Recitation - V

Signals

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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

• Others are purely software signals (interrupt, bad system call, segmentation fault)
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-\ pressed by user
- **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
Process Groups

- Every process belongs to exactly one process group.

- `getpgid()` — Return process group of current process
- `setpgid()` — Change process group of a process
Sending Signals

- **Sending signals from the keyboard**
  - Typing `ctrl-c` (`ctrl-z`) sends a **SIGINT** (**SIGTSTP**) to every job in the foreground process group.
    - **SIGINT**: default action is to terminate each process.
    - **SIGTSTP**: default action is to stop (suspend) each process.
Signals from Keyboard

The most common way of sending signals to processes is using the keyboard:

- **Ctrl-C**: Causes the system to send an **INT** signal (**SIGINT**) to the running process.
- **Ctrl-Z**: Causes the system to send a **TSTP** signal (**SIGTSTP**) to the running process.
- **Ctrl-\**: Causes the system to send a **ABRT** signal (**SIGABRT**) to the running process.
Signals from Command-Line

• The `kill` command has the following format:

```
kill [options] pid
```

  --l lists all the signals you can send
  --signal is a signal number
  – the default is to send a TERM signal to the process.

• The `fg` command will resume execution of the process (that was suspended with Ctrl-Z), by sending it a CONT signal.

$ kill 10231 // SIGTERM : default signal
$ kill -9 10231 // SIGKILL
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)
Actions on Signal

do_signal ( )

Ignoring the signal

Executing the default action

Executing the signal handler
Default Actions

- **Abort** – terminate the process after generating a dump
- **Exit** – terminate the process without generating a dump
- **Ignore** – the signal is ignored
- **Stop** – suspends the process
- **Continue** – resumes the process, if suspended
## 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>SIGEMT</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>
</tbody>
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<tbody>
<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>SIGTSTP</td>
<td>stop process</td>
<td>stop signal from keyboard</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>SIGIO</td>
<td>discard signal</td>
<td>I/O is possible on a descriptor</td>
</tr>
<tr>
<td>24</td>
<td>SIGXCPU</td>
<td>terminate process</td>
<td>cpu time limit exceeded</td>
</tr>
<tr>
<td>25</td>
<td>SIGXFSZ</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>SIGTHR</td>
<td>terminate process</td>
<td>thread interrupt</td>
</tr>
</tbody>
</table>
Catching the Signal

User Mode

- Normal program flow
- Signal handler
- Return code on the stack

Kernel Mode

- do_signal()
  - handle_signal()
  - setup_frame()

- system_call()
  - sys_sigreturn()
  - restore_sigcontext()
Changing Default Action

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

Actions:

- SIG_DSL: Reset to default Action
- SIG_IGN: Ignore Signal
- func(): user defined function
Non-Catchable Signals

• Most signals may be caught by the process, but there are a few signals that the process cannot catch, and cause the process to terminate.
  – For example: kill and stop.
• If you install no signal handlers of your own the runtime environment sets up a set of default signal handlers.
  – For example:
    • The default signal handler for the TERM signal calls the exit().
    • The default handler for the ABRT is to dump the process's memory image into a file, and then exit.
```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("\nType a message\n");
        if ( gets(input) == NULL )
            perror("Saw EOF ");
        else
            printf("You typed: %s\n", 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");
    exit(0)
}
```
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 );
}
```
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 );
}
Alarming 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:
  – unsigned int alarm(unsigned int numseconds)
• Alarms can be interrupted by other signals
• Examples: mysleep.c, impatient.c
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

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

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


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

void main()
{
    char x[200];

    signal(SIGALRM, hello);
    set_ticker(5,1);

    while(1)
    {
        printf("enter a word: ");
        fgets(x, 200, stdin);
        printf(">>> %s", x);
    }
}
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);
}
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
  - Generating & Catching Signals
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