# Signals

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*Slides adapted from Dr. B. Fraser*

# Topics

1) We can create processes, but how can they communicate?

a)How can regular code with loops and functions handle an asynchronous communication?

b)How can a child send a message to the parent?

# Introduction to Signals

# Signals

- Signals are.. notifications with specific meanings.

  – Programs and the kernel can send signals to itself or other programs.

- Wonka Golden Ticket Example

  – Parent process spawns children to search for a golden ticket.

  – Parent: .. Register a signal handle.

  – Child: .. Send a signal to parent when discovered a ticket.

# Pseudocode for Signals

- Parent

```
handler() {
    print "Found ticket!"
}

main() {
    pid = fork()

    if (pid != 0) {
        register signal handler
        wait forever
    }
}
```

sigaction(...)

- Child

```
...
main() {
    ...
    if(pid != 0} {
        ...
    } else {
        if (found_ticket()) {
            signal parent
        }
    }
}
```

kill(...)

# Function Pointers

- Variables
  - Normal variables hold values.
  - Pointers hold the address of a variable.
  - Function pointers.. hold the address of a function.

They allow us to pass around (and call) functions

my_function

```
handler() {
    print "Found ticket!"
}
```

# Why Function Pointers?

- Imagine an embedded system receiving bluetooth data.
  - How does the bluetooth module / library
  - .. tell the rest of the system there is data available?
- Idea 1:
  - Application just keep asking it!
  - Slow, power hungry!
- Idea 2:
  - Have bluetooth module directly execute our application's code!
  - How? Have the module to call our function.
  - How? Give it.. a function pointer.

# Coding with Function Pointers

function_pointers.c

```c
#include <stdio.h>

void happy(int score) {
    printf("%d is great!\n", score);
}

void sad(int score) {
    printf("%d sucks!\n", score);
}

int main() {
    // Declare function pointer variable
    void (*my_function)(int);

    // Change value, just like a variable; no ()
    my_function = happy;

    for (int i = 0; i < 10; i++) {
        // Call it
        my_function(i);
    }

    return 0;
}
```

Looks complex, but
it's just the prototype with:
a) .. Variable name in brackets
b) .. * before the name

Can also use:
my_function = &happy;

Call the function pointer like it's
..
just a normal function.

# ABCD: Function Pointers

- Which of the following gets the address of a function?

(a) &foo()
(b) *foo()
(c) &foo
(d) foo

- Which of the following correctly creates a function pointer named func that points to int foo(char a, int b)?

(a) int (*foo)(char a, int b) = func;
(b) int (*func)(char a, int b) = foo;
(c) int *(foo)(char a, int b) = func;
(d) int *(func)(char a, int b) = foo;

# Coding with Signals

# man 7 signal

- Run: man 7 signal
  - Some examples (scroll down to `Standard signals`)
    - Integer symbols
    - SIGINT: CTRL-C
    - SIGKILL: kill call
    - SIGSEGV: Invalid memory reference

```
printf("SIGINT=%d\n", SIGINT);
printf("SIGKILL=%d\n", SIGKILL);
printf("SIGTERM=%d\n", SIGTERM);
printf("SIGSEGV=%d\n", SIGSEGV);
printf("SIGUSR1=%d\n", SIGUSR1);
printf("SIGUSR2=%d\n", SIGUSR2);
```

```
SIGINT=2
SIGKILL=9
SIGTERM=15
SIGSEGV=11
SIGUSR1=10
SIGUSR2=12
```

  - How to send a signal (scroll up to `Sending a signal`)
    - raise(): to itself
    - kill(): to a process
  - Signal handler
    - man sigaction
    - The important part is filling out struct sigaction.

  When using signals, you need to use signal safe functions.

# Signals and Function Pointers

- To receive a signal we must:
  - write a function to handle a certain signal.
  - register handler with Linux using sigaction():
    pass it a function pointer to our handler.

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

Signal to handle, such as SIGSEGV

Struct configuring our handler.

struct sigaction

```
.sa_handler = .. Our handler func ptr
.sa_flags = ..   Custom flags (0)
.sa_mask = .. Set with sigemptyset()
```

Gives us back the old signal handler.

# Sigaction

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

- signum
  - The signal number to register the handler
- act
  - Specify action to perform
  - Recall: Define a struct C: struct sigaction act;
  - Contain three major fields:
    1. act.sa_handler = handler_func;
       - A pointer void (*sa_handler)(int) to signal handler, receiving the signal number
       - SIG_DFL (default) or SIG_IGN (ignore)
    2. act.sa_flags = 0;
       - A mask to modify the behavior of signal. By default we use 0
    3. sigemptyset(&act.sa_mask);
       - Specify signals should be blocked during signal handler execution in addition to the triggering signal
- oldact
  - Nullable
  - Return back original handler

# Signal Safety

- When using signals, you need to use signal safe functions in handler

Run: man 7 signal-safety

async-signal-safe function: can be safely called from within a signal handler

- The function should guarantee not to interfere any operation being interrupted

Example: all stdio library functions are not async-signal-safe!

Reason:

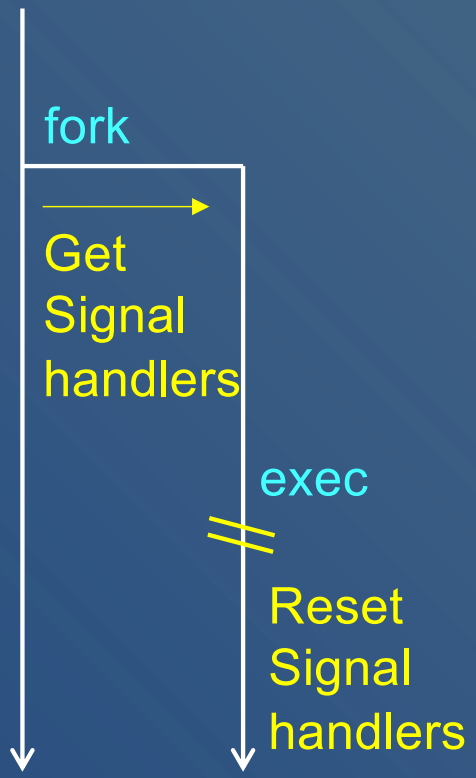
- When performing buffered I/O, need allocated data buffer & pointers
- When main program partially updates the buffer, signal handler that uses it result in wrong buffer status

Workaround: use read(), write() instead

- The file descriptor for stdin/out is STDIN_FILENO, STDOUT_FILENO

# Signal with Fork

- fork(): inherit signal handler in the new process
- fork() + exec(): not inherit signal handler (normally)



# Activity: sigaction()

- (10 min) Write a program that:
  - use sigaction() to install a SIGINT signal handler:
    Print "CTRL-C pressed"
  - infinite loop calling sleep()
- Test using CTRL-C to test
  - Use btop to send SIGINT, and kill
- Hints
  - Use write(STDOUT_FILENO, ....) instead of printf() (not signal safe)
  - sigaction()'s struct:
    - Create a struct, then one at a time initialize the fields
    - Set the .sa_handler to your function.
    - Set the .sa_flags to 0 (don't need any here)
    - Initialize .sa_mask to empty; man sigemptyset()

# Code

- Note function pointers
- Note struct initialization
  - Pass by ptr

sig_handle_sigint.c +

```c
#define _POSIX_C_SOURCE 200809
#include <signal.h>
#include <stdbool.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>

static char *message = "CTRL-C Pressed\n";
void handle_sigint(int signum) {
  write(STDOUT_FILENO, message, strlen(message));
  // printf("%s", message);  // Don't use; not signal safe.
}

int main() {

  struct sigaction act;
  act.sa_handler = handle_sigint;
  act.sa_flags = 0;
  sigemptyset(&act.sa_mask);

  // Register signal handler
  int ret = sigaction(SIGINT, &act, NULL);
  if (ret == -1) {
    perror("Sigaction() failed");
    exit(EXIT_FAILURE);
  }

  while (true) {
    sleep(1);
  }
}
```

# Activity: kill()

- (5 min) Write a program that creates two processes:
  - parent process should:
    - use sigaction() install SIGINT signal handler. Print "CTRL-C pressed"
    - infinite loop calling sleep()
  - child process should:
    - infinite loop that periodically sends SIGINT to the parent & sleeps
- Hint
  - kill()

# Code

```
42    } else {
43      // Child to send signals
44      while (true) {
45        sleep(2);
46        printf("HEY Parent!\n");
47        if (kill(getppid(), SIGINT) == -1) {
48          perror("Unable to send signal to parent.");
49          exit(EXIT_FAILURE);
50        }
51      }
52    }
```

# ABCD: Signals

- What is wrong with this signal handler for SIGINT?

```
void do_signal(int signum) {
        printf("Signal %d\n", signum);
}
```

(a) It has the wrong name.
(b) It has the wrong arguments.
(c) It has the wrong return type.
(d) It calls the wrong function.

- What is the data type of the *second* argument to sigaction()?

(a) Function pointer to signal handler.
(b) Pointer to a struct which contains a function pointer.
(c) The signal number to respond to.
(d) Pointer to the mask of signals to block while in the signal handler

# Summary

- Signals are notifications with specific meanings.
  - Allow asynchronous communication.
- Configure to receive using sigaction()
  - Configuration done with a struct
  - Set signal handler with a function pointer
- Send any signal with kill()