Exceptional Control Flow: Signals and Nonlocal Jumps

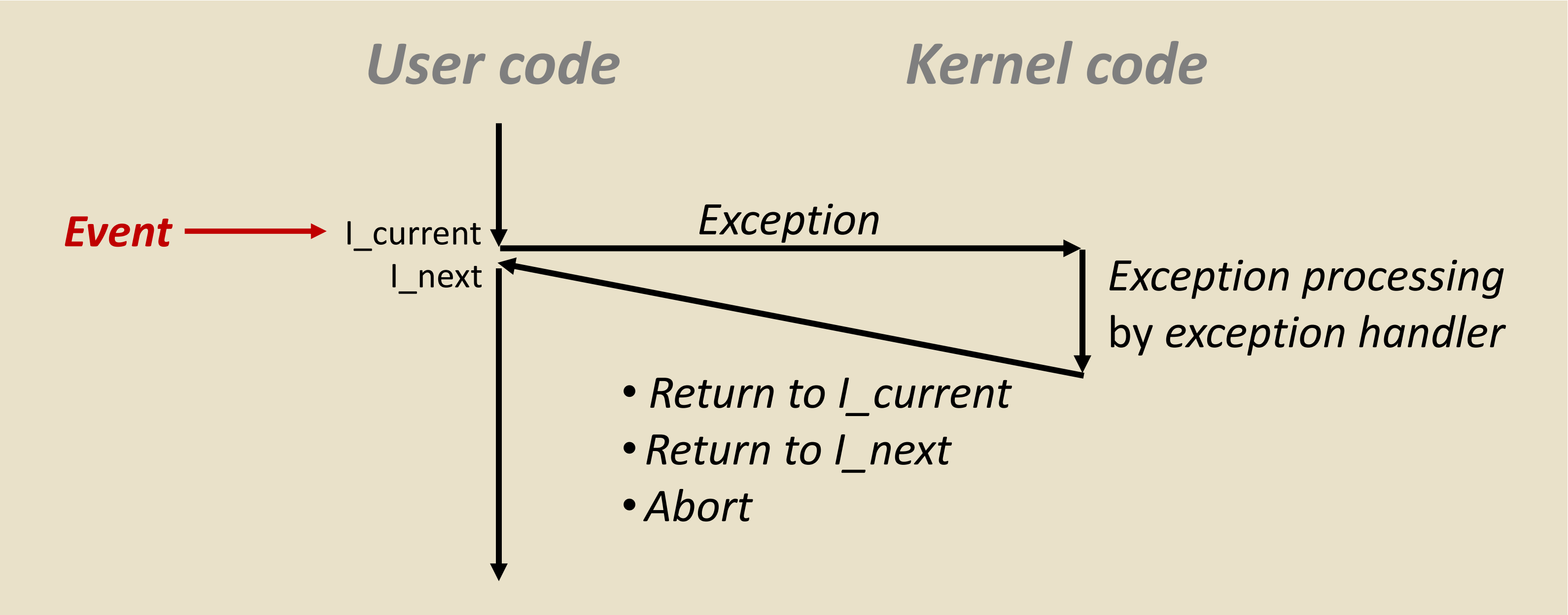
These slides adapted from materials provided by the textbook authors.

Signals and Nonlocal Jumps

- **Review**
- Shells
- Signals
- Nonlocal jumps

Exceptions

- **An *exception* is a transfer of control to the OS *kernel* in response to some *event* (i.e., change in processor state)**
  - Kernel is the memory-resident part of the OS
  - Examples of events: Divide by 0, arithmetic overflow, page fault, I/O request completes, typing Ctrl-C



Exceptions & Interrupts

- **Interrupts**
  - Asynchronous
  - Cause: Signal from I/O device
  - Returns control to next instruction
- **Traps**
  - Synchronous
  - Cause: Intentional exception (system calls)
  - Returns control to next instruction
- **Faults**
  - Synchronous
  - Cause: Potentially recoverable error
  - Either re-executes faulting (current) instruction or aborts
- **Aborts**
  - Synchronous
  - Cause: Unrecoverable error
  - Never returns

Review: syscalls

- **`getpid`, `getppid`**
  - Returns pid of calling process (`getpid`), or its parent (`getppid`).
- **`fork`**
  - Copies current process state.
  - "Call once, return twice"
- **`exit`**
  - Terminates calling process.
  - Never returns.
- **`execve`**
  - Replaces calling process' state with code/state for new program.
  - Only returns if there was an error.
- **`wait`, `waitpid`**
  - Doesn't return until a child process terminates.
- **`setjmp`, `longjmp`**

ECF Exists at All Levels of a System

- **Exceptions**
  - Hardware and operating system kernel software
- **Process Context Switch**
  - Hardware timer and kernel software
- **Signals**
  - Kernel software and application software

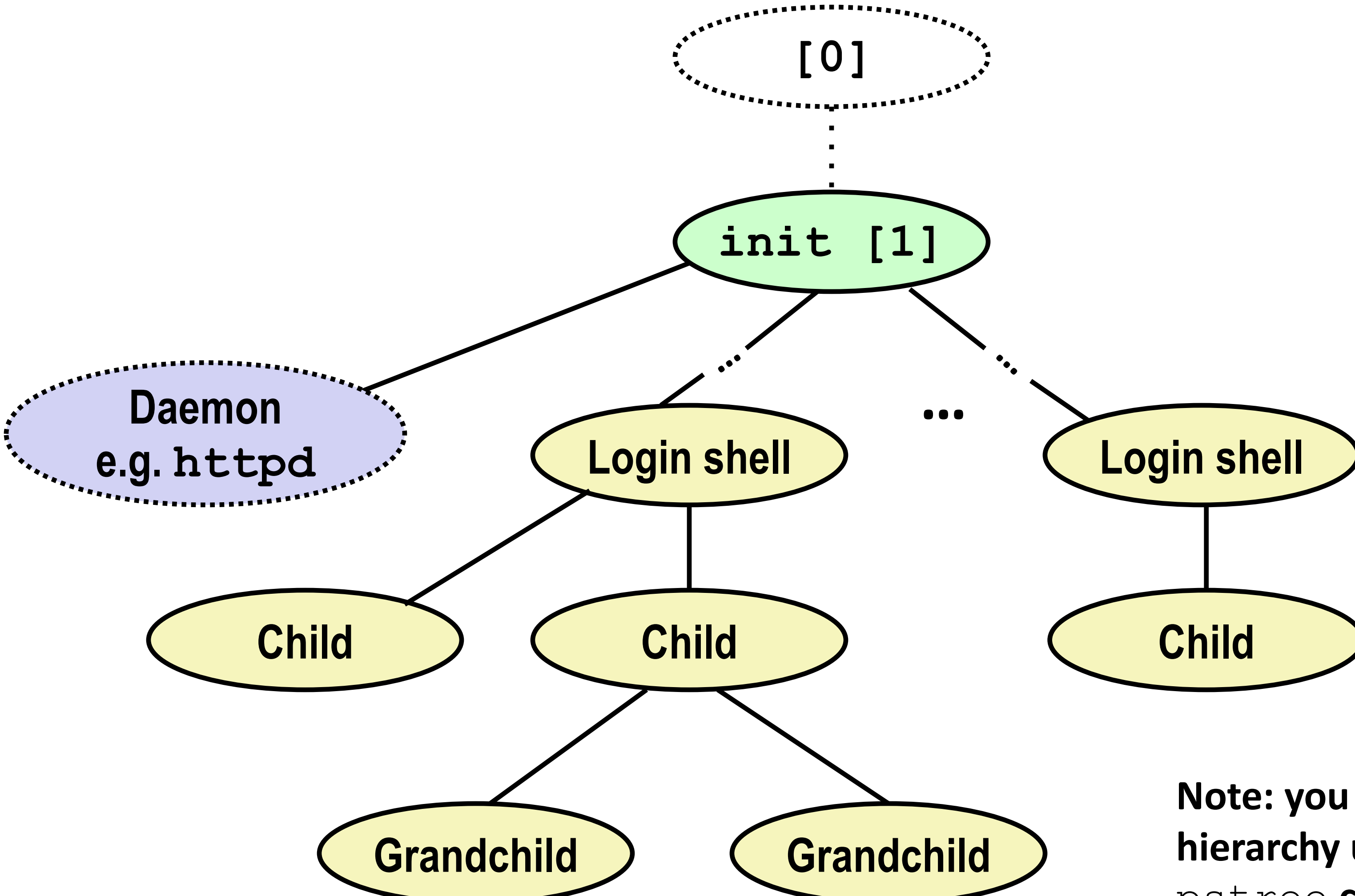
Previous

New

Signals and Nonlocal Jumps

- Review
- **Shells**
- Signals
- Nonlocal jumps

Linux Process Hierarchy



Note: you can view the hierarchy using the Linux `pstree` command

Shell Programs

- A ***shell*** **is an application program that runs programs on behalf of the user.**
  - **`sh`** Original Unix shell (Stephen Bourne, AT&T Bell Labs, 1977)
  - **`csh/tcsh`** BSD Unix C shell
  - **`bash`** "Bourne-Again" Shell (default Linux shell)

```
int main()
{
    char cmdline[MAXLINE]; /* command line */

    while (1) {
        /* read */
        printf("> ");
        Fgets(cmdline, MAXLINE, stdin);
        if (feof(stdin))
            exit(0);

        /* evaluate */
        eval(cmdline);
    }
}
```

shellex.c

Execution is a sequence of read/evaluate steps

Simple Shell `eval` Function

```c
void eval(char *cmdline)
{
    char *argv[MAXARGS]; /* Argument list execve() */
    char buf[MAXLINE];   /* Holds modified command line */
    int bg;              /* Should the job run in bg or fg? */
    pid_t pid;           /* Process id */

    strcpy(buf, cmdline);
    bg = parseline(buf, argv);
    if (argv[0] == NULL)
        return;   /* Ignore empty lines */

    if (!builtin_command(argv)) {
        if ((pid = Fork()) == 0) {   /* Child runs user job */
            if (execve(argv[0], argv, environ) < 0) {
                printf("%s: Command not found.\n", argv[0]);
                exit(0);
            }
        }

        /* Parent waits for foreground job to terminate */
        if (!bg) {
            int status;
            if (waitpid(pid, &status, 0) < 0)
                unix_error("waitfg: waitpid error");
        }
        else
            printf("%d %s", pid, cmdline);
    }
    return;
}
```

shellex.c

Problem with Simple Shell Example

- **Our example shell correctly waits for and reaps foreground jobs**

- **But what about background jobs?**
  - Will become zombies when they terminate
  - Will never be reaped because shell (typically) will not terminate
  - Will create a memory leak that could run the kernel out of memory

ECF to the Rescue!

- **Solution: Exceptional control flow**
  - The kernel will interrupt regular processing to alert us when a background process completes
  - In Unix, the alert mechanism is called a ***signal***