Linux/Unix Signals

- Signals are simple form of interprocess-communication

- Signals can be generated from a variety of sources
  - From another process via `kill()`
  - From the operating system (e.g. timer)
  - From within the process (e.g. system call)
  - From a fault in the process (e.g. div-by-zero)

- Processes can define how they want to handle signals
  - Using the `signal()` library function (simple)
  - Using the `sigaction()` system call (powerful)

- Signal SIGKILL always terminates receiving processes

- Only owner of a processes can send signal to it
Default handling of signal can be:

- **Term** ... terminate the process
- **Ign** ... ignored - the signal does nothing
- **Core** ... terminate the process and dump memory image to file named core
- **Stop** ... pause the process
- **Cont** ... continue the process (if paused)

Processes can choose to ignore a signal.

Processes can set a custom *signal handler* for signal.

Except SIGKILL and SIGSTOP cannot be caught, blocked, or ignored.

See `man 7 signal` for details of signals and default handling.
Operating System-Generated Signals

Signals from internal process activity, e.g.

- SIGILL ... illegal instruction  \(\text{(Term by default)}\)
- SIGABRT ... generated by \texttt{abort()}  \(\text{(Core by default)}\)
- SIGFPE ... floating point exception \(\text{(Core by default)}\)
- SIGSEGV ... invalid memory reference \(\text{(Core by default)}\)

Signals from external process events, e.g.

- SIGHUP ... hangup detected on controlling terminal/process
- SIGINT ... interrupt from keyboard (ctrl-c) \(\text{(Term by default)}\)
- SIGPIPE ... broken pipe \(\text{(Term by default)}\)
- SIGCHLD ... child process stopped or died \(\text{(Igm by default)}\)
- SIGTSTP ... stop typed at tty (ctrl-z) \(\text{Stop by default)}\)
**Signal Handlers**

*Signal Handler* = a function invoked in response to a signal - knows which signal it was invoked by - needs to ensure that invoking signal (at least) is blocked - carries out appropriate action; may return
#include <signal.h>
typedef void (*sighandler_t)(int);
sighandler_t signal(int signum, sighandler_t handler);

- old way to create signal handler - do not use in new code
- set how to handle a signal signum (e.g. SIGINT)
- handler can be one of ...
  - SIG_IGN ... ignore signal signum
  - SIG_DFL ... use default handler for signum
  - a user-defined function for signum signals
    - function type must be void (int)
- returns previous value of signal handler, or SIG_ERR
#include <signal.h>

int sigaction(int signum, const struct sigaction *act, struct sigaction *oldact);

- set how to handle a signal signum (e.g. SIGINT)
- act defines how signal should be handled
- oldact saves a copy of how signal was handled
- if act->sa_handler == SIG_IGN, signal is ignored
- if act->sa_handler == SIG_DFL, default handler is used
- on success, returns 0; on error, returns -1 and sets errno

For much more information: man 2 sigaction
Details on struct sigaction ...

- `void (*sa_handler)(int)`
  - pointer to a handler function, or SIG_IGN or SIG_DFL
- `void (*sa_sigaction)(int, siginfo_t *, void *)`
  - pointer to handler function; used if SA_SIGINFO flag is set
  - allows more context info to be passed to handler
- `sigset_t sa_mask`
  - a mask, where each bit specifies a signal to be blocked
- `int sa_flags`
  - flags to modify how signal is treated
  (e.g. don’t block signal in its own handler)
Details on `siginfo_t` ...

- `si_signo` ... signal being handled
- `si_errno` ... any `errno` value associated with signal
- `si_pid` ... process ID of sending process
- `si_uid` ... user ID of owner of sending process
- `si_status` ... exit value for process termination
- etc. etc. etc.

For more details: `bits/types/siginfo_t.h` (system-dependent)
#include <signal.h>

void signal_handler(int signum) {
    printf("signal number %d received\n", signum);
}

int main(void) {
    struct sigaction action = {.sa_handler = signal_handler};
    sigaction(SIGUSR1, &action, NULL);
    printf("I am process %d waiting for signal %d\n", getpid(), SIGUSR1);
    // loop waiting for signal
    // bad consumes CPU/electricity/battery
    // sleep would be better
    while (1) {
    }
}

source code for busy_wait_for_signal.c
#include <unistd.h>

unsigned int sleep(unsigned int seconds);

- sleep() suspended the caller for seconds of real-time
- efficient way to wait for an event such as a signal
- allows operating system to run other processes
Waiting For an Event - The Smart Way

```c
#include <signal.h>

void signal_handler(int signum) {
    printf("signal number %d received\n", signum);
}

int main(void) {
    struct sigaction action = {.sa_handler = signal_handler};
    sigaction(SIGUSR1, &action, NULL);
    printf("I am process %d waiting for signal %d\n", getpid(), SIGUSR1);
    // suspend execution for 1 hour
    sleep(3600);
}
```

source code for wait_for_signal.c
sending signals with kill()

```c
#include <sys/types.h>
#include <signal.h>

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

- send signal number `sig` to process number `pid`
- if successful, return 0; on error, return -1 and set `errno`

```c
int main(int argc, char *argv[]) {
    if (argc != 3) {
        fprintf(stderr, "Usage: %s <signal> <pid>
        return 1;
    }
    int signal = atoi(argv[1]);
    int pid = atoi(argv[2]);
    kill(pid, signal);
}
```

source code for send_signal.c
```c
#include <signal.h>

int main(void) {
    // catch SIGINT which is sent if user types cntrl-d
    struct sigaction action = {.sa_handler = SIG_IGN};
    sigaction(SIGINT, &action, NULL);
    while (1) {
        printf("Can't interrupt me, I'm ignoring ctrl-C\n");
        sleep(1);
    }
}
```

Source code for ignore_control_c.c
#include <signal.h>

void ha_ha(int signum) {
    printf("Ha Ha!\n"); // I/O can be unsafe in a signal handler
}

int main(void) {
    // catch SIGINT which is sent if user types cntrl-d
    struct sigaction action = {.sa_handler = ha_ha};
    sigaction(SIGINT, &action, NULL);
    while (1) {
        printf("Can't interrupt me, I'm ignoring ctrl-C\n");
        sleep(1);
    }
}

source code for laugh_at_control_c.c
#include <signal.h>

int signal_received = 0;

void stop(int signum) {
    signal_received = 1;
}

int main(void) {
    // catch SIGINT which is sent if user types cntrl-C
    struct sigaction action = {.sa_handler = stop};
    sigaction(SIGINT, &action, NULL);
    while (!signal_received) {
        printf("Type ctrl-c to stop me\n");
        sleep(1);
    }
    printf("Good bye\n");
}

source code for stop_with_control_c.c
example - catching an internal error with a signal handler

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

void report_signal(int signum) {
    printf("Signal %d received\n", signum);
    printf("Please send help\n");
    exit(0);
}

int main(int argc, char *argv[]) {
    struct sigaction action = {.sa_handler = report_signal};
    sigaction(SIGFPE, &action, NULL);
    // this will produce a divide by zero
    // if there are no command-line arguments
    // which will cause program to receive SIGFPE
    printf("%d\n", 42/(argc - 1));
    printf("Good bye\n");
}
```

source code for catch_error.c