndParseCmdLine(&prog, &args)) {
  child_pid = fork();      // create a child process
   if (child_pid == 0) {
     exec(prog, args);       // I'm the child process.  Run program
    // NOT REACHED
   } else {
     wait(child_pid);       // I'm the parent, wait for child
   }
}
```