Fork() System Call and Processes

CS449 Spring 2016

Terminating signals review

SIGKILL: Terminates a process immediately. This signal cannot be handled (caught), ignored or blocked. (The "kill -9" command in linux generates this signal).

SIGTERM: Terminates a process immediately. However, this signal can be handled, ignored or caught in code. If the signal is not caught by a process, the process is killed. Also, this is used for graceful termination of a process. (The "kill" command in linux if specified without any signal number like -9, will send SIGTERM)

SIGINT: Interrupts a process. (The default action is to terminate gracefully). This too, like, SIGTERM can be handled, ignored or caught. The difference between SIGINT and SIGTERM is that the former can be sent from a terminal as input characters. This is the signal generated when a user presses Ctrl+C. (Sidenote: Ctrl+C denotes EOT(End of Transmission) for (say) a network stream)

SIGQUIT: Terminates a process. This is different from both SIGKILL and SIGTERM in the sense that it generates a **core dump** of the process and also cleans up resources held up by a process. Like SIGINT, this can also be sent from the terminal as input characters. It can be handled, ignored or caught in code. This is the signal generated when a user presses Ctrl+\.

SIGABRT: The abort signal is normally sent by a program when it wants to terminate itself and leave a **core dump** around. This can be handy during debugging and when you want to check assertions in code. The easiest way for a process to send a SIGABRT to itself is via the abort() function, which does nothing more than a raise(SIGABRT), which, in turn, does a kill(getpid(), SIGABRT). Programs normally drop a core file and exit when receiving this signal

Terminating signals review

A **core dump**, memory **dump**, or system **dump** consists of the recorded state of the working memory of a computer program at a specific time, generally when the program has crashed or otherwise terminated abnormally.

Programs and Processes

- Program: Executable binary (code and static data)
- Process: A program loaded into memory
  - Program (executable binary with data and text section)
  - Execution state (heap, stack, and processor registers)

Program

```
int foo() {
    return 0;
}

int main() {
    foo();
    return 0;
}
```

Process

```
int foo() {
    return 0;
}

int main() {
    foo();
    return 0;
}
```

Heap

Stack

Registers

fork()

- A system call that creates a new process identical to the calling one
  - Makes a copy of text, data, stack, and heap
  - Starts executing on that new copy
- Uses of fork()
  - To create a parallel program with multiple processes (E.g. Web server forks a process on each HTTP request)
  - To launch a new program using exec() family of functions (E.g. Linux shell forks an ‘ls’ process)

fork() example

```
#include <stdio.h>
#include <unistd.h>
int main()
{
  int seq = 0;
  if(fork()==0)
  {
    printf("Child! Seq=%d\n", ++seq);
  }
  else
  {
    printf("Parent! Seq=%d\n", ++seq);
  }
  printf("Both! Seq=%d\n", ++seq);
  return 0;
}
```

```
>> ./a.out
Parent! Seq=1
Both! Seq=2
Child! Seq=1
Both! Seq=2
```

fork() example

```
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#include <unistd.h>
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{
  int seq = 0;
  if(fork()==0)
  {
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  else
  {
    printf("Parent! Seq=%d\n", ++seq);
  }
  printf("Both! Seq=%d\n", ++seq);
  return 0;
}
```
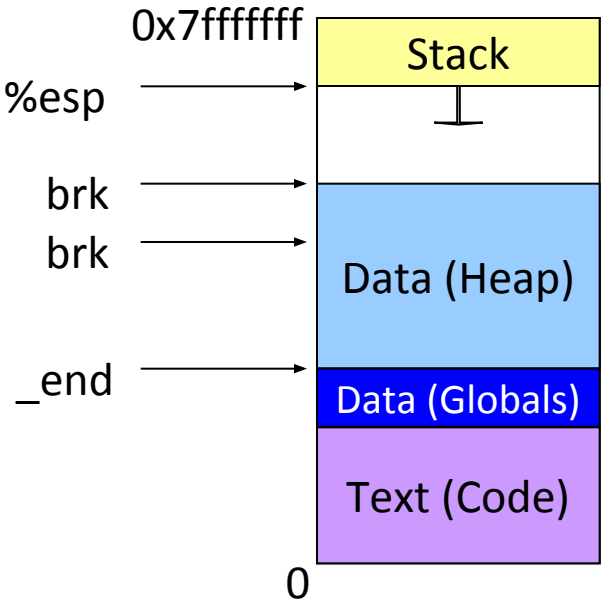
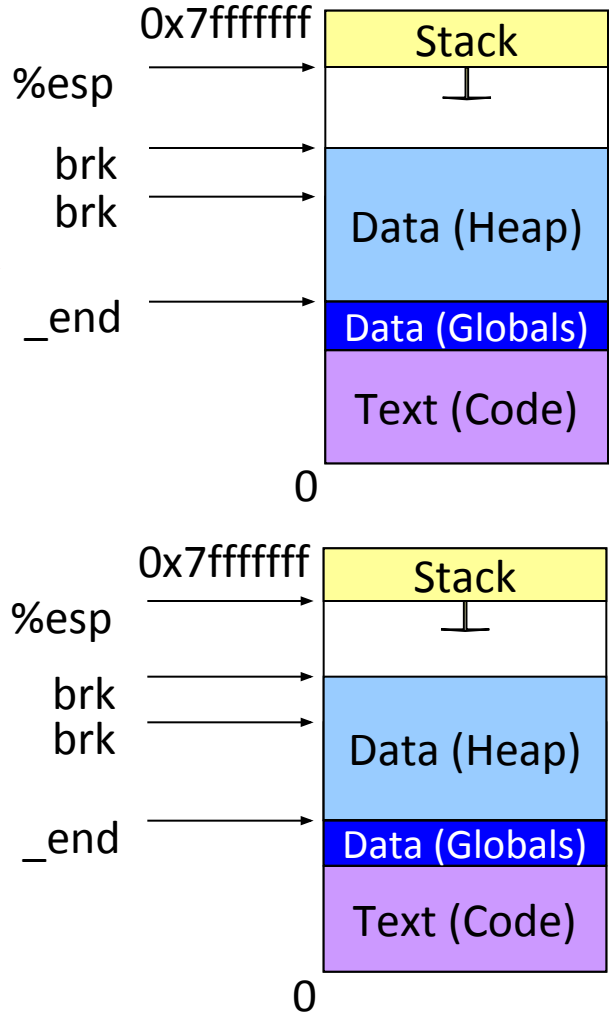

```
>> ./a.out
Parent! Seq=1
Both! Seq=2
Child! Seq=1
Both! Seq=2
```

- Differentiate child and parent using return value of fork()
  - "Child" process return value is 0
  - "Parent" process gets child's process id number
- **Copies** execution state (not shares)
  - Child copies stack variable seq onto its own stack
  - Child / parent has own copy of seq

Before fork()



After fork()



Copy-On-Write

- Inefficient to physically copy memory from parent to child
  - Code (text section) remains identical after fork
  - Even portions of data section, heap, and stack may remain identical after fork
- Copy-On-Write
  - OS memory management policy to **lazily** copy pages only when they are modified
  - Initially map same physical page to child virtual memory space (but in read mode)
  - Write to child virtual page triggers page protection violation (exception)
  - OS handles exception by making physical copy of page and remapping child virtual page to that page

How do Parent / Child Run in Parallel?

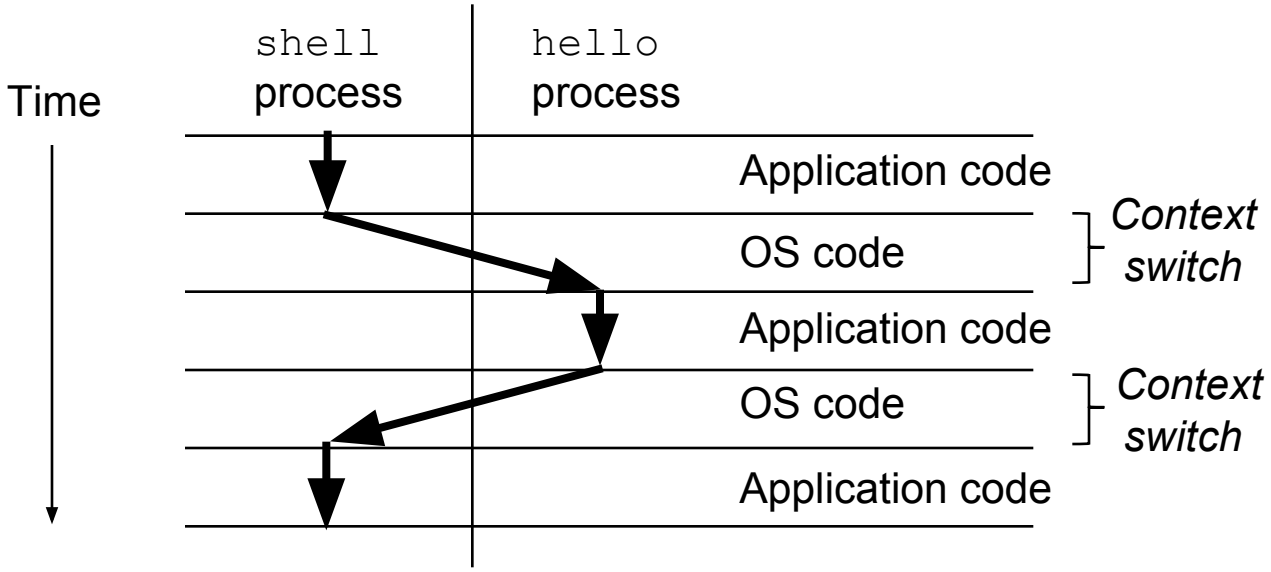
- Obvious answer: by running on different processors on a multiprocessor system
- What if it's a uniprocessor system?
- What if other processors are already busy?
- Answer: by context switching (running each process in short time slots)

Process Context

- Context: set of data that must be saved by a task on interruption and restored on continuation
- Process Context
  - Process registers (including program counter, stack pointer etc.)
  - Memory management info (pointer to page table etc.)
  - I/O status info (pointer to file descriptor table etc.)
  - Process scheduling info (scheduling priority etc.)
  - Process ID, or PID (unique identifier for process)
- Data structure in OS containing process context information is called **process control block (PCB)**

Context Switching

- OS provides the illusion of a dedicated machine per process
- Context switch
  - Saving context of one process, restoring that of another one
  - Processor alternates between executing different processes



Dispatch Mechanism

- OS maintains list of all processes (PCBs)
- Each process has a mode
  - Running: Executing on the CPU
  - Ready: Waiting to execute on CPU
  - Blocked: Waiting for I/O or synchronization with another thread
- Dispatch Loop

```
while (1) {
    run process for a while;
    stop process and save its state;
    load state of another process;
}
```

How does dispatcher gain control?

- Must change from user to system mode
  - Problem: Only one CPU, and CPU can only do one thing at a time
  - A user process running means the dispatcher isn't

- Two ways OS gains control

- Exceptions: Events caused by process execution
  - System calls, page faults, segfault, etc
- Hardware interrupts: Events external to process
  - Typing at keyboard, network packet arrivals
  - Control switch to OS via Interrupt Service Routine (ISR)

- How does OS guarantee it will regain control?
  - By setting a timer interrupt (allows fair scheduling of processes)

Spawning a New Program

- Combination of fork() and exec(…)
  - fork(): Clone current process
  - exec(…): copy new program on top of current process
- Exec(...) family of functions
  - execl, execlp, execle, execv, execve, execvp
  - User space wrappers for the **execve** system call
  - Also called the “program loader”
    - Loads in text and data sections of a binary executable
    - Links in any shared objects and perform relocations
    - Sets up stack and starts executing
  - What Linux shell calls when launching a program

execvp() example

```
#include <stdio.h>
#include <unistd.h>
int main()
{
  if(fork()==0)
  {
    char *args[3] = {"ls", "-al", NULL};
    execvp(args[0], args);
    // DOES NOT GET HERE
  }
  else
  {
    printf("Parent!\n");
  }
  printf("Only parent!\n");
  return 0;
}
```

```
>> ./a.out
Parent!
Only parent!
drwx------  4 wahn UNKNOWN1    4096 Oct 21 08:13 .
drwxr-xr-x 10 wahn UNKNOWN1    2048 Oct 21 08:13 ..
-rwxr-xr-x  1 wahn UNKNOWN1    6743 Oct 21 08:12 a.out
```

- execvp never returns since memory is overwritten using another program image

Managing processes (Unix)

- Finding processes
  - ‘ps’
- Monitoring Processes
  - ‘top’
- Stopping processes
  - ‘kill <pid>’ (for a soft kill using SIGTERM)
  - ‘kill -9 <pid>’ (for a hard kill using SIGKILL)
- Procfs (/proc/)

Using ‘ps’

- Listing processes associated with this terminal

```
(84) thot $ ps -f
UID        PID  PPID  C STIME TTY          TIME CMD
wahn     11848 11847  0 06:27 pts/1    00:00:00 -bash
wahn     15754 11848  0 11:24 pts/1    00:00:00 ps -f
```

- Listing all processes

```
(85) thot $ ps -ef
UID        PID  PPID  C STIME TTY          TIME CMD
root         1    0  0 Aug26 ?        00:00:11 /sbin/init
root         2    0  0 Aug26 ?        00:00:00 [kthreadd]
root         3    2  0 Aug26 ?        00:00:03 [migration/0]
root         4    2  0 Aug26 ?        00:00:04 [ksoftirqd/0]
root         5    2  0 Aug26 ?        00:00:00 [migration/0]
```

Using ‘kill’

- Killing your own shell

```
(51) thot $ ps -f
UID        PID  PPID  C STIME TTY          TIME CMD
wahn     11848 11847  0 06:27 pts/1    00:00:00 -bash
wahn     15904 11848  0 11:36 pts/1    00:00:00 ps -f
(52) thot $ kill 11848
(53) thot $ kill -9 11848
Connection to thot.cs.pitt.edu closed.
```

Procfs

- File system based export of process information
  - Mounted on /proc/
  - Contains information on every process on the system
  - Organized by PID
  - **/proc/self** exports information for the running process

- Information available
  - Resources in use
  - Resources allowed to use
  - Virtual memory map
  - Cmdline
  - Etc…

Procfs usage examples

- Listing open file descriptors for process

```
(84) thot $ ls -l /proc/self/fd
total 0
lrwx------ 1 wahn UNKNOWN1 64 Sep 11 13:37 0 -> /dev/pts/0
lrwx------ 1 wahn UNKNOWN1 64 Sep 11 13:37 1 -> /dev/pts/0
lrwx------ 1 wahn UNKNOWN1 64 Sep 11 13:37 2 -> /dev/pts/0
lr-x------ 1 wahn UNKNOWN1 64 Sep 11 13:37 3 -> /proc/16970/fd
```

- Showing virtual memory map

```
(85) thot $ cat /proc/self/maps
00400000-0040b000 r-xp 00000000 fd:00 2681                 /bin/cat
0080a000-0080b000 rw-p 0000a000 fd:00 2681                 /bin/cat
0080b000-0082c000 rw-p 00000000 00:00 0                    [heap]
34ff600000-34ff78b000 r-xp 00000000 fd:00 131              /lib64/libc-2.12.so
34ff98e000-34ff98f000 rw-p 0018e000 fd:00 131              /lib64/libc-2.12.so
7fffffea000-7ffffffff000 rw-p 00000000 00:00 0             [stack]
```