CS 33
Signals Part 1
Whoops ...

$ SometimesUsefulProgram xyz
Are you sure you want to proceed? Y
Are you really sure? Y
Reformatting of your disk will begin in 3 seconds.
Everything you own will be deleted.
There's little you can do about it.
Too bad ...

Oh dear...
One Approach …
A Gentler Approach

• Signals
  – get a process’s attention
    » send it a signal
  – process must either deal with it or be terminated
    » in some cases, the latter is the only option
Stepping Back …

• What are we trying to do?
  – interrupt the execution of a program
    » cleanly terminate it
    or
    » cleanly change its course
  – not for the faint of heart
    » it’s difficult
    » it gets complicated
    » (not done in Windows)
Signals

• Generated (by OS) in response to
  – exceptions (e.g., arithmetic errors, addressing problems)
    » synchronous signals
  – external events (e.g., timer expiration, certain keystrokes, actions of other processes)
    » asynchronous signals

• Effect on process:
  – termination (possibly after producing a core dump)
  – invocation of a procedure that has been set up to be a signal handler
  – suspension of execution
  – resumption of execution
Terminology

signal generation

signal pending

signal delivery

$\textit{time}$
## Signal Types

<table>
<thead>
<tr>
<th>Signal Type</th>
<th>Description</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGABRT</td>
<td>abort called</td>
<td>term, core</td>
</tr>
<tr>
<td>SIGALRM</td>
<td>alarm clock</td>
<td>term</td>
</tr>
<tr>
<td>SIGCHLD</td>
<td>death of a child</td>
<td>ignore</td>
</tr>
<tr>
<td>SIGCONT</td>
<td>continue after stop</td>
<td>cont</td>
</tr>
<tr>
<td>SIGFPE</td>
<td>erroneous arithmetic operation</td>
<td>term, core</td>
</tr>
<tr>
<td>SIGHUP</td>
<td>hangup on controlling terminal</td>
<td>term</td>
</tr>
<tr>
<td>SIGILL</td>
<td>illegal instruction</td>
<td>term, core</td>
</tr>
<tr>
<td>SIGINT</td>
<td>interrupt from keyboard</td>
<td>term</td>
</tr>
<tr>
<td>SIGKILL</td>
<td>kill</td>
<td>forced term</td>
</tr>
<tr>
<td>SIGPIPE</td>
<td>write on pipe with no one to read</td>
<td>term</td>
</tr>
<tr>
<td>SIGQUIT</td>
<td>quit</td>
<td>term, core</td>
</tr>
<tr>
<td>SIGSEGV</td>
<td>invalid memory reference</td>
<td>term, core</td>
</tr>
<tr>
<td>SIGSTOP</td>
<td>stop process</td>
<td>forced stop</td>
</tr>
<tr>
<td>SIGTERM</td>
<td>software termination signal</td>
<td>term</td>
</tr>
<tr>
<td>SIGTSTOP</td>
<td>stop signal from keyboard</td>
<td>stop</td>
</tr>
<tr>
<td>SIGTTIN</td>
<td>background read attempted</td>
<td>stop</td>
</tr>
<tr>
<td>SIGTTOU</td>
<td>background write attempted</td>
<td>stop</td>
</tr>
<tr>
<td>SIGUSR1</td>
<td>application-defined signal 1</td>
<td>stop</td>
</tr>
<tr>
<td>SIGUSR2</td>
<td>application-defined signal 2</td>
<td>stop</td>
</tr>
</tbody>
</table>
Sending a Signal

- **int kill(pid_t pid, int sig)**
  - send signal *sig* to process *pid*

- **Also**
  - *kill* shell command
  - type `ctrl-c`
    - sends signal 2 (SIGINT) to current process
  - type `ctrl-\`
    - sends signal 3 (SIGABRT) to current process
  - type `ctrl-z`
    - sends signal 20 (SIGTSTP) to current process
  - do something illegal
    - bad address, bad arithmetic, etc.
Handling Signals

```c
#include <signal.h>

typedef void (*sighandler_t)(int);
sighandler_t signal(int signo, 
   sighandler_t handler);

sighandler_t OldHandler;

OldHandler = signal(SIGINT, NewHandler);
```
Special Handlers

- **SIG_IGN**
  - ignore the signal
  - `signal(SIGINT, SIG_IGN);`

- **SIG_DFL**
  - use the default handler
    - usually terminates the process
  - `signal(SIGINT, SIG_DFL);`
Example

```c
int main() {
    void handler(int);

    signal(SIGINT, handler);
    while(1)
        ;
    return 1;
}

void handler(int signo) {
    printf("I received signal %d. "
        "Whoopee!!\n", signo);
}
```
```c
int sigaction(int sig, const struct sigaction *new,
              struct sigaction *old);

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

int main() {
    struct sigaction act; void myhandler(int);
    sigemptyset(&act.sa_mask); // zeroes the mask
    act.sa_flags = 0;
    act.sa_handler = myhandler;
    sigaction(SIGINT, &act, NULL);
    ...
}
```
Example

```c
int main() {
    void handler(int);
    struct sigaction act;
    act.sa_handler = handler;
    sigemptyset(&act.sa_mask);
    act.sa_flags = 0;
    sigaction(SIGINT, &act, 0);

    while(1)
        ;
    return 1;
}

void handler(int signo) {
    printf("I received signal %d. "
          "Whoopee!!\n", signo);
}
```
You run the example program, then quickly type ctrl-C. What is the most likely explanation if the program then terminates?

a) you’re really quick or the system is really slow
b) this “can’t happen;” thus there’s a problem with the system
c) there’s something else going on we haven’t yet explained
Getting More Out of Signals (1)

- Getting more than the signal number
  - for example, which arithmetic problem caused a SIGFPE?
- Use `sa_sigaction` rather than `sa_handler`

```c
struct sigaction act;
act.sa_sigaction = arith_error;
    /* not sa_handler! */
sigemptyset(&act.sa_mask);
act.sa_flags = SA_SIGINFO;
    /* means that we're using sa_sigaction */
sigaction(SIGFPE, &act, 0);
```
Getting More Out of Signals (2)

```c
void arith_error(int signo, siginfo_t *infop, void *ctx) {

    if (infop->si_code == FPE_INTDIV) {
/* deal with integer divide by zero */
        ...
    }
    ...
}
```
Waiting for a Signal ...

```c
signal(SIGALRM, RespondToSignal);

...

struct timeval waitperiod = {0, 1000};
    /* seconds, microseconds */
struct timeval interval = {0, 0};
struct itimerval timerval;
timerval.it_value = waitperiod;
timerval.it_interval = interval;

setitimer(ITIMER_REAL, &timerval, 0);
    /* SIGALRM sent in ~one millisecond */
pause(); /* wait for it */
printf("success!\n");
```
signal(SIGALRM, RespondToSignal);

...

```
struct timeval waitperiod = {0, 1000};
   /* seconds, microseconds */
struct timeval interval = {0, 0};
struct itimerval timerval;
timerval.it_value = waitperiod;
timerval.it_interval = interval;

setitimer(ITIMER_REAL, &timerval, 0);
   /* SIGALRM sent in ~one millisecond */
pause(); /* wait for it */
printf("success!\n");
```

This program is guaranteed to print “success!”.
  a) yes
  b) no
Doing It Safely

```c
sigset_t set, oldset;
sigemptyset(&set);
sigaddset(&set, SIGALRM);
sigprocmask(SIG_BLOCK, &set, &oldset);
    /* SIGALRM now masked */
...
ssetitimer(ITIMER_REAL, &timerval, 0);
    /* SIGALRM sent in ~one millisecond */

sigsuspend(&oldset);    /* wait for it safely */
    /* SIGALRM masked again */
...

sigprocmask(SIG_SETMASK, &oldset, (sigset_t *)0);
    /* SIGALRM unmasked */
printf("success!\n");
```
Quiz 3

```c
sigset_t set, oldset;
sigemptyset(&set);
sigaddset(&set, SIGALRM);
sigprocmask(SIG_BLOCK, &set, &oldset);
    /* SIGALRM now masked */
...
sisetimer(ITIMER_REAL, &timerval, 0);
    /* SIGALRM sent in ~one millisecond */
sigsuspend(&oldset);
    /* wait for it safely */
    /* SIGALRM masked again */
...
sigprocmask(SIG_SETMASK, &oldset, (sigset_t *)0);
    /* SIGALRM unmasked */
printf("success!\n");
```

This program is now guaranteed to print “success!”.

a) yes
b) no
Signal Sets

• To clear a set:

  ```c
  int sigemptyset(sigset_t *set);
  ```

• To add or remove a signal from the set:

  ```c
  int sigaddset(sigset_t *set, int signo);
  int sigdelset(sigset_t *set, int signo);
  ```

• Example: to refer to both SIGHUP and SIGINT:

  ```c
  sigset_t set;

  sigemptyset(&set);
  sigaddset(&set, SIGHUP);
  sigaddset(&set, SIGINT);
  ```
Masking (Blocking) Signals

```
#include <signal.h>
int sigprocmask(int how, const sigset_t *set, sigset_t *old);
```

- used to examine or change the signal mask of the calling process
  - *how* is one of three commands:
    - **SIG_BLOCK**
      - the new signal mask is the union of the current signal mask and set
    - **SIG_UNBLOCK**
      - the new signal mask is the intersection of the current signal mask and the complement of set
    - **SIG_SETMASK**
      - the new signal mask is set
Timed Out!

```c
int TimedInput() {
    signal(SIGALRM, timeout);
    ...
    alarm(30);    /* send SIGALRM in 30 seconds */
    GetInput();    /* possible long wait for input */
    alarm(0);     /* cancel SIGALRM request */
    HandleInput();
    return(0);
}

nogood:
    return(1);
}

void timeout() {
    goto nogood;    /* not legal but straightforward */
}
```
Doing It Legally (but Weirdly)

```c
sigjmp_buf context;

int TimedInput() {
    signal(SIGALRM, timeout);
    if (sigsetjmp(context, 1) == 0) {
        alarm(30);
        GetInput(); /* possible long wait for input */
        alarm(0);   /* cancel SIGALRM request */
        HandleInput();
        return 0;
    } else
    return 1;
}

void timeout() {
    siglongjmp(context, 1); /* legal but weird */
}
```
Quiz 4

sigjmp_buf ctx;
int SaveIt() {
    return sigsetjmp(ctx, 1);
}

int TimedInput() {
    ...
    if (SaveIt() == 0) {
        alarm(30);
        getInput();
        alarm(0);
        HandleInput();
        return 0;
    } else return 1;
}

Does this work?

a) yes
b) no

void timeout() {
    siglongjmp(ctx, 1);
}
Exceptions

• Other languages support exception handling

    try {
        something_a_bit_risky();
    } catch (ArithmeticException e) {
        deal_with_it(e);
    }

• Can we do something like this in C?
Exception Handling in C

```c
void Exception(int sig) {
    THROW(sig)
}

int computation(int a) {
    return a/(a-a);
}

int main() {
    signal(SIGFPE, Exception);
    signal(SIGSEGV, Exception);
    TRY {
        computation(1);
    } CATCH(SIGFPE) {
        fprintf(stderr, "SIGFPE\n");
    } CATCH(SIGSEGV) {
        fprintf(stderr, "SIGSEGV\n");
    } END

    return 0;
}
```
Exception Handling in C

```c
#define TRY
{
    int excp;
    if ((excp = sigsetjmp(ctx, 1)) == 0)
```

```c
#define CATCH(a_excp)
    else if (excp == a_excp)
```

```c
#define END }
```

```c
#define THROW(excp)
    siglongjmp(ctx, excp);
```
Exception Handling in C

```c
sigjmp_buf ctx;

int main() {
    ...
    {
        int excp;
        if ((excp = sigsetjmp(ctx, 1)) == 0) {
            TRY
            computation(1);
        } else if (excp == SIGFPE) {
            CATCH
            fprintf(stderr, "SIGFPE\n");
        } else if (excp == SIGSEGV) {
            CATCH
            fprintf(stderr, "SIGFPE\n");
        }
        END
    }
    return 0;
}

void exception(int sig) {
    THROW
    siglongjmp(ctx, sig);
}
```