COMP1521 21T3 — Signals

https://www.cse.unsw.edu.au/~cs1521/21T3/

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)

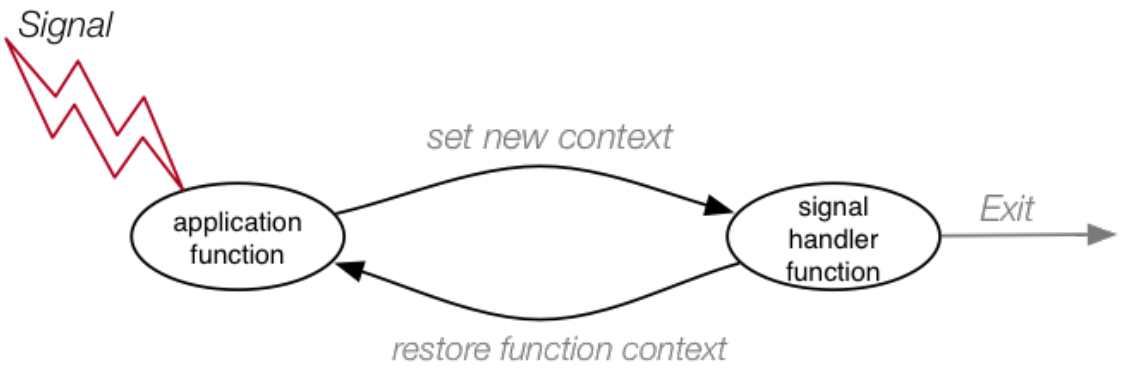
Signals from external process events, e.g.

- `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

```
#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 ...

```
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)

Signal Handlers

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

```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 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