LECTURE - X

SIGNALS -II

Tevfik Koşar

Louisiana State University

October 5th, 2010

Signals from a Process

#include <signal.h>

int kill(pid_t pid, int sig);

If pid > 0: Sig is sent to the process with **pid**

If pid = 0: Sig is sent to all processes whose group ID is equal to the process group ID of the sender

If pid = -1: If **root**, sig is sent to all processes excluding system processes

If **not root**, sig is sent to all processes with the same uid as the user, excluding the sender.

sig=0; error checking, i.e. validity of pid

Signal Semantics

- A signal is pending if it has been sent but not yet received.
  - There can be at most one pending signal of any particular type.
  - Signals are not queued!
- A process can block the receipt of certain signals.
  - Blocked signals can be delivered, but will not be received until the signal is unblocked.
  - There is one signal that can not be blocked by the process. (**SIGKILL**)
- A pending signal is received at most once.
  - Kernel uses a bit vector for indicating pending signals.

Implementation

- Kernel maintains **pending** and **blocked** bit vectors in the context of each process.
  - **pending** – represents the set of pending signals
    - » Kernel sets bit k in **pending** whenever a signal of type k is delivered.
    - » Kernel clears bit k in **pending** whenever a signal of type k is received.
  - **blocked** – represents the set of blocked signals
    - » Can be set and cleared by the application using the **sigprocmask** function.

Receiving Signals

- **Handling signals**
  - Suppose kernel is returning from exception handler and is ready to pass control to process p.
  - Kernel computes **pnb** = **pending** & ~**blocked**
    - The set of pending nonblocked signals for process p
  - if (**pnb** != 0) {
    - Choose least nonzero bit k in **pnb** and force process p to receive signal k.
    - The receipt of the signal triggers some action by p.
    - Repeat for all nonzero k in **pnb**.

    }
  - Pass control to next instruction in the logical flow for p.

Overlapping Signals

- SIGY interrupts SIGX
  - ex: phone then door
  - When you press CTRL-C then CTRL-\, the program first jumps to inthandler, then to quithandler, then back to inthandler, then back to main loop.
- SIGX interrupts SIGX
  - ex: two people coming to your door
  - Three ways this can be handled:
    1. Recursively call the same handler
    2. Ignore the second signal, like a phone without call waiting
    3. Block the second signal until done handling the first
  - Method 3 is safest and default in modern systems
- Interrupted System Calls
  - receiving a signal while waiting for input

Example

```
main(int ac, char *av[])
{
        void    inthandler(int);
        void    quithandler(int);
        char    input[100];

        signal( SIGINT,  inthandler );    // set trap
        signal( SIGQUIT, quithandler );   // set trap

        int i=1;
        while (i<5){
                sleep(1);
                printf("main:%d\n",i++);
        }

}
```


Ignore other Interrupts inside Handler

```
void quithandler(int s)
{
        printf(" Received signal %d .. waiting\n", s );
        .....
       printf("  Leaving quithandler \n");
}

void inthandler(int s)
{
        signal(SIGQUIT, SIG_IGN);
        printf(" Received signal %d .. waiting\n", s );
        .....
        printf("  Leaving inthandler \n");
        signal( SIGQUIT, quithandler );
}
```


Masking Signals - Avoid Race Conditions

- The occurrence of a second signal while the signal handler function executes.
  - The second signal can be of different type than the one being handled, or even of the same type.
- The system also contains some features that will allow us to block signals from being processed.
  - A global context which affects all signal handlers, or a per-signal type context.

Masking Signals *(cont.)*

- Each process maintains a signal mask which controls which signals are immediately delivered to the process and which have delivery deferred.
- If a signal is in the signal mask, it is said to be *blocked*.
- The signal mask for a process is initially empty, which means any signal can be delivered.
- Some signals (in particular, `SIGKILL` and `SIGSTOP`) cannot be deferred. Including them in a signal mask is not an error, but will not be effective.
- Blocking a signal is a temporary measure; don't confuse it with ignoring (with `SIG_IGN`) a signal.

sigprocmask() Function

- The system call allows to specify a set of signals to block, and returns the list of signals that were previously blocked.

```
sigprocmask(int how, const sigset_t *set,
    sigset_t *oldset)
```

1. `int how`:
   - Add (`SIG_BLOCK`)
   - Delete (`SIG_UNBLOCK`)
   - Set (`SIG_SETMASK`).
2. `const sigset_t *set`:
   - The set of signals.
3. `sigset_t *oldse`:
   - If this parameter is not `NULL`, then it'll contain the previous mask.

Manipulating Signal Sets

The `sa_mask` component of the `sigaction` structure contains a set of signals. This set is modified using the following functions (or macros):

- `sigemptyset (sigset_t *set);` -- init to no signals
- `sigfillset (sigset_t *set);` -- init to all signals
- `sigaddset (sigset_t *set, int signo);` -- add signal
- `sigdelset (sigset_t *set, int signo);` -- remove signal
- `sigismember (sigset_t *set, int signo);` -- check signal

Block other Interrupts inside Handler

```
void inthandler(int s)
{
        sigset_t sigset, sigoldset;

        sigemptyset(&sigset);
        sigaddset(&sigset, SIGQUIT);
        sigprocmask(SIG_SETMASK, &sigset, &sigoldset);

        printf(" Received signal %d .. waiting\n", s );
        ....
        printf("  Leaving SIGINT Handler \n");

        sigprocmask(SIG_SETMASK, &sigoldset, NULL);

}
```


sigaction() Function

- The *sigaction()* function allows the calling process to examine and/or specify the action to be associated with a specific signal.

```
int sigaction(int sig,
  struct sigaction *new_act,
  struct sigaction *old_act);
```


sigaction() Function *(cont.)*

- This function is "newer" than `signal`, and provides considerably more flexibility.
- Like `signal`, the first argument is a signal number (or name).
- The second argument is a pointer to a structure containing the new characteristics for the signal; the third argument points to a structure which will receive the old characteristics of the signal. Either or both of these pointers may be `NULL`, allowing any combination of setting or querying the action associated with a signal.

sigaction Structure

- `struct sigaction` has the following members:
  - `sa_handler` – set to `SIG_DFL`, `SIG_IGN`, or pointer to handler function (compare this with the second argument to `signal`).
  - `sa_mask` – a set of additional signals to be blocked during execution of the function identified by `sa_handler`.
  - `sa_flags` – special flags that affect the signal behavior.
  - `sa_sigaction` (used only for POSIX real-time signals).

```
struct sigaction {
        void (*sa_handler)(int);
        void (*sa_sigaction)(int, siginfo_t *, void *);
        sigset_t sa_mask;
        int sa_flags;
        void (*sa_restorer)(void);
}
```


sa_flags

SA_NOCLDSTOP: If signum is SIGCHLD, do not receive notification when child processes stop.

SA_NOCLDWAIT: If signum is SIGCHLD, do not transform children into zombies when they terminate.

SA_RESETHAND: Restore the signal action to the default state once the signal handler has been called.

SA_ONSTACK: Call the signal handler on an alternate signal stack provided by sigaltstack(2).

SA_RESTART: Provide behaviour compatible with BSD signal semantics. by making certain system calls restartable across signals.

SA_NODEFER: Do not prevent the signal from being received from within its own signal handler.

SA_SIGINFO: The signal handler takes 3 arguments, not one. In this case, sa_sigaction should be set instead of sa_handler.

sigaction() *(cont.)*

- A new signal mask is calculated and installed only for the duration of the signal-catching function, which includes the signal being delivered.
- Once an action is installed for a specific signal, it remains installed until another action is explicitly requested.

sigaction() Example

```
main()
{
        struct sigaction newhandler;            /* new settings         */
        sigset_t         blocked;               /* set of blocked sigs  */
        void             inthandler();          /* the handler          */

        newhandler.sa_handler = inthandler;      /* handler function     */
        sigfillset(&blocked);                   /* mask all signals     */
        newhandler.sa_mask = blocked;           /* store blockmask      */

        int i;
        for (i=1; i<31;i++)
                if (i!=9 && i!=17) /* catch all except these signals */
                   if ( sigaction(i, &newhandler, NULL) == -1 )
                        printf("error with signal %d\n", i);
        while(1){}
}
```


Real-time Signals

- POSIX.4 adds some additional signal facilities. The key features are:
  - The real-time signals are in addition to the existing signals, and are in the range `SIGRTMIN` to `SIGRTMAX`.
  - Real-time signals are queued, not just registered (as is done for non real-time signals).
  - The source of a real-time signal (`kill`, `sigqueue`, asynchronous I/O completion, timer expiration, etc.) is indicated when the signal is delivered.
  - A data value can be delivered with the signal.

sigqueue()

The `sigqueue()` function provides a means to queue a signal, and provide additional signal data. The function fails immediately if queueing is not possible.

```
int sigqueue(pid_t pid, int signo, const
                        union sigval value);
```

The union `sigval` has the following members:

```
int sival_int;     // a simple integer value
void *sival_ptr;   // a pointer
```


Summary

- Signals
  - Generating & Catching Signals
  - Overlapping Signals
  - Preventing Race Conditions
  - Masking Signals

- Read Ch 10 from Stevens Book

Acknowledgments

- Advanced Programming in the Unix Environment by R. Stevens
- The C Programming Language by B. Kernighan and D. Ritchie
- Understanding Unix/Linux Programming by B. Molay
- Lecture notes from B. Molay (Harvard), T. Kuo (UT-Austin), G. Pierre (Vrije), M. Matthews (SC), B. Knicki (WPI), and M. Shcklette (UChicago).