Recitation 8: Signals & Shells

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15213 Section A

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- Office hours:
  - NSH 2504 (lab) / 2507 (conference room)
  - Thursday 5-6

- Lab 5
  - due Thursday, 31 Oct @ 11:59pm
    - Halloween Night … happy reaping!

Today's Plan

- Process IDs & Process Groups
- Process Control
- Signals
- Preemptive Scheduler
  - Race hazards
- Reaping Child Processes

Lab 5: Shell

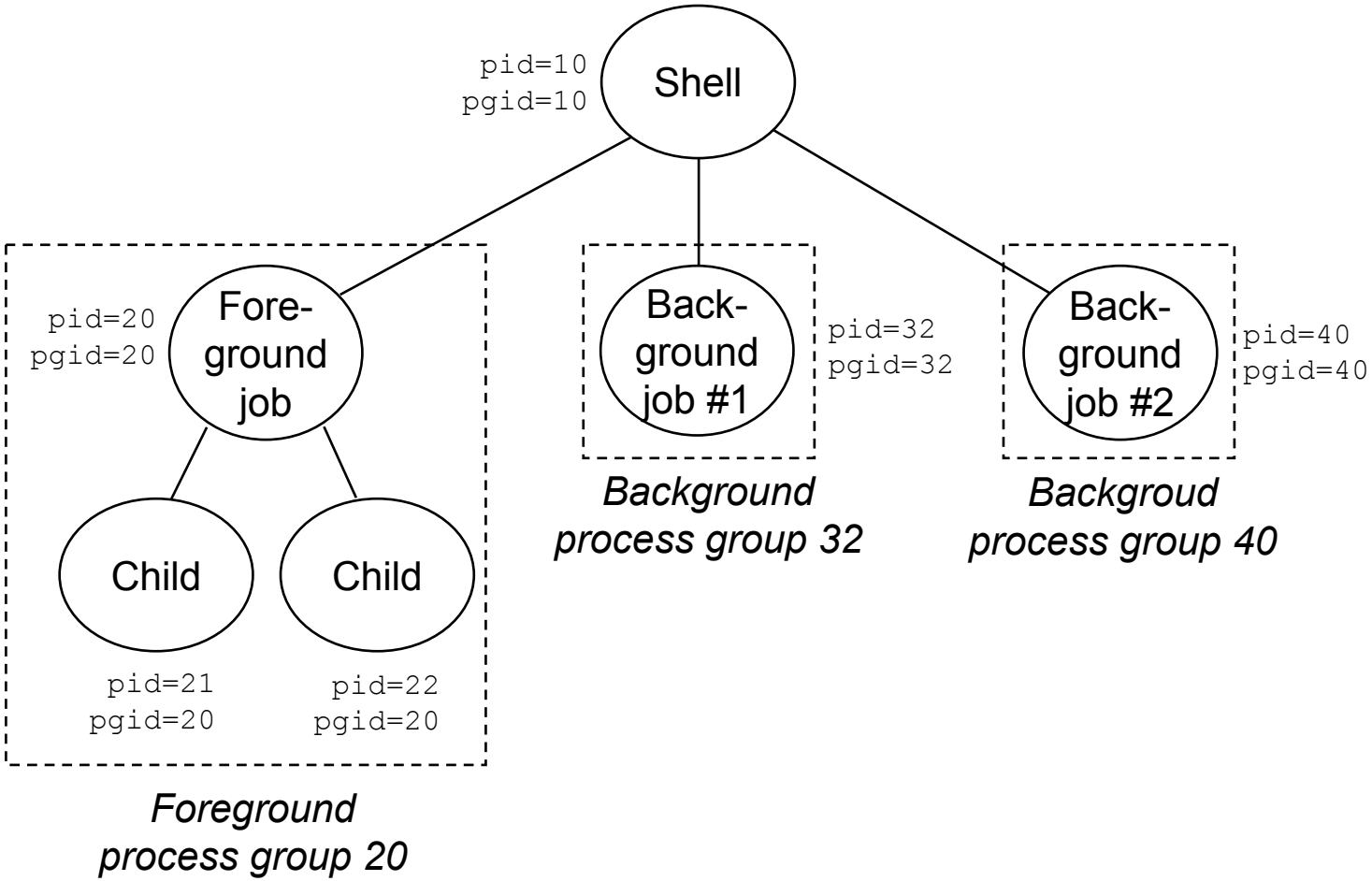
- **`tshref`**
  - Use as a guide for output
  - You shell should have same behavior

How Programmers Play with Processes

- Process: executing copy of program
- Basic functions
  - **`fork()`** spawns new process
  - **`exit()`** terminates calling process
  - **`wait()`** and **`waitpid()`** wait for and reap terminated children
  - **`execl()`** and **`execve()`** run a new program in an existing process

Process IDs & Process Groups

- Each process has its own, unique process ID
  - `pid_t getpid();`
- Each process belongs to exactly one process group
  - `pid_t getpgid();`
- To which process group does a new process initially belong?
  - Its parent's process group
- A process can make a process group for itself and its children
  - `setpgid(0, 0);`


pid=10
pgid=10
Shell
pid=20
pgid=20
Fore-
ground
job
Back-
ground
job #1
pid=32
pgid=32
Back-
ground
job #2
pid=40
pgid=40
Child
Child
pid=21
pgid=20
pid=22
pgid=20
Background
process group 32
Backgroud
process group 40
Foreground
process group 20

Signals

- Section 8.5 in text
  - Read at least twice … really!
- A signal tells our program that some event has occurred
  - For instance, a child process has terminated
- Can we use signals to count events?
  - No

Important Signals

- SIGINT
  - Interrupt signal from keyboard (ctrl-c)
- SIGTSTP
  - Stop signal from keyboard (ctrl-z)
- SIGCHLD
  - A child process has stopped or terminated

Look at Figure 8.23 for a complete list of Linux signals

Sending a Signal

- Send a signal
  - Sent by either the kernel
  - Or another process
- Why is a signal sent?
  - The kernel detects a system event.
    - Divide-by-zero (SIGFPE)
    - Termination of a child process (SIGCHLD)
  - Another process invokes a system call.
    - **`kill(pid_t pid, int SIGINT)`**
      - **`kill(1500, SIGINT)`**
        - » **Send SIGINT to *process* 1500**
      - **`kill(-1500, SIGINT)`**
        - » **Send SIGINT to *progress group* 1500**
    - **`alarm(unsigned int secs)`**

Receiving a Signal

- Default action
  - The process terminates [and dumps core]
  - The process stops until restarted by a SIGCONT signal
  - The process ignore the signal
- Can modify the default action with the **`signal`** function
  - Additional action: “Handle the signal”
    - **`void sigint_handler(int sig);`**
    - **`signal(SIGINT, sigint_handler);`**
  - Cannot modify action for SIGSTOP and SIGKILL

Receiving a Signal

- **`pending`**: bit vector: bit *k* is set when signal type *k* is delivered, clear when signal received
- **`blocked`**: bit vector of signals that should not be received
- Only receive non-blocked, pending signals
  - **`pending & ~blocked`**

Synchronizing Processes

- Preemptive scheduler run multiple programs “concurrently” by time slicing
  - How does time slicing work?
  - The scheduler can stop a program at any point
  - Signal handler code can run at any point, too
- Program behaviors depend on how the scheduler interleaves the execution of processes
- Racing condition between parent and child!
  - Why?

Race Hazard

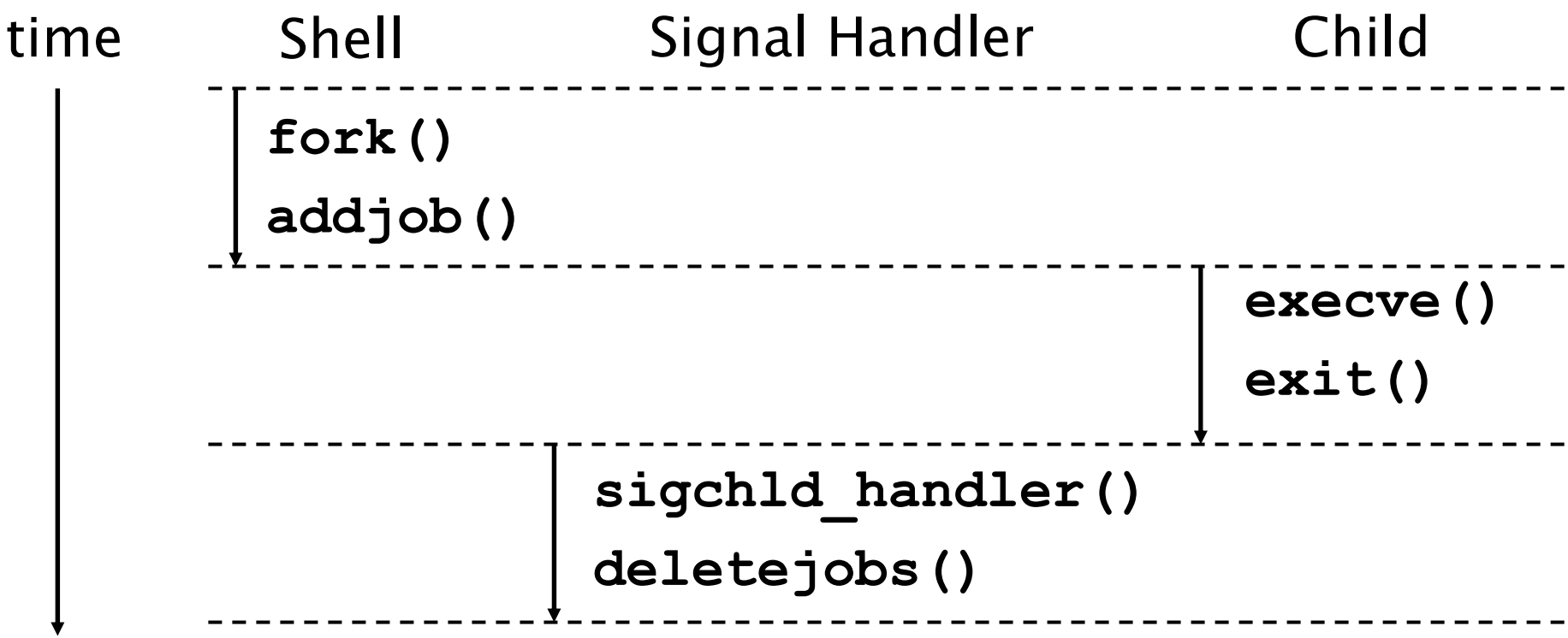
- Different behaviors of program depending upon how the schedule interleaves the execution of code.

Parent & Child Race Hazard

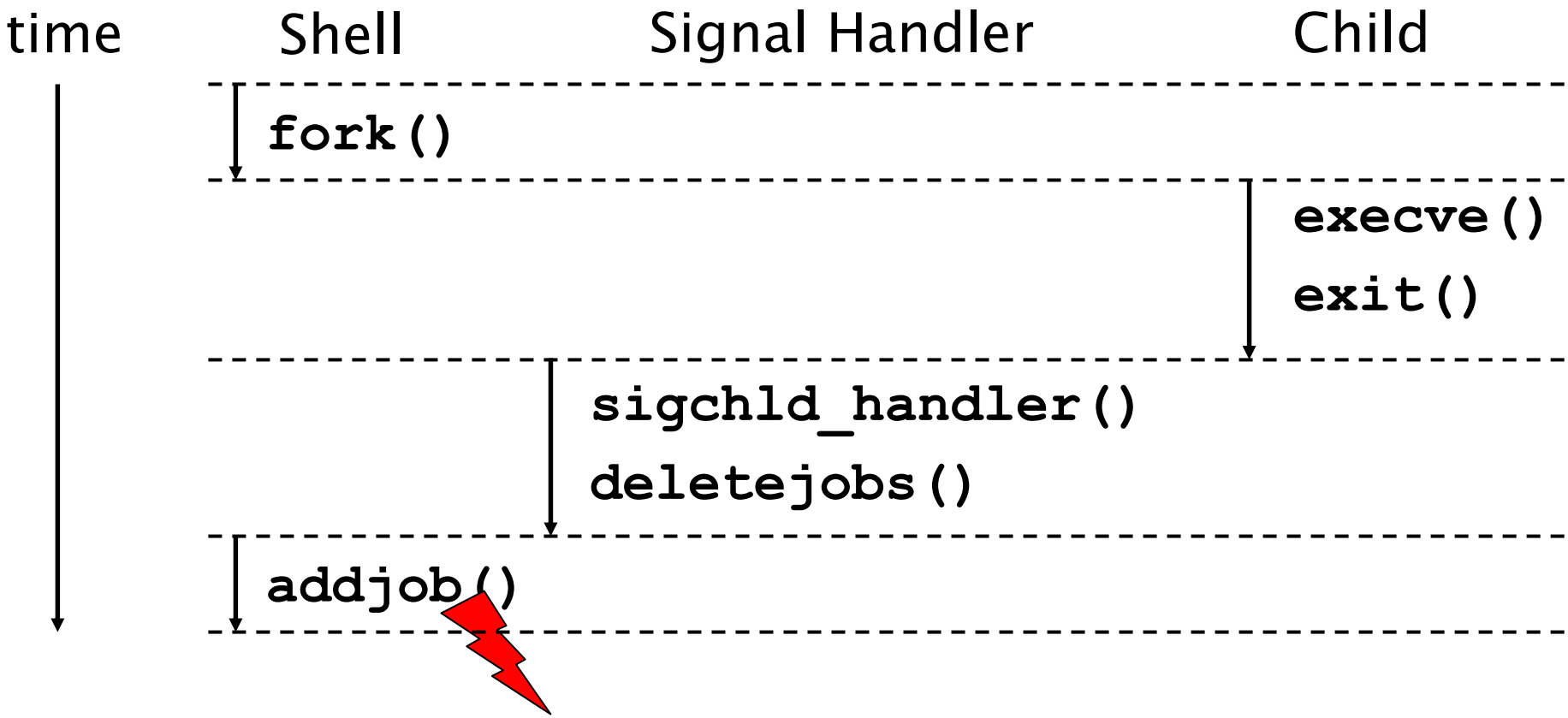
```
sigchld_handler() {
  pid = waitpid(…);
  deletejob(pid);
}

eval() {
  pid = fork();
  if(pid == 0)
  { /* child */
    execve(…);
  }
  /* parent */
  /* signal handler might run BEFORE addjob() */
  addjob(…);
}
```

An Okay Schedule



A Problematic Schedule



Job added to job list *after* the signal handler tried to delete it!

Solution to Race Hazard

```
sigchld_handler() {
  pid = waitpid(…);
  deletejob(pid);
}

eval() {
  sigprocmask(SIG_BLOCK, …)
  pid = fork();
  if(pid == 0)
  { /* child */
    sigprocmask(SIG_UNBLOCK, …)
    execve(…);
  }
  /* parent */
  /* signal handler might run BEFORE addjob() */
  addjob(…);
  sigprocmask(SIG_UNBLOCK, …)
}
```

More details 8.5.6 (page 633)

Reaping Child Process

- Child process becomes zombie when terminates
  - Still consume system resources
  - Parent performs reaping on terminated child
    - Using either **`wait`** or **`waitpid`** syscall
- Where to wait children processes to terminate?
  - Two waits
    - **`sigchld_handler`**
    - **`eval`**: for foreground processes
  - One wait
    - **`sigchld_handler`**
    - But what about foreground processes?

Busy Wait

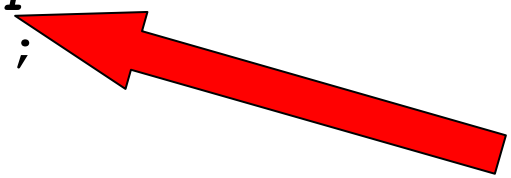
```
void eval() {
   …
   /* parent */
   addjob(…);
   while(fg process still alive){
      ;
   }
}

sigchld_handler() {
   pid = waitpid(…);
   deletejob(pid);
}
```

Pause

```
void eval() {
   …
   /* parent */
   addjob(…);
   while(fg process still alive){
      pause();
   }
}

sigchld_handler() {
   pid = waitpid(…);
   deletejob(pid);
}
```



If signal handled (SIGCHLD) before call to **pause**, then **pause** will not return

Sleep

```
void eval() {
   …
   /* parent */
   addjob(…);
   while(fg process still alive){
      sleep(1);
   }
}

sigchld_handler() {
   pid = waitpid(…);
   deletejob(pid);
}
```

waitpid

- Used for reaping zombied child processes
- `pid_t waitpid(pid_t pid, int *status, int options)`
  - **`pid`**: wait until child process with pid has terminated
    - **`-1`**: wait for any child process
  - **`status`**: tells why child terminated
  - **`options`**:
    - WNOHANG: return immediately if no children have exited (zombied)
      - **`waitpid`** returns -1
    - WUNTRACED: report status of stopped children too

waitpid's status

- `int status;`
  `waitpid(pid,&status, NULL)`
- **`WIFEXITED(status)`**: child exited normally
  - **`WEXITSTATUS(status)`**: return code when child exits
- **`WIFSIGNALED(status)`**: child exited because a signal was not caught
  - **`WTERMSIG(status)`**: gives the number of the terminating signal
- **`WIFSTOPPED(status)`**: child is stopped
  - **`WSTOPSIG(status)`**: gives the number of the stop signal

Summary

- Process provides applications with the illusions of:
  - Exclusively use of the processor and the main memory
- At the interface with OS, applications can:
  - Creating child processes
  - Run new programs
  - Catch signals from other processes
- Use **`man`** if anything is not clear!