COMP1521 21T2 — Signals

https://www.cse.unsw.edu.au/~cs1521/21T2/

Linux/Unix Signals

- signal 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

Signal Handling

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 for SIGKILL and SIGSTOP, which 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   (***Term*** by default)
- SIGABRT ... generated by `abort()`   (***Core*** by default)
- SIGFPE ... floating point exception   (***Core*** by default)
- SIGSEGV ... invalid memory reference   (***Core*** by default)

Signals from external process events, e.g.

- SIGHUP ... hangup detected on controlling terminal/process
- SIGINT ... interrupt from keyboard (ctrl-c) (***Term*** by default)
- SIGPIPE ... broken pipe   (***Term*** by default)
- SIGCHLD ... child process stopped or died   (***Ign*** by default)
- SIGTSTP ... stop typed at tty (ctrl-z)   (***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
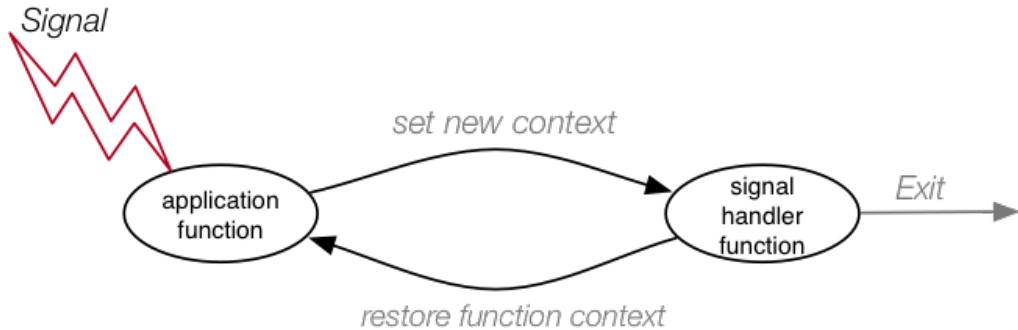
signal() — installing a signal handler, the old way

```
#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

`sigaction()` — installing a signal handler, the new way

```c
#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

Signal Handlers

Details on `struct sigaction` ...

```c
struct sigaction {
    void (*sa_handler) (int);
    void (*sa_sigaction) (int, siginfo_t *, void *);
    sigset_t sa_mask;
    int sa_flags;
    /* ... */
};
```

- `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 …

```
typedef struct {
    int      si_signo;  /* signal number of signal being handled */
    int      si_code;   /* signal code - more information about why */
    pid_t    si_pid;    /* process ID of sending process */
    uid_t    si_uid;    /* user ID of owner of sending process */
    void    *si_addr;   /* address of faulting instruction */
    int      si_status; /* exit value for process termination */
    /* ... */
} siginfo_t;
```

System-dependent; these are (a subset of) mandated fields.

Waiting for an event … the dumb 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);
    // loop waiting for signal
    // bad consumes CPU/electricity/battery
    // sleep would be better
    while (1) {
    }
}
```

source code for busy_wait_for_signal.c

Waiting for an event … the smart way

```
#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 an signal
- allows operating system to run other processes

Example: waiting for an event

```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

kill() — sending signals

```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>\n", argv[0]);
        return 1;
    }
    int signal = atoi(argv[1]);
    int pid = atoi(argv[2]);
    kill(pid, signal);
}
```
source code for send_signal.c

Example: ignoring a signal

```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

Example: a simple signal handler

```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

Example: another simple signal handler

```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