OS Kernels

Microkernel	Hybrid	Monolithic
Minix	OSX / macOS	Linux
	Windows 10	Windows 9x and earlier
		MSDOS
		Chrome
		IRIX
		SunOS
		BeOS

CSE 3320

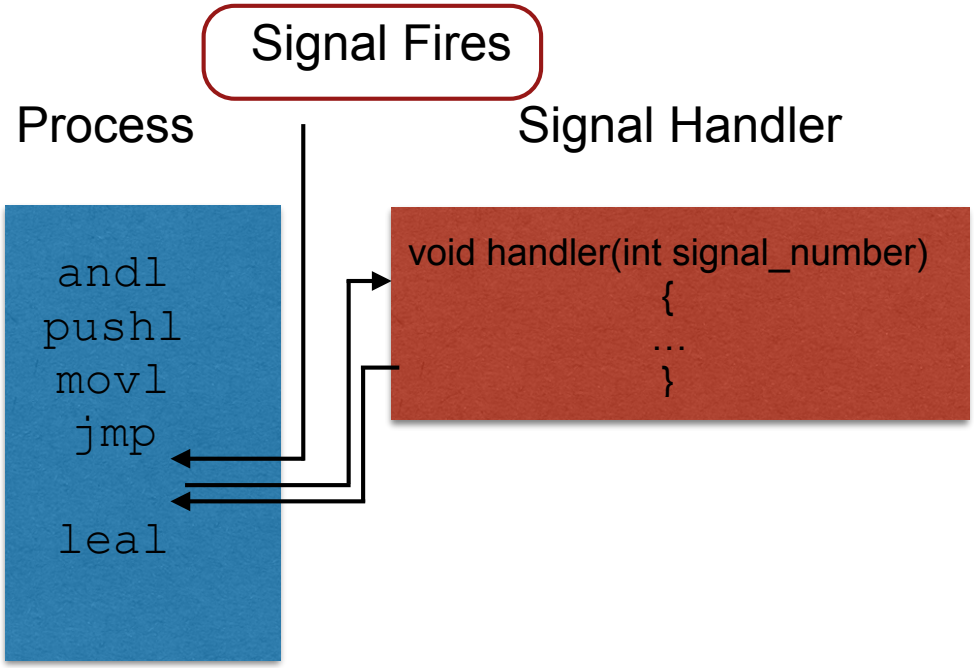
Signals

Trevor Bakker

The University of Texas at Arlington

Signals

- A signal is a asynchronous notification of an event
- Signals are how the operating system communicates with an application process.
- When a signal is received the process stops running and the assigned signal handler is run.
- When the signal has been handled the process resumes where it left off.



Some examples

- SIGSEGV - Known as a segmentation fault. It occurs when a process makes an illegal memory reference. The process halts and the default signal handler exits the process.
- SIGINT - The interrupt signal occurs when the user types ctrl-c. The default signal handler will exit the process.

Sending Signals

- By keyboard
  - ctrl-c sends the SIGINT signal and the receiving process exits
  - ctrl-z sends the SIGTSTP signal and the receiving process is suspended
  - ctrl-\ sends the SIGQUIT signal and the receiving process exits

Sending signals via shell commands

kill -signal pid

- Send a signal, specified by -signal, to the process with the process id pid.
- If no signal is specified then the signal sent is SIGTERM

Example:

kill -9 3412

kill -SIGQUIT 3412

Send signal via a function

int kill(pid_t pid, int sig)

- Send a signal, specified by -signal, to the process with the process id pid.
- If no signal is specified then the signal sent is SIGTERM

Example:

```
pid_t pid = getpid();      // process gets its own pid
kill(pid, SIGINT);         // and sends itself a SIGINT
```

Send signal via a function

int raise(int sig)

- Send a signal to the current process

Example:

```
raise(SIGINT);  // process sends itself a SIGINT
```

Signal Numbers

```
[bakker@crystal ~]$ kill -l
 1) SIGHUP       2) SIGINT       3) SIGQUIT      4) SIGILL
 5) SIGTRAP      6) SIGABRT      7) SIGBUS       8) SIGFPE
 9) SIGKILL     10) SIGUSR1     11) SIGSEGV     12) SIGUSR2
13) SIGPIPE     14) SIGALRM     15) SIGTERM     16) SIGSTKFLT
17) SIGCHLD     18) SIGCONT     19) SIGSTOP     20) SIGTSTP
21) SIGTTIN     22) SIGTTOU     23) SIGURG      24) SIGXCPU
25) SIGXFSZ     26) SIGVTALRM   27) SIGPROF     28) SIGWINCH
29) SIGIO       30) SIGPWR      31) SIGSYS      34) SIGRTMIN
35) SIGRTMIN+1  36) SIGRTMIN+2  37) SIGRTMIN+3  38) SIGRTMIN+4
39) SIGRTMIN+5  40) SIGRTMIN+6  41) SIGRTMIN+7  42) SIGRTMIN+8
43) SIGRTMIN+9  44) SIGRTMIN+10 45) SIGRTMIN+11 46) SIGRTMIN+12
47) SIGRTMIN+13 48) SIGRTMIN+14 49) SIGRTMIN+15 50) SIGRTMAX-14
51) SIGRTMAX-13 52) SIGRTMAX-12 53) SIGRTMAX-11 54) SIGRTMAX-10
55) SIGRTMAX-9  56) SIGRTMAX-8  57) SIGRTMAX-7  58) SIGRTMAX-6
59) SIGRTMAX-5  60) SIGRTMAX-4  61) SIGRTMAX-3  62) SIGRTMAX-2
63) SIGRTMAX-1  64) SIGRTMAX
```

Signal Terminology

- A signal is *generated* for a process when the event that causes the signal occurs. The event can be a hardware exception, a software condition, or a call to the kill function
- When a signal is generated the kernel usually sets a flag in the process table

Signal Terminology

- A signal is *delivered* to a process when the action for a signal is taken.
- During the time between the generation of the signal and the delivery of the signal the signal is said to be *pending*.

Signal Handling

- Every signal is assigned a default handler. Usually they just exit the process.
- Programs can install their own signal handlers for most signals.
  - Can’t install handlers for:
    - SIGKILL
    - SIGSTOP

Installing a signal handler

```
SIGACTION(2)                Linux Programmer's Manual                SIGACTION(2)

NAME
       sigaction - examine and change a signal action

SYNOPSIS
       #include <signal.h>

       int sigaction(int signum, const struct sigaction *act, struct sigaction *oldact);
```

- The function *handler* specified in the sigaction struct is installed as the new handler for the signal specified by signum.
- The new handler is called every time the process receives a signal of type signum.

Signal Handler Example

- See sigint.c and multiple_signal_handlers.c on course website under Code Samples

Blocking Signals

- We can block signals, but why would we want to?
  - Race conditions. What happens when a signal is received while we are in the middle of handling the same type of signal?
- The POSIX standard provides a way to block signals.

Blocking Signals

- Each process has a signal mask
  - The operating system uses the mask to determine which signals to deliver.
- The function sigprocmask() provides a way for programs to modify their signal mask to block and unblock signals.

Blocking Signals

- If a signal is generated for a process but blocked then the signal remains pending for the process until the process either:
  - unblocks the signal
  - changes the action to ignore the signal

Multiple Blocked Signals

- The POSIX standard allows the OS to deliver one or multiple copies of the signal.
- Most UNIX implementations do not queue signals and just deliver a singe one.

sigprocmask()

```
SIGPROCMASK(2)              BSD System Calls Manual              SIGPROCMASK(2)

NAME
     sigprocmask -- manipulate current signal mask

SYNOPSIS
     #include <signal.h>

     int
     sigprocmask(int how, const sigset_t *restrict set, sigset_t *restrict oset);
```

- First parameter is *how.* It can be:
  - SIG_BLOCK - adds the provided set to the current signal mask
  - SIG_UNBLOCK - removes the provided set from the current signal mask
  - SIG_SETMASK - the current mask is replaced by the provided set

sigprocmask()

```
SIGPROCMASK(2)              BSD System Calls Manual              SIGPROCMASK(2)

NAME
     sigprocmask -- manipulate current signal mask

SYNOPSIS
     #include <signal.h>

     int
     sigprocmask(int how, const sigset_t *restrict set, sigset_t *restrict oset);
```

- Second parameter is a pointer to the a signal mask called *set.*
- Third parameter is a pointer to which the old set can be returned.

Signal Blocking Example

- See sig_set_example.c on course website under Code Samples