# Basic Signal Programming

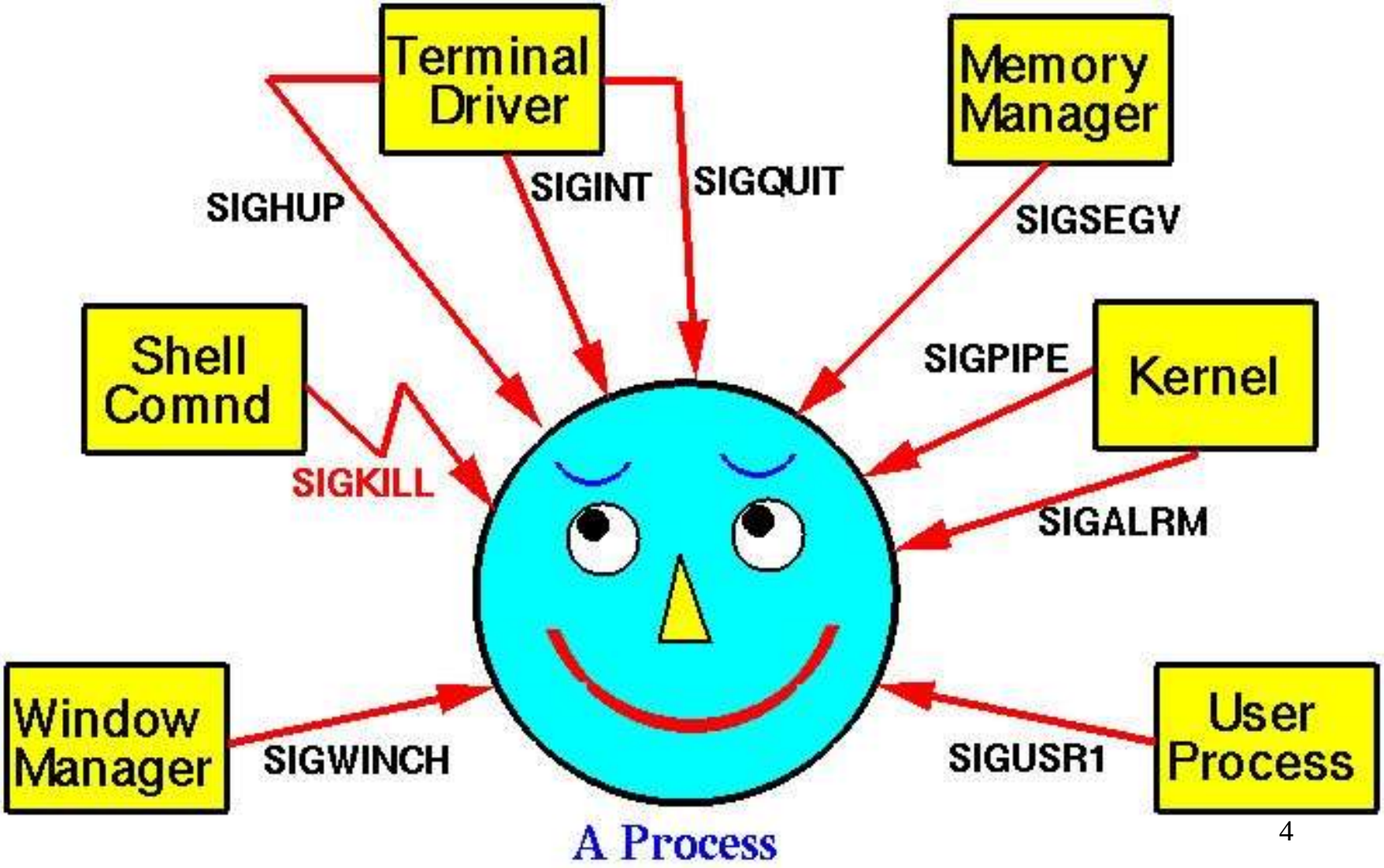
# What is a *signal*?

- **Signals are generated when an event occurs that requires attention. It can be considered as a software version of a hardware interrupt**
- **Signal Sources:**
  - **Hardware - division by zero**
  - **Kernel – notifying an I/O device for which a process has been waiting is available**
  - **Other Processes – a child notifies its parent that it has terminated**
  - **User – key press (*i.e.*, `Ctrl-C`)**

# What signals are available?

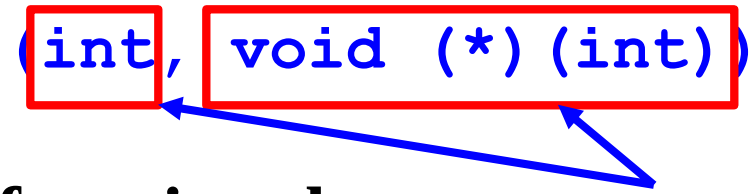
- **Signal names are defined in `signal.h`**
- **The following are examples:**
  - **`SIGALRM` – alarm clock**
  - **`SIGBUS` – bus error**
  - **`SIGFPE` – floating point arithmetic exception**
  - **`SIGINT` – interrupt (*i.e.*, `Ctrl-C`)**
  - **`SIGQUIT` – quit (*i.e.*, `Ctrl-\`)**
  - **`SIGTERM` – process terminated**
  - **`SIGUSR1` and `SIGUSR2` – user defined signals**
- **You can ignore *some* signals**
- **You can also catch and handle some signals.**

# Signal Sources



# Function `signal()`

```
void (*signal(int, void (*)(int)))(int);
```



- `signal()` **is a function that accepts *two* arguments and returns a pointer to a function that takes one argument, the signal handler, and returns nothing. If the call fails, it returns** `SIG_ERR`**.**
- **The arguments are**
  - **The first is an integer (*i.e.*,** `int`**), a *signal name*.**
  - **The second is a function that accepts an** `int` **argument and returns nothing, the *signal handler*.**
  - **If you want to ignore a signal, use** `SIG_IGN` **as the second argument.**
  - **If you want to use the default way to handle a signal, use** `SIG_DFL` **as the second argument.**

# Examples

- **The following ignores signal `SIGINT`**

```
signal(SIGINT, SIG_IGN);
```

- **The following uses the default way to handle `SIGALRM`**

```
signal(SIGALRM, SIG_DFL);
```

- **The following installs function `INThandler()` as the signal handler for signal `SIGINT`**

```
signal(SIGINT, INThandler);
```

# Install a Signal Handler: 1/2

```
#include <stdio.h>
#include <signal.h>

void  INThandler(int);

void main(void)
{
    if (signal(SIGINT, SIG_IGN) != SIG_IGN)
        signal(SIGINT, INThandler);
    while (1)
        pause();
}
```

# Install a Signal Handler: 2/2

```
void  INThandler(int sig)
{
    char c;
    signal(sig, SIG_IGN);
    printf("Ouch, did you hit Ctrl-C?\n",
           "Do you really want to quit [y/n]?");
    c = getchar();
    if (c == 'y' || c = 'Y')
       exit(0);
    else
       signal(SIGINT, INThandler);
}
```

*ignore the signal first*

*reinstall the signal handler*

# Here is the procedure

1. **Prepare a function that accepts an integer, a signal name, to be a signal handler.**
2. **Call `signal()` with a signal name as the first argument and the signal handler as the second.**
3. **When the signal you want to handle occurs, *your* signal handler is called with the argument the signal name that just occurred.**
4. **Two important notes:**
   a. **You might want to ignore that signal in your handler**
   b. **Before returning from your signal handler, don't forget to re-install it.**

# Handling Multiple Signal Types: 1/2

- You can install multiple signal handlers:

```
signal(SIGINT, INThandler);
signal(SIGQUIT, QUIThandler);

void  INThandler(int sig)
{
    // SIGINT handler code
}

void  QUIThandler(int sig)
{
    // SIGQUIT handler code
}
```

# Handling Multiple Signal Types: 2/2

- Or, you can use one signal handler and install it multiple times

```
signal(SIGINT, SIGhandler);
signal(SIGQUIT, SIGhandler);

void SIGhandler(int sig)
{
    switch (sig) {
        case SIGINT:    // code for SIGINT
        case SIGQUIT:   // code for SIGQUIT
        default:        // other signal types
    }
}
```

# Handling Multiple Signal Types Example: 1/4

```
#include <stdio.h>
#include <stdlib.h>
#include <signal.h>

#define  MAX_i          10000
#define  MAX_j          20000
#define  MAX_SECOND     (2)

void   INThandler(int);
void   ALARMhandler(int);

int    SECOND, i, j
```

# Handling Multiple Signal Types Example: 2/4

```
void INThandler(int sig)
{
    char c;
    signal(SIGINT, SIG_IGN);
    signal(SIGALRM, SIG_IGN);
    printf("INT handler: i = %d and j = %d\n", i, j);
    printf("INT handler: want to quit [y/n]?");
    c = tolower(getchar());
    if (c == 'y') {
       printf("INT handler: done"); exit(0);
    }
    signal(SIGINT, INThandler);
    signal(SIGALRM, ALARMhandler);
    alarm(SECOND);
}
```

*This is a Unix system call*

# Handling Multiple Signal Types Example: 3/4

```
void  ALARMhandler(int sig)
{
   signal(SIGINT, SIG_IGN);
   signal(SIGALRM, SIG_IGN);
   printf("ALARM handler: alarm signal received\n");
   printf("ALARM handler: i = %d and j = %d\n", i, j);
   alarm(SECOND);
   signal(SIGINT, INThandler);
   signal(SIGALRM, ALARMhandler);
}
```

*set alarm clock to* SECOND *seconds*

# Handling Multiple Signal Types Example: 4/4

```
void main(int argc, char *argv[])
{
    long sum;

    SECOND = abs(atoi(argv[1]));
    signal(SIGINT, INThandler);
    signal(SIGALRM, ALARMhandler);
    alarm(SECOND);
    for (i = 1; i <= MAX_i, i_++) {
        sum = 0;
        for (j = 1; j <= MAX_j; j++)
            sum += j;
    }
    printf("Computation is done.\n\n");
}
```

# Raise a Signal within a Process: 1/2

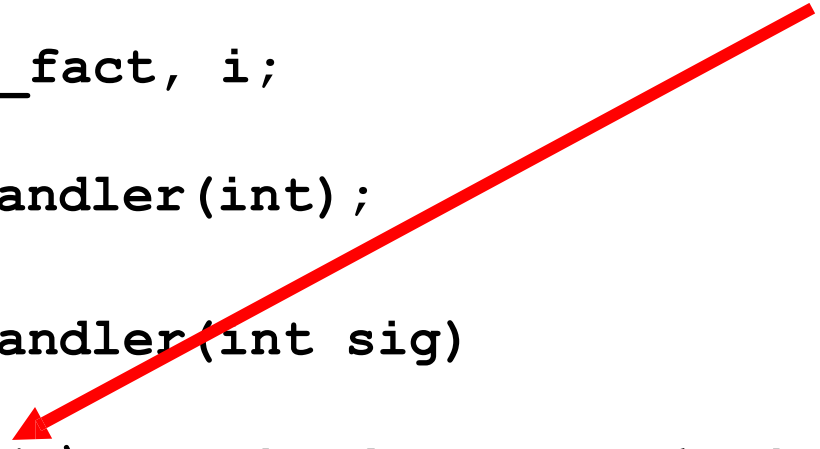
- Use ANSI C function `raise()` to "raise" a signal

```
int  raise(int sig);
```

- Raise() returns non-zero if unsuccessful.

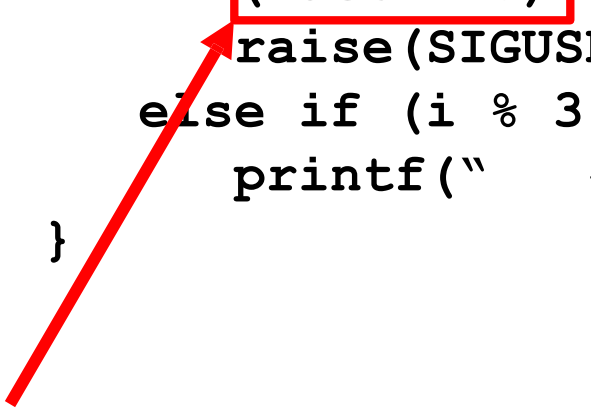
```
#include <stdio.h>
#include <signal.h>

long  pre_fact, i;

void SIGhandler(int);


void SIGhandler(int sig)
{
   printf("\nReceived a SIGUSR1 signal %ld! = %ld\n",
           i-1, pre_fact);
}
```

*Check here if it is a* `SIGUSR1`*!*



# Raise a Signal within a Process: 2/2

```
void  main(void)
{
    long fact;
    signal(SIGUSR1, SIGhandler);
    for (prev_fact=i=1; ; i++, prev_fact = fact) {
        fact = prev_fact * i;
        if (fact < 0)
            raise(SIGUSR1);
        else if (i % 3 == 0)
            printf("   %ld = %ld\n", i, fact);
    }
}
```



*Assuming an integer overflow will wrap around!*

# Send a Signal to a Process

- **Use Unix system call `kill()` to send a signal to another process:**

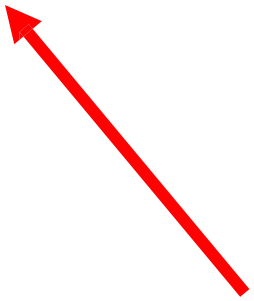
```
int  kill(pid_t pid, int sig);
```

- **`kill()` sends the `sig` signal to process with ID `pid`.**
- **So, you must find some way to know the process ID of the process a signal is sent to.**

# Kill Example: process-a (1)

```
#include <stdio.h>
#include <signal.h>
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/shm.h>

void SIGINT_handler(int);
void SIGQUIT_handler(int);

int    ShmID;
pid_t  *ShmPTR;
```

*used to save shared memory ID*



*my PID will be stored here*

# Kill Example: process-a (2)

```
void  main(void)
{
   int    i;
   pid_t  pid = getpid();
   key_y  MyKey;

   signal(SIGINT, SIGINT_handler);
   signal(SIGQUIT, SIGQUIT_handler);
   MyKey = ftok("./", 'a');
   ShmID = shmget(MyKey, sizeof(pid_t), IPC_CREAT|0666);
   ShmPTR = (pid_t *) shmat(shmID, NULL, 0);
   *ShmPTR = pid;
   for (i = 0; ; i++) {
      printf("From process %d: %d\n", pid, i);
      sleep(1);
   }
}
```

# Kill Example: process-a (2)

*use* `Ctrl-C` *to interrupt*

```
void SIGINT_handler(int sig)
{
   signal(sig, SIG_IGN);
   printf("From SIGINT: got a Ctrl-C signal %d\n", sig);
   signal(sig, SIGINT_handler);
}
```

*use* `Ctrl-\` *to kill this program*

```
void SIGQUIT_handler(int sig)
{
   signal(sig, SIG_IGN);
   printf("From SIGQUIT: got a Ctrl-\\ signal %d\n", sig);
   printf("From SIGQUIT: quitting\n");
   shmdt(ShmPTR);
   shmctl(ShmID, IPC_RMID, NULL);
   exit(0);
}
```

# Kill Example: process-b (1)

```
#include <stdio.h>
#include <signal.h>
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/shm.h>

Void main(void)
{
   pid_t  pid, *ShmPTR;
   key_t  MyKey;
   int    ShmID;
   char   c;

   MyKey = ftok("./", 'a');
   ShmID = shmget(MyKey, sizeof(pid_t), 0666);
   ShmPTR = (pid_t *) shmat(ShmID, NULL, 0);
   pid    = *ShmPTR;
   shmdt(ShmPTR);  /* see next page */
```

*detach the shared memory after taking the* `pid`

# Kill Example: process-b (2)

```
    while (1) {
        printf("(i for interrupt or k for kill)? ");
        c = getchar();
        if (c == 'i' || c == 'I') {
            kill(pid, SIGINT);
            printf("A SIGKILL signal has been sent\n");
        }
        else if (c == 'k' || c == 'K') {
            printf("About to sent a SIGQUIT signal\n");
            kill(pid, SIGQUIT);
            exit(0);
        }
        else
            printf("Wrong keypress (%c).  Try again!\n", c);
    }
}
```

*You can kill process-a from within process-b!*

# The Unix `Kill` Command

- **The `kill` command can also be used to send a signal to a process:**

```
kill -l  /* list all signals */
kill -XXX pid1  pid …… pid
```

- **In the above `XXX` is the signal name without the initial letters `SIG`.**
- **`kill -KILL 1357 2468` kills process 1357 and 2468.**
- **`kill -INT 6421` sends a `SIGINT` to process 6421.**
- **A `kill` without a signal name is equivalent to `SIGTERM`.**
- **`-9` is equal to `-SIGKILL`.**

Mazenet