Unix Process Programming

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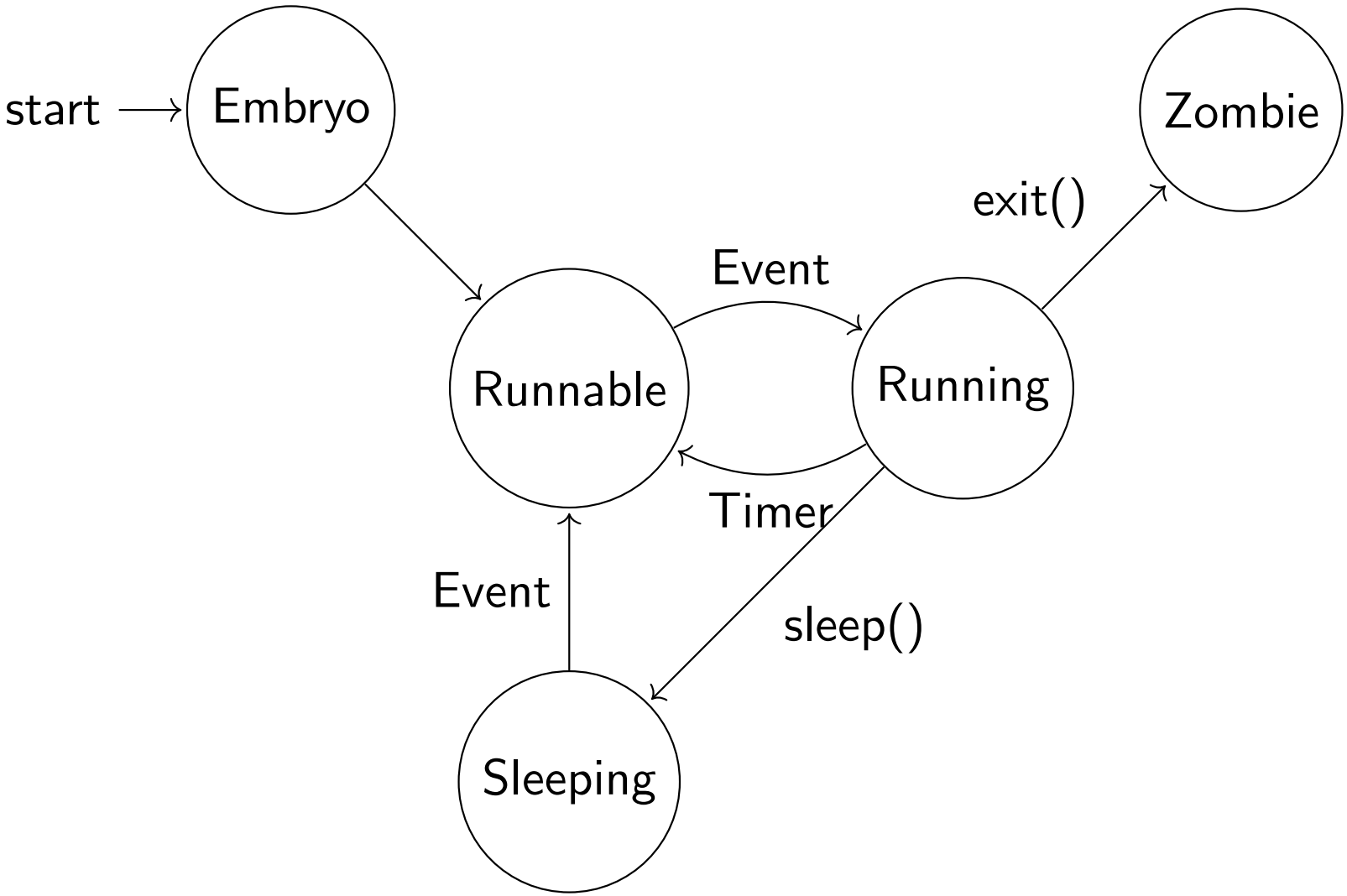
The life of a process



All transition are due to INTERRUPTS.

Processes organization

- The processes are organized into a tree structure.
- The first process is created by the kernel as part of the initialization.
- Except for the first process, processes are created only by processes.
- The **fork()** system call creates a new process.
- The process invoking the **fork()** is called the **parent** process.
- The created process is called the **child** process.

Process creation/exiting system calls.

exit()

- Process resources are freed. (mostly)
- Process enters the ZOMBIE state.
- Children of the process are adopted by the first process.
- Process really dies when its parent **wait()**s on it.

pid=wait()

- If there are no child process returns error.
- If there are ZOMBIE children:
  - one of them (really) dies.
  - The **id** of the dead process is returned.
- If there are no ZOMBIE children:
  - wait for one of the children to become ZOMBIE.

exec(filename, argv)

- The code/data/stack of the current process is freed.
- The executable at **filename** is loaded and begins runing at **main**.
- The **argv** parameter of **exec** is supplied to the new executable:
  - **main(argc, argv)**
- Nothing else changes:
  - Files open.
  - Current working directory.
  - etc.
- NOTE: This is NOT a **call**.
- The new code/data **replaces** the previous code/data.

pid=fork()

- A new child process is created.
- The parent process proceeds with the return value being the process id of the child process.
- The child process begins as a replication of its parent with one difference:
  - The return value is zero.

pid=fork() finegrained

Hypothetical **fork**ing code:

```
movl $1,%eax
int  $64
movl %eax, pid
```

Run time result:

movl $1,%eax int $64	
Parent continues	Child created
movl %eax, pid (pid==child process id)	movl %eax, pid (pid==0)

fork()/exec()/exit()

```
pid = fork();
if (pid < 0)  // fork failed
    exit();
if (pid == 0) { // Child code
   char *argv[] = {"ls", 0};
    exec("ls",argv);
    exit();  // exec failed
} else { // Parent process executes here

}
```

First process and the **/init** program

The first process

- The kernel sets the initial state to:
  - cwd is "/".
  - No file is open.
- Sets standard input, standard output, and standard error, to the console device.
- Creates a process to run the shell (**sh**).
- Enters an infinite loop of **wait()**'s.
- It uses the system calls:
  - **open**.
  - **mknod**.
  - **dup**.
  - **fork**.
  - **exec**.
  - **exit**.

/init (1): Sets standard input and output

```
int main(void) {
  int pid, wpid;

  if (open("console", O_RDWR) < 0) {
    mknod("console", 1, 1);
    open("console", O_RDWR);
  }
  dup(0);  // stdout
  dup(0);  // stderr
```

/init (2): Forks to shell, wait loop

```
for(;;) {
  printf(1, "init: starting sh\n");
  pid = fork();
  if(pid < 0) {
    printf(1, "init: fork failed\n");
    exit();
  }
  if (pid == 0) {
    char *argv[] = { "sh", 0 };
    exec("sh", argv);
    printf(1, "init: exec sh failed\n");
    exit();
  }
  while((wpid=wait()) >= 0 && wpid != pid)
    printf(1, "zombie!\n");
}
```

sh main functionality

sh main loop

```
while (read(0, cmd, ...) > 0) {
 if (cmd is internal command)
  executeInternalCmd(cmd);
 else
  forkExternalCmd(cmd);
}
exit();
```

- Internal cmd "cd" causes execution of the `chdir` system call.
- External commands are assumed to be executble files.

sh example: Simple exec

Typing:

```
ls
```

will use the following code,

```
pid = fork();
if (pid == 0) {
 char *argv[] = {"ls", 0};
 exec("ls", argv);
 exit();
}
wait();
```

sh example: Simple exec

Typing:

```
ls
```

will use the following code, where the parent **sh** executes:

```
pid = fork();
if (pid == 0) {
  char *argv[] = {"ls", 0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Simple exec

Typing:

```
ls
```

will use the following code, and the child **sh** executes:

```
pid = fork();
if (pid == 0) {
 char *argv[] = {"ls", 0};
 exec("ls", argv);
 exit();
}
wait();
```

sh example: Simple exec

Typing:

```
ls -l
```

will use the code,

```
pid = fork();
if (pid == 0) {
  char *argv[] = {"ls", "-l",0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Simple exec

Typing:

```
ls -l
```

will use the code, where the parent **sh** executes:

```
pid = fork();
if (pid == 0) {
  char *argv[] = {"ls", "-l",0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Simple exec

Typing:

```
ls -l
```

will use the code, and the child **sh** executes:

```
pid = fork();
if (pid == 0) {
 char *argv[] = {"ls", "-l",0};
 exec("ls", argv);
 exit();
}
wait();
```

sh example: Output redirection

Typing:

```
ls > a.txt
```

will use the code,

```
pid = fork();
if (pid == 0) {
  close (1);
  open("a.txt", O_CREAT);
  char *argv[] = {"ls", 0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Output redirection

Typing:

```
ls > a.txt
```

will use the code, where the parent **sh** executes:

```
pid = fork();
if (pid == 0) {
  close (1);
  open("a.txt", O_CREAT);
  char *argv[] = {"ls", 0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Output redirection

Typing:

```
ls > a.txt
```

will use the code, and the child **sh** executes:

```
pid = fork();
if (pid == 0) {
 close (1);
 open("a.txt", O_CREAT);
 char *argv[] = {"ls", 0};
 exec("ls", argv);
 exit();
}
wait();
```

sh example: Output redirection

Typing:

```
ls -l > b.txt
```

will use the code,

```
pid = fork();
if (pid == 0) {
  close (1);
  open("b.txt", O_CREAT);
  char *argv[] = {"ls", "-l", 0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Output redirection

Typing:

```
ls -l > b.txt
```

will use the code, where the parent **sh** executes:

```
pid = fork();
if (pid == 0) {
  close (1);
  open("b.txt", O_CREAT);
  char *argv[] = {"ls", "-l", 0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Output redirection

Typing:

```
ls -l > b.txt
```

will use the code, and the child **sh** executes:

```
pid = fork();
if (pid == 0) {
  close (1);
  open("b.txt", O_CREAT);
  char *argv[] = {"ls", "-l", 0};
  exec("ls", argv);
  exit();
}
wait();
```

sh example: Input redirection

Typing:

```
sh < b.txt
```

will use the code,

```
pid = fork();
if (pid == 0) {
  close (0);
  open("b.txt", O_RONLY);
  char *argv[] = {"sh", 0};
  exec("sh", argv);
  exit();
}
wait();
```

sh example: Input redirection

Typing:

```
sh < b.txt
```

will use the code, where the parent **sh** executes:

```
pid = fork();
if (pid == 0) {
  close (0);
  open("b.txt", O_RONLY);
  char *argv[] = {"sh", 0};
  exec("sh", argv);
  exit();
}
wait();
```

sh example: Input redirection

Typing:

```
sh < b.txt
```

will use the code, and the child **sh** executes:

```
pid =  fork();
if (pid == 0) {
 close (0);
 open("b.txt", O_RONLY);
 char *argv[] = {"sh", 0};
 exec("sh", argv);
 exit();
}
wait();
```

sh example: Pipe

Typing:

```
cat a.bat | sh
```

will use the code:

```
int p[2];
pipe(p);
pid = fork();
if (pid == 0) {
 close (1);
 dup(p[1]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"cat", 0};
 exec("cat", argv);
 exit();
}
```

```
pid = fork()
if (pid == 0) {
 close(0);
 dup(p[0]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"sh", 0};
 exec("sh", argv);
 exit();
}
close(p[0]);
close(p[1]);
wait();
```

sh example: Pipe

Typing:

```
cat a.bat | sh
```

will use the code: where the parent **sh** executes:

```
int p[2];
pipe(p);
pid = fork();
if (pid == 0) {
 close (1);
 dup(p[1]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"cat", 0};
 exec("cat", argv);
 exit();
}
```

```
pid = fork()
if (pid == 0) {
 close(0);
 dup(p[0]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"sh", 0};
 exec("sh", argv);
 exit();
}
close(p[0]);
close(p[1]);
wait();
```

sh example: Pipe

Typing:

```
cat a.bat | sh
```

will use the code: the first child **sh** executes:

```
int p[2];
pipe(p);
pid = fork();
if (pid == 0) {
 close (1);
 dup(p[1]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"cat", 0};
 exec("cat", argv);
 exit();
}
```

```
pid = fork()
if (pid == 0) {
 close(0);
 dup(p[0]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"sh", 0};
 exec("sh", argv);
 exit();
}
close(p[0]);
close(p[1]);
wait();
```

sh example: Pipe

Typing:

```
cat a.bat | sh
```

will use the code: the second child **sh** executes:

```
int p[2];
pipe(p);
pid = fork();
if (pid == 0) {
 close (1);
 dup(p[1]);
 close(p[0]);
 close(p[1]);
 char *argv[] = {"cat", 0};
 exec("cat", argv);
 exit();
}
```

```
 pid = fork()
 if (pid == 0) {
  close(0);
  dup(p[0]);
  close(p[0]);
  close(p[1]);
  char *argv[] = {"sh", 0};
  exec("sh", argv);
  exit();
 }
 close(p[0]);
 close(p[1]);
 wait();
```