Signals

Revisiting Symbolic Links

Getting the actual filename referred by symbolic link:

- command line:
  - `readlink` - display value of a symbolic link

- in C:
  - `#include <unistd.h>`
  - `int readlink(const char *path, char *buf, size_t bufsiz);`

Readlink Example

```c
char *readlink_malloc (const char *filename)
{
    int size = 100;
    char *buffer = NULL;
    buffer = (char *) malloc (size);
    int nchars = readlink (filename, buffer, size);
    if (nchars < 0)
    {
        free (buffer);
        return NULL;
    }
    if (nchars < size)
    {
        return buffer;
        size *= 2;
    }
}
```

What is a Signal?

- A signal is a software interrupt delivered to a process by the OS because:
  - it did something (segfault, FPE)
  - the user did something (pressed ^C)
  - another process wants to tell it something (SIGUSR?)

- Sending a signal is one way a process can communicate with other processes

- Some signals is asynchronous, they may be raised at any time (user pressing ^C)

- Some signals are directly related to hardware (illegal instruction, arithmetic exception, such as attempt to divide by 0) - synchronous signals

Common Signals

- SIGHUP (1): hangup - sent to a process when its controlling terminal has disconnected
- SIGINT (2): interrupt - Ctrl-C pressed by user
- SIGQUIT (3): quit - Ctrl-
- SIGILL (4): Illegal instruction (default core)
- SIGABRT (6): Abort process
- SIGKILL (9): kill (cannot be caught or ignored)
- SIGSEGV (11): Segmentation fault
- SIGALRM (14): Alarm cock timeout
- SIGUSR[1,2]: User-defined signals
- `kill -l` will list all signals

Signal Disposition

- Ignore the signal (most signals can simply be ignored, except SIGKILL and SIGSTOP)
- Handle the signal disposition via a signal handler routine. This allows us to gracefully shutdown a program when the user presses Ctrl-C (SIGINT).
- Block the signal. In this case, the OS queues signals for possible later delivery
- Let the default apply (usually process termination)
Default Signal Actions (BSD)

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Default Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SIGHUP</td>
<td>terminate process</td>
<td>terminal line hangup</td>
</tr>
<tr>
<td>2</td>
<td>SIGINT</td>
<td>terminate process</td>
<td>interrupt program</td>
</tr>
<tr>
<td>3</td>
<td>SIGQUIT</td>
<td>create core image</td>
<td>quit program</td>
</tr>
<tr>
<td>4</td>
<td>SIGILL</td>
<td>create core image</td>
<td>illegal instruction</td>
</tr>
<tr>
<td>5</td>
<td>SIGTRAP</td>
<td>create core image</td>
<td>trace trap</td>
</tr>
<tr>
<td>6</td>
<td>SIGABRT</td>
<td>create core image</td>
<td>abort program</td>
</tr>
<tr>
<td>7</td>
<td>SIGTSTP</td>
<td>create core image</td>
<td>emulate instruction</td>
</tr>
<tr>
<td>8</td>
<td>SIGFPE</td>
<td>create core image</td>
<td>floating-point exception</td>
</tr>
<tr>
<td>9</td>
<td>SIGKILL</td>
<td>terminate process</td>
<td>kill program</td>
</tr>
<tr>
<td>10</td>
<td>SIGBUS</td>
<td>create core image</td>
<td>bus error</td>
</tr>
<tr>
<td>11</td>
<td>SIGSEGV</td>
<td>create core image</td>
<td>segmentation violation</td>
</tr>
<tr>
<td>12</td>
<td>SIGSYS</td>
<td>create core image</td>
<td>non-existent system call</td>
</tr>
<tr>
<td>13</td>
<td>SIGPIPE</td>
<td>terminate process</td>
<td>write on a pipe with</td>
</tr>
<tr>
<td>14</td>
<td>SIGALRM</td>
<td>terminate process</td>
<td>real-time timer expired</td>
</tr>
<tr>
<td>15</td>
<td>SIGTERM</td>
<td>terminate process</td>
<td>software termination</td>
</tr>
<tr>
<td>16</td>
<td>SIGURG</td>
<td>discard signal</td>
<td>urgent condition present on socket</td>
</tr>
<tr>
<td>17</td>
<td>SIGSTOP</td>
<td>stop process</td>
<td>stop (cannot be caught or ignored)</td>
</tr>
<tr>
<td>18</td>
<td>SIGSTP</td>
<td>stop process</td>
<td>stop signal from keyb</td>
</tr>
<tr>
<td>19</td>
<td>SIGCONT</td>
<td>discard signal</td>
<td>continue after stop</td>
</tr>
<tr>
<td>20</td>
<td>SIGCHLD</td>
<td>discard signal</td>
<td>child status has changed</td>
</tr>
<tr>
<td>21</td>
<td>SIGTTIN</td>
<td>stop process</td>
<td>background read attempt</td>
</tr>
<tr>
<td>22</td>
<td>SIGTTOU</td>
<td>stop process</td>
<td>background write attempt</td>
</tr>
<tr>
<td>23</td>
<td>SIGIOT</td>
<td>discard signal</td>
<td>I/O is possible on a desc</td>
</tr>
<tr>
<td>24</td>
<td>SIGCPU</td>
<td>terminate process</td>
<td>cpu time limit exceeded</td>
</tr>
<tr>
<td>25</td>
<td>SIGFPE</td>
<td>terminate process</td>
<td>file size limit exceeded</td>
</tr>
<tr>
<td>26</td>
<td>SIGVTALRM</td>
<td>terminate process</td>
<td>virtual time alarm</td>
</tr>
<tr>
<td>27</td>
<td>SIGPROF</td>
<td>terminate process</td>
<td>profiling timer alarm</td>
</tr>
<tr>
<td>28</td>
<td>SIGWINCH</td>
<td>discard signal</td>
<td>Window size change</td>
</tr>
<tr>
<td>29</td>
<td>SIGINFO</td>
<td>discard signal</td>
<td>status request from keyboard</td>
</tr>
<tr>
<td>30</td>
<td>SIGUSR1</td>
<td>terminate process</td>
<td>User defined signal 1</td>
</tr>
<tr>
<td>31</td>
<td>SIGUSR2</td>
<td>terminate process</td>
<td>User defined signal 2</td>
</tr>
<tr>
<td>32</td>
<td>SIGTRAP</td>
<td>terminate process</td>
<td>thread interrupt</td>
</tr>
</tbody>
</table>

Changing Default Action

```c
void (*signal(int sig, void (*func)(int)))(int);

• void (* signal (int sig, void (*func)(int)))(int);
• typedef void (* sig_t) (int);
• sig_t signal(int sig, sig_t func);
```

Actions:
• SIG_DFL: Reset to default Action
• SIG_IGN: Ignore Signal
• func(): user defined function

Catching a Signal

```c
main(int ac, char *av[])
{
    void inthandler(int);
    void quithandler(int);
    char input[100];
    signal( SIGINT,  inthandler );    //set trap
    signal( SIGQUIT, quithandler );   //set trap
    do {
        printf("Type a message
");
        if ( fgets(input) == NULL )
            perror("Saw EOF ");
        else
            printf("You typed: %s
", input);
    } while( strcmp( input , "quit" ) != 0 );
}
```

Catching a Signal (cont.)

```c
void inthandler(int s)
{
    printf(" Received signal %d .. waiting\n", s);
    sleep(2);
    printf(" Leaving inthandler \n");
}

void quithandler(int s)
{
    printf(" Received signal %d .. waiting\n", s);
    sleep(3);
    printf(" Leaving quithandler \n");
}
```

User Defined Signals

```c
main(int ac, char *av[])
{
    void signalhandler(int);
    signal( SIGUSR1,  signalhandler );
    signal( SIGUSR2,  signalhandler );
    while(1) pause();
}

void signalhandler(int s)
{
    printf(" Received signal %d\n", s);
}
```
STOP & CONT Signals

main(int ac, char *av[])
{
    signal(SIGSTOP, signalhandler);  
    signal(SIGCONT, signalhandler);  
    int i=0;  
    while(1){  
        printf("i=%d\n", i++);  
        sleep(1);  
    }  
}
void signalhandler(int s)
{
    printf("Received signal %d\n", s);  
}

Alarm Signals

• SIGALRM can be used as a kind of “alarm clock” for a process
• By setting a disposition for SIGALRM, a process can set an alarm to go off in \( x \) seconds with the call:
  
  \[
  \text{unsigned int alarm(unsigned int numseconds)}
  \]
• Alarms can be interrupted by other signals
• Examples: msysleep.c, impatient.c

Alarm Signal

main()
{
    void wakeup();
    printf("about to sleep for 4 seconds\n");
    signal(SIGALRM, wakeup);  /* catch it */
    alarm(4);  /* set clock */
    pause();  /* sleep */
    printf("Morning so soon?\n");  /* back to work */
}
void wakeup()
{
    printf("Wakeup: Alarm received from kernel!\n");
}

Interval Timers

#include <sys/time.h>

• int getitimer(int which, struct itimerval *value);
• int setitimer(int which, const struct itimerval *value, 
    struct itimerval *ovalue);

Three Timers:
• ITIMER_REAL: decrements in real time
• ITIMER_VIRTUAL: decrements only when the process is executing
• ITIMER_PROF: decrements both when the process executes and when the system is executing on behalf of the process.

Interval Timer Struct

struct itimerval {
    struct timeval it_interval;  /* next value */
    struct timeval it_value;  /* current value */
};

struct timeval {
    long tv_sec;  /* seconds */
    long tv_usec;  /* microseconds */
};

Interval Time Example

#include <stdio.h>
#include <signal.h>
#include <sys/time.h>

void main()
{
    char x[200];
    signal(SIGALRM, hello);
    set_ticket(5,1);
    while(1)
    {
        printf("enter a word: ");
        fgets(x, 200, stdin);
        print(">>> ka", x);
    }
}
Interval Time Example (cont.)

```c
void set_ticker(int start, int interval)
{
    struct itimerval new_timeset;

    new_timeset.it_interval.tv_sec  = interval;
    new_timeset.it_interval.tv_usec = 0;
    new_timeset.it_value.tv_sec     = start  ;
    new_timeset.it_value.tv_usec    = 0  ;

    return setitimer(ITIMER_REAL, &new_timeset, NULL);
}
```

Interval Time Example (cont.)

```c
void hello(int s)
{
    static int counter = 5;

    printf("hello\n");
    counter--;
    printf("* TICK: counter is now %d\n", counter);
    if (counter == 0 ){
        printf("* TICK: Time is up\n");
        exit(0);
        counter = 5;
    }
}
```

Summary

- Signals
  - Signal Types & Actions
  - Catching Signals
  - STOP & CONT Signals
  - ALARM Signals
  - Interval Timers
- Read Ch 10 from Stevens Bok
- Source Codes available in: /classes/cs4304/cs4304_kos/code

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).