System Calls for Processes

Ref: Chapter 5 of [HGS].

Process:

- A program in execution.
- Several processes are executed concurrently by the **scheduler**.
- Each process has a unique ID (called process ID or pid).
- When a process P is created, there is a parent process for P. (Note: Process with pid zero is its own parent.)

Useful Shell commands:

- `ps`: Gives the list of processes that are currently running.
- `kill`: Command to kill one or more processes.

Example: Suppose the `ps` command shows that processes with IDs 1274 and 1297 are running. To kill these processes the command is:

```
% kill -9 1274 1297
```

System calls for obtaining pid:

```
pid_t  getpid (void);
pid_t  getppid (void);
```

- Headers: `<sys/types.h>` and `<unistd.h>`.
- The type `pid_t` is usually `unsigned long`.
- `getpid`: Returns the pid of the process.
- `getppid`: Returns parent's pid.
- No error exit for either function.

Sample code segment:

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
```

```
int main(void) {
  printf("Pid = %ld\n", getpid());
  printf("Parent's Pid = %ld\n",
         getppid());
  return 0;
}
```

System call `fork`:

```
pid_t  fork (void);
```

- Headers: `<sys/types.h>` and `<unistd.h>`.
- Creates a new process by copying the parent's memory image.
- Both processes continue to execute after the call to `fork`.
- Returns zero to child and the pid of the child to the parent.
- Another system call (one from the family of `exec` system calls) is used to make parent and child execute different programs.
- Returns `-1` in case of failure.

(Bad) Example:

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
    .
    .
  int x = 0;
  fork();
  x = 1;
    .
    .
```

- After the call to `fork`, there are two independent processes.
- Each process has its own location for the variable `x`.

Better Example: Handout 14.1.

Failure of `fork` call:

- The total number of processes in the system exceeds a preset limit or the total number of processes for the user exceeds a preset limit.
- No child process is created when `fork` fails.
- The value of `errno` is `EAGAIN`.

System calls `getuid` and `geteuid`:

```
pid_t  getuid (void);
pid_t  geteuid (void);
```

- Headers: `<sys/types.h>` and `<unistd.h>`.
- In addition to pid, each process has a (real) user id and an effective user id.
- `getuid`: Returns the (real) user id of the process.
- `geteuid`: Returns effective user id of the process. (Recall: Setuid bit for executables.)
- No error exit for either function.

Additional notes about processes:

- A child process inherits parent's privileges and resources such as files.
- The child process competes for the CPU along with the parent.
- There are situations where the parent waits for the child to complete (e.g. shell).

System call `wait`:

```
pid_t  wait (int *estatus);
```

- Headers: `<sys/types.h>` and `<sys/wait.h>`.
- Causes the caller to wait until some child terminates – one form of synchronization.
- Normally, returns the pid of the child that terminated.
- If no child is waiting, the call returns `-1` and `errno` has the value `ECHILD`.

- If `estatus` is NULL, it is ignored; otherwise, the exit status of terminating child is returned in `*estatus`. (The exit status is 0 if the child terminated normally; nonzero otherwise.)

Program Example: Handout 14.2.

System call `waitpid`:

```
pid_t  waitpid (pid_t  pid,
                int  *estatus,
                int  options );
```

- Headers: Same as `wait`.
- Causes the caller to wait until the child with id given by `pid` terminates.
- If `pid` is `-1` and `options` is 0, then `waitpid` behaves exactly like `wait`.
- Most common value for `options` is `WNOHANG`. In that case, if the specified child is still running, the call returns 0 and the caller does not wait.

- Helpful when the parent process wants to perform some actions while the specified child is running.

Reading assignment: Program example on page 107 of [HGS].

Two special processes:

- The `swapper` process: Pid = 0; the `swapper` is its own parent.
- The `init` process: Pid = 1; its parent is the `swapper` process.

Orphan processes:

- A process which is still running but whose parent has terminated.
- Doesn't stay an orphan for too long.
- Orphan processes are "adopted" by the `init` process.

Zombie processes:

- Dictionary meaning of "zombie": One who seems more dead than alive.
- A process which has terminated before its parent had a chance to wait for it.

Example:

```
if ((cid = fork()) == 0) {
    -- code for child --
}
else {
   -- parent --
   -- many lines of code--
   c = wait(&status);
   .
   .
}
```

- Child may exit before parent reaches the `wait` call; child becomes a zombie.

Why are zombies bad?

- Kernel maintains a process table, with one entry per process. (The size of this table is the maximum number of processes allowed in the system.)
- When a process P terminates, the exit status of P must be conveyed to P's parent.
- The parent may be going through a long program before waiting for the child.
- So, some information about process P must be kept in the process table even though P can't execute anymore.
- The process table entry given to P can't be given to another process until P is "completely dead" (i.e., the exit status of P has been given to P's parent).

The `exec` family of system calls:

- Used in conjunction with `fork` to create processes executing different code.

- Traditional way: Child executes an appropriate `exec` call.
- Two sets of calls: `execl` and `execv`.
- `execl`: Used when the command line arguments are known at compile time and can be passed as a list.
- `execv`: Used to command line arguments as an array (similar to `argv[]`).
- Commonly used forms: `execlp` and `execvp`.
- The `'p'` suffix indicates that the call will search the directories in the `PATH` environment variable.

System calls `execlp` and `execvp`:

```
int execlp( const char *prog,
            const char *arg0, ...,
            const char *argn, NULL );

int execvp( const char *prog,
            const char *argv[] );
```


- Header: `<unistd.h>`.
- Note that `execlp` has a variable number of arguments; the `NULL` pointer indicates the end of the list.
- Using exec is different from usual function calls; in particular, a call to exec should not return if there are no errors.

Program examples: Handouts 14.3 and 14.4.