CSE 421/521 - Operating Systems
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Recitation - V

Signals

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What is a Signal?

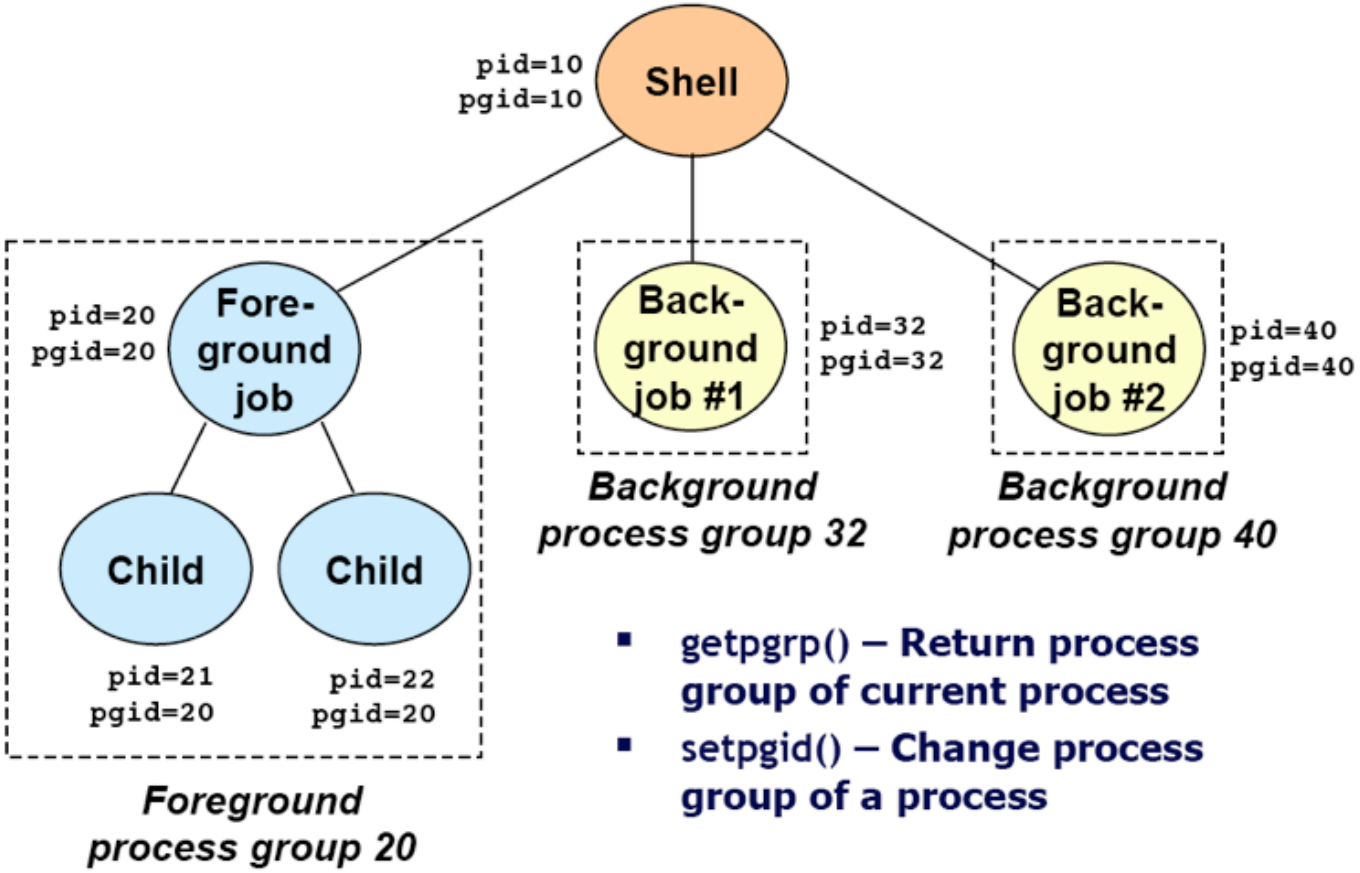
- A signal is a software interrupt delivered to a process by the OS because:
  - it did something (segfault, FPE)
  - the user did something (pressed ^C)
  - another process wants to tell it something (SIGUSR?)
- Sending a signal is one way a process can communicate with other processes
- Some signals 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

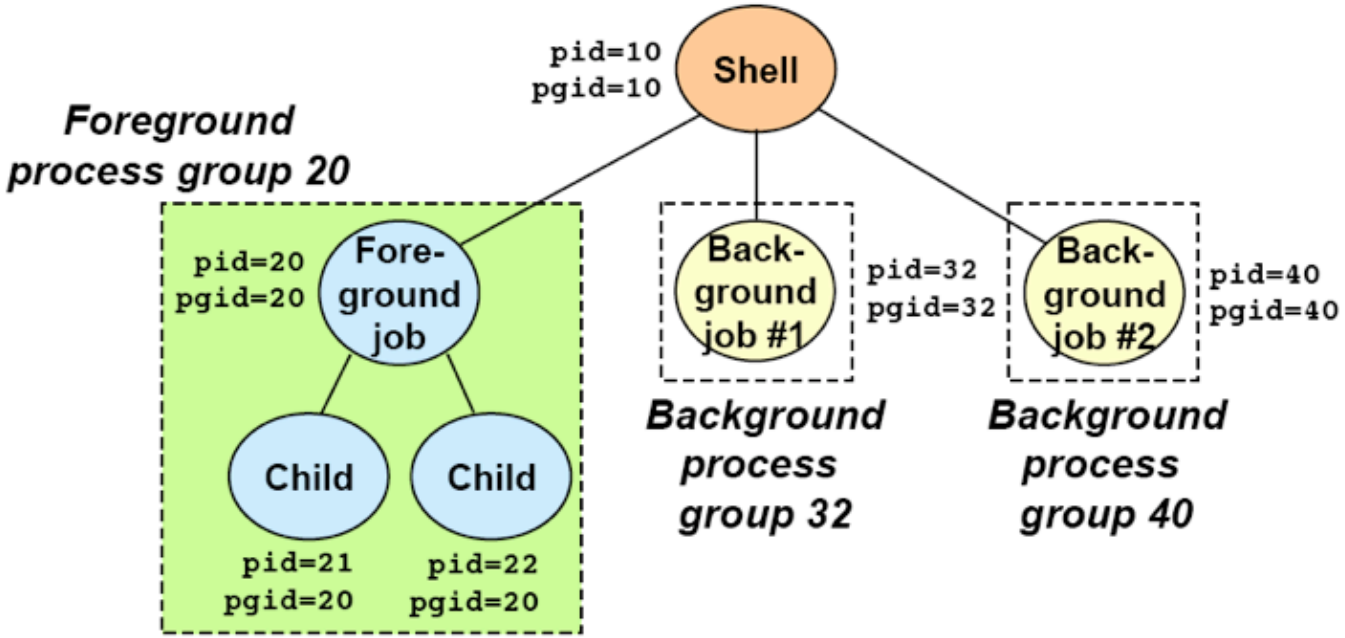
- **Every process belongs to exactly one process group.**



- **getpgrp() – 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

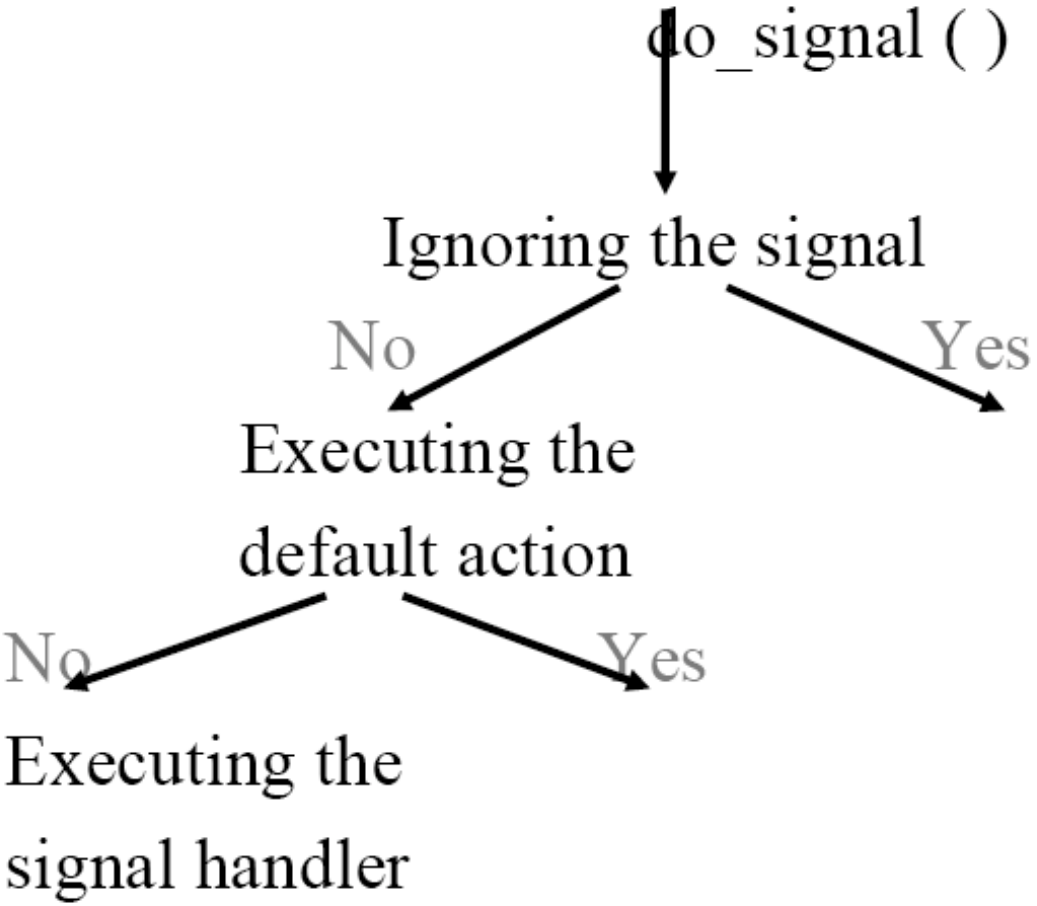
  - `-l` lists all the signals you can send
  - *-signal* is a signal number
  - the default is to send a TERM signal to the process.
- The `fg` command will resume execution of the process (that was suspended with Ctrl-Z), by sending it a CONT signal.

```
$ 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



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

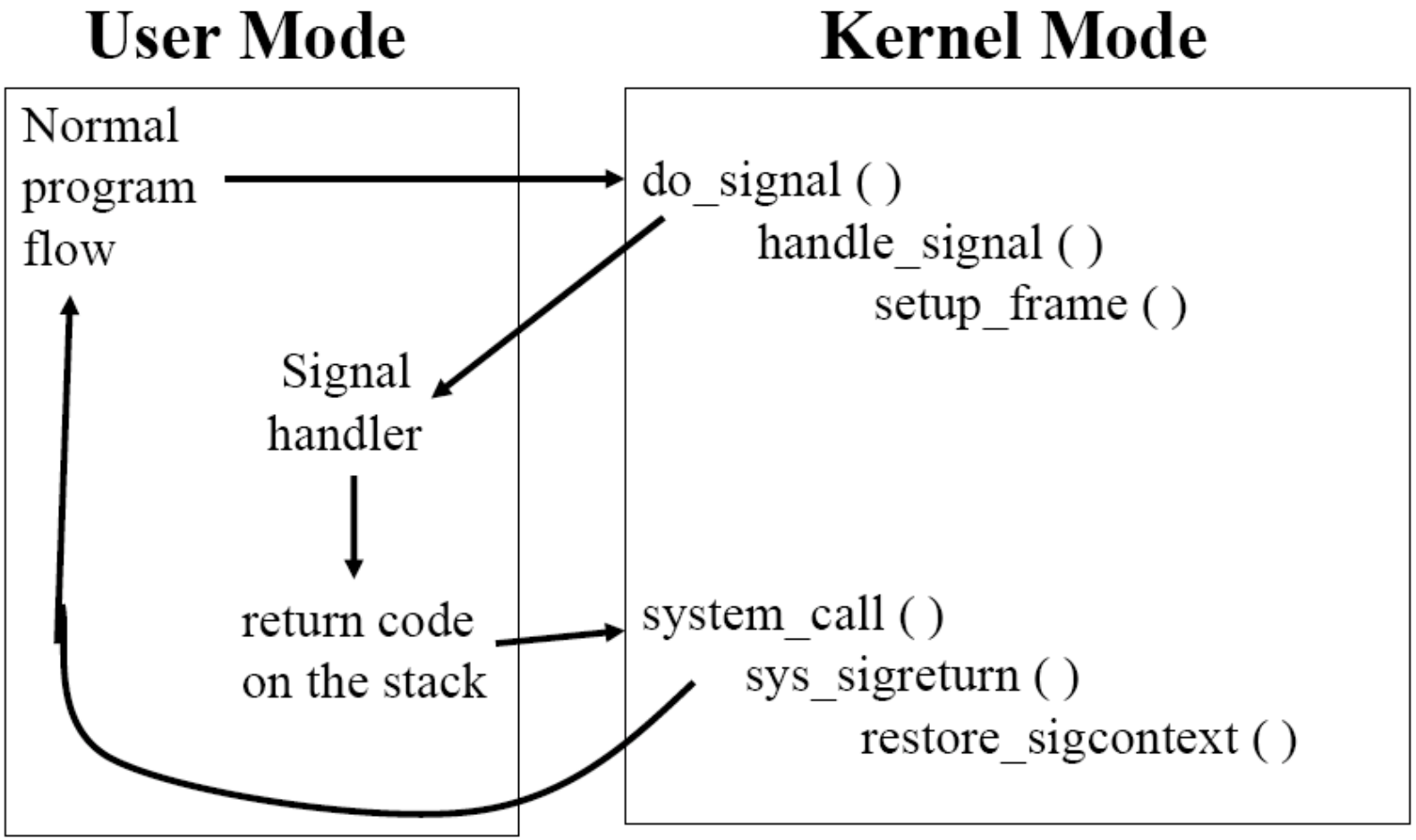
Default Signal Actions (BSD)

No	Name	Default Action	Description
1	SIGHUP	terminate process	terminal line hangup
2	SIGINT	terminate process	interrupt program
3	SIGQUIT	create core image	quit program
4	SIGILL	create core image	illegal instruction
5	SIGTRAP	create core image	trace trap
6	SIGABRT	create core image	abort program
7	SIGEMT	create core image	emulate instruction
8	SIGFPE	create core image	floating-point exception
9	SIGKILL	terminate process	kill program
10	SIGBUS	create core image	bus error
11	SIGSEGV	create core image	segmentation violation
12	SIGSYS	create core image	non-existent system call
13	SIGPIPE	terminate process	write on a pipe with
14	SIGALRM	terminate process	real-time timer expired
15	SIGTERM	terminate process	software termination

Default Signal Actions (BSD)

No	Name	Default Action	Description
16	SIGURG	discard signal	urgent condition present on socket
17	SIGSTOP	stop process	stop (cannot be caught or ignored)
18	SIGTSTP	stop process	stop signalfrom keyb
19	SIGCONT	discard signal	continue after stop
20	SIGCHLD	discard signal	child status has changed
21	SIGTTIN	stop process	background read attempt
22	SIGTTOU	stop process	background write attempt
23	SIGIO	discard signal	I/O is possible on a desc
24	SIGXCPU	terminate process	cpu time limit exceeded
25	SIGXFSZ	terminate process	file size limit exceeded
26	SIGVTALRM	terminate process	virtual time alarm
27	SIGPROF	terminate process	profiling timer alarm
28	SIGWINCH	discard signal	Window size change
29	SIGINFO	discard signal	status request from keyboard
30	SIGUSR1	terminate process	User defined signal 1
31	SIGUSR2	terminate process	User defined signal 2
32	SIGTHR	terminate process	thread interrupt

Catching the Signal



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.

Catching a Signal

```
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.)*

```
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

```
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 );
}
```

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

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 timeITIMER_VIRTUAL: decrements only when the process is executingITIMER_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_ticker(5,1);

        while(1)
        {
                printf("enter a word: ");
                fgets(x, 200, stdin);
                printf(">>> %s", x);
        }
}
```

Interval Time Example *(cont.)*

```
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.)*

```
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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