

Lecture 20: Process Control

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601.229 Computer Systems Fundamentals



Control Flow

- ▶ The CPU executes one instruction after another
- ▶ Typically, they are next to each other in memory (unless jumps, branches, and returns from subroutine)
- ▶ Exceptional Control Flow, triggered by
 - ▶ hardware exception
 - ▶ software exception

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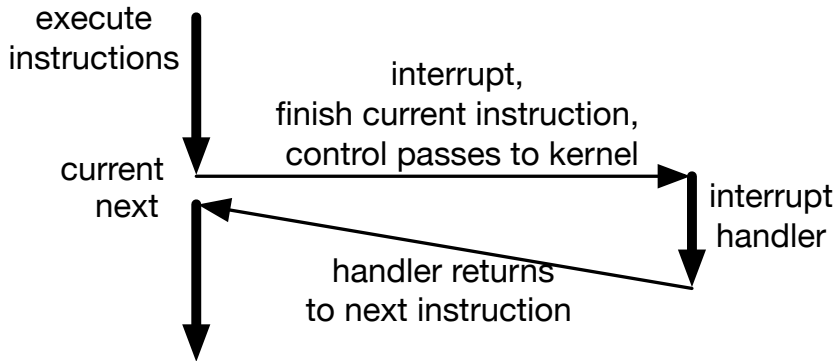
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- ▶ Faults
 - ▶ maybe recoverable, e.g., swapped out memory ("page fault")
 - ▶ if recovered, return to regular control flow
- ▶ Aborts
 - ▶ unrecoverable fatal error, e.g., memory corrupted
 - ▶ application process is terminated

Abrupt Change in Control Flow



Processes

Process

- ▶ Exceptions are the basic building block for processes
- ▶ Modern computers seem to run several things at once
 - ▶ retrieve and display web pages
 - ▶ play music in the background
 - ▶ accept emails and alert you to them

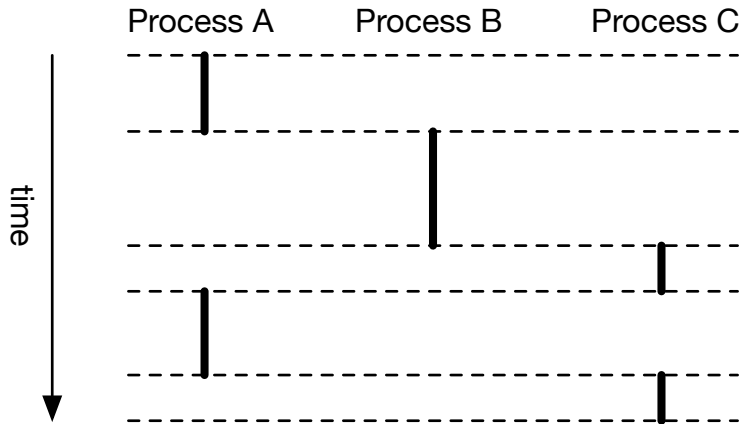
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- ▶ Process = a running program
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- ▶ Multi-tasking: modern OS that allow multiple processes at once

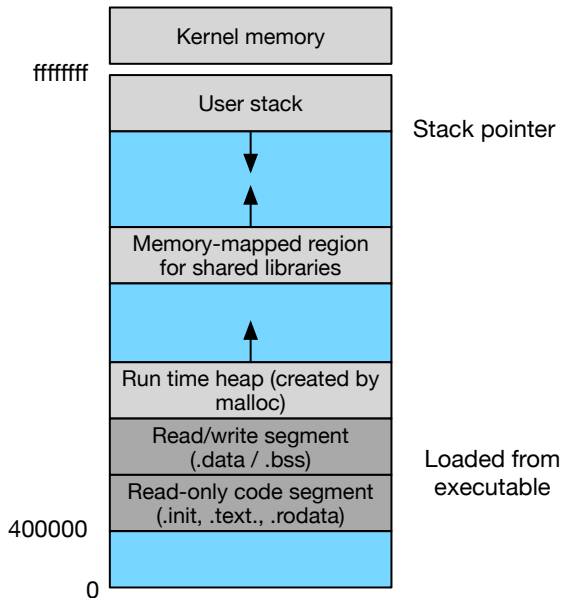
Logical Control Flow



User and Kernel Mode

- ▶ Mode bit in control register
- ▶ Kernel mode: may execute any instruction, access any memory
- ▶ User mode: limited to private memory
- ▶ Switch from user to kernel mode
 - ▶ voluntary (sleep)
 - ▶ triggered by interrupt
 - ▶ system call

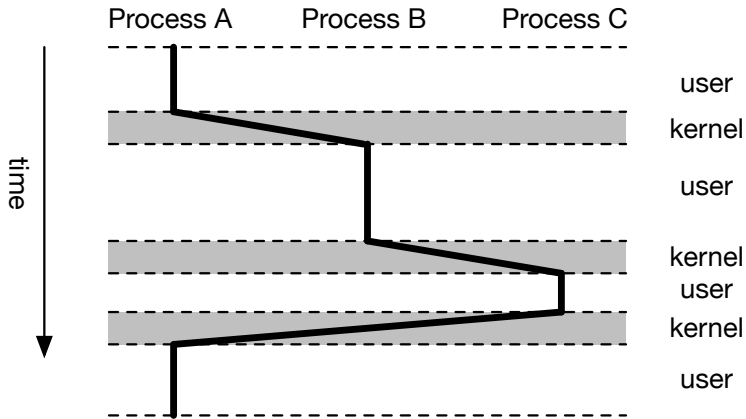
Private Address Space



Process Context

- ▶ Kernel maintains context for each process
- ▶ Context
 - ▶ program counter
 - ▶ register values
 - ▶ address table (more on that soon)
 - ▶ opened files
 - ▶ various meta information (e.g., process name)
- ▶ In Linux, each process context viewable in `/proc` "file" system

Context Switches



System calls

Examples

Number	Name	Description
0	read	read from file
1	write	write to file
2	open	open file
3	close	close file
33	pause	suspend process until signal arrives
39	getpid	get process id
57	fork	create new process
60	exit	end process
61	wait4	wait for a process to terminate
62	kill	kill another process

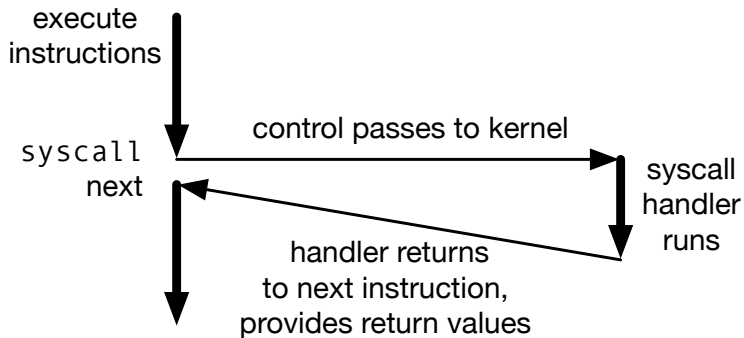
Assembly Example

```
.section .data
string:
    .ascii "hello, world!\n"
string_end:
    .equ len, string_end - string

.section .text
.globl main
main:
    movq $1, %rax        ; write is system call 1
    movq $1, %rdi        ; arg1: stdout is "file" 1
    movq string, %rsi    ; arg2: hello world string
    movq len, %rdx       ; arg3: length of string
    syscall

    movq $60, %rax       ; exit is system call 60
    movq $0, %rdi        ; exit status
    syscall
```

System Call Control



Clicker Quiz

Clicker quiz omitted from public slides

Process control

Creating New Processes

- ▶ C code that spawns a child process

```
int main() {  
    int x = 1;  
    pid_t  pid = fork();  
  
    if (pid == 0) {  
        printf("child x=%d", ++x);  
        exit(0);  
    }  
    printf("parent x=%d", --x);  
    exit(0);  
}
```

- ▶ When run, it returns
parent x=0
child x=2

Syscall 57: Fork

- ▶ `fork()` creates a child process
- ▶ Call once, return twice
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- ▶ Concurrent execution
 - ▶ parent and child processes run concurrently
 - ▶ no guarantee which proceeds first (and for how long)
- ▶ Duplicate by separate address space
 - ▶ initially memory is identical
 - ▶ each process makes changes to its private copy

Another Example

► Multiple forks

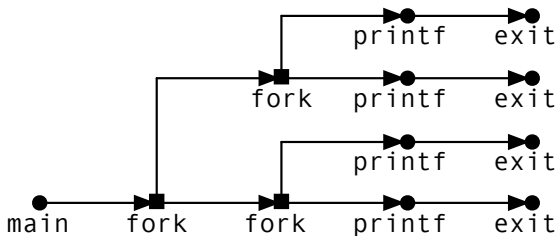
```
int main() {  
    fork();  
    fork();  
    printf("hello\n");  
    exit(0);  
}
```

Another Example

- ▶ Multiple forks

```
int main() {  
    fork();  
    fork();  
    printf("hello\n");  
    exit(0);  
}
```

- ▶ Outputs "hello" 4 times



Death in the Family

- ▶ What happens when what dies when?
- ▶ Child process dies
 - ▶ process still in kernel's process table
 - ▶ waiting for parent to read exit status
 - ▶ "zombie": dead, but still active
- ▶ Parent process dies
 - ▶ children processes become orphaned
 - ▶ orphan killing: terminate all orphaned processes
 - ▶ re-parenting: make init process (pid: 1) parent
(→ a "daemon" process)

Waiting for Child to Die

1. Parent spawns child process
2. Both processes running
3. Parent waits for child to complete
 - ▶ C: `waitpid()`
 - ▶ Assembly: `syscall 61`
4. Parent stalls
5. Child dies (zombie)
6. Parent receives exit status of child
7. Child dies completely

- ▶ Parent process may execute another program
 - ▶ C: `execve(filename, argv, envp)`
 - ▶ Assembly: `syscall 59`
- ▶ Passes environment variables (`envp`)
- ▶ Executed command takes over
- ▶ If both should run: `fork` first