Signals
Signals

- **Signal**: abstraction for exceptional control flow
  - A standard, clean way to handle exceptions
  - Low-level details do not matter

- Signals are sent and received
  - Kernel sends a signal when it detects an exception
  - Processes can also send each other signals
  - The destination process may ignore the signal, terminate, or catch the signal w/ a signal handler

- `man 7 signal` for complete guide ("kill -l" for short list)
  - We'll just learn the basics today
Important signals

- **SIGINT** (#2) – interrupt from keyboard (CTRL-C)
- **SIGABRT** (#6) – abort() function was called
- **SIGBUS** (#7) – I/O bus error
- **SIGFPE** (#8) – floating-point exception
- **SIGKILL** (#9) – kill process
- **SIGSEGV** (#11) – segmentation fault
- **SIGALRM** (#14) – interval timer; set with `alarm()`
- **SIGTERM** (#15) – terminate process (softer than SIGKILL)
- **SIGCHLD** (#17) – a child process has terminated
- **SIGUSR1 / SIGUSR2** – custom signals
Handling signals in C

- `#include <signal.h>`
- `signal() / sigaction()`: install signal handler
  - Parameters
    - `signum` – signal number
    - `handler` – new action
      - `SIG_IGN` – ignore
      - `SIG_DFL` – restore default
      - otherwise: the address of a signal handler function (i.e., a function pointer)
  - `sigaction` is more portable but also more complex
- Signal handlers are just regular functions
  - Must take an int (the signal number) and return void
  - May include `&` operator or omit it when calling `signal()`
    - Cannot pass actual function in C, so it assumes you meant the address
Sending signals in C

- `#include <signal.h>`
- `raise() / kill()`: send a signal
  - Former sends to current process, latter sends to a specific pid
    - Must have permission to do so (generally must be the same user)
    - Can also use the `kill` command-line utility (e.g., “kill -9 <pid>” to send SIGKILL)
- Some signals have special call mechanisms
  - `SIGALRM` can be requested using `alarm()`
    - Must provide the number of seconds that should elapse before the signal is sent
Safe signal handlers

• Most important
  – Keep it simple
  – Only use async-signal-safe functions
    • See `man 7 signal` for a list
    • If you want console output, use `write` not `printf`!

• Less important
  – Save/restore "errno" global variable
  – Declare global variables as "volatile"
  – Declare global flags using atomic type
  – If you want the handler to continue handling the same signal, make sure you re-install it (or use `sigaction` to avoid this)
void handler (int sig)
{
    write(1, "Hello!\n", 8);
}

int main ()
{
    signal(SIGUSR1, handler);
    raise(SIGUSR1);
    raise(SIGSEGV);
    return 0;
}
```c
void handler (int sig)
{
    write(1, "OK\n", 4);
    exit(0);
}

int main ()
{
    int *p = 0;
    signal(SIGSEGV, handler);       // install segfault handler
    int v = *p;                     // null pointer dereference
    printf("Here!\n");              // won't get here
    return v;
}
```
#define BUFSIZE 1024

void handler (int sig)
{
    write(1, "Signal!\n", 9);
}

int main ()
{
    char buf[BUFSIZE];
    int i = 0;

    // install signal handler
    signal(SIGINT, handler);

    // read / print loop
    while (fgets(buf, BUFSIZE, stdin) != 0) {
        printf("Line %d: %s", i++, buf);
    }

    return 0;
}
Signals in debuggers

• By default, signals are caught by gdb
  - Some cause execution to be paused for debugging
    • E.g., SIGINT (CTRL-C)
  - Some are also passed through to the user program
    • SIGSEGV and others

• GDB allows you to change this behavior
  - `info signal` – show current behavior
  - `handle <signal> <option>` – change behavior
    • `stop/nostop`: pause the program?
    • `print/noprint`: notify the user w/ a message?
    • `pass/nopass`: pass signal through to program?
Parallel computation w/ processes

- Spawn multiple processes
  - Use a shell script or multiple `fork()` calls
  - Processes run concurrently
    - If CPU is single-core, they multitask on that core
    - If CPU is multi-core, they execute in parallel

- Communicate via signals, files, or sockets
  - No shared memory in address space
  - Use message-passing to coordinate computation
    - More about this in CS 361 (and potentially CS 470)

- Next week we'll see a different approach
  - **Shared memory**: multiple threads share a single address space
  - Faster but potentially more dangerous