Mini-Shell

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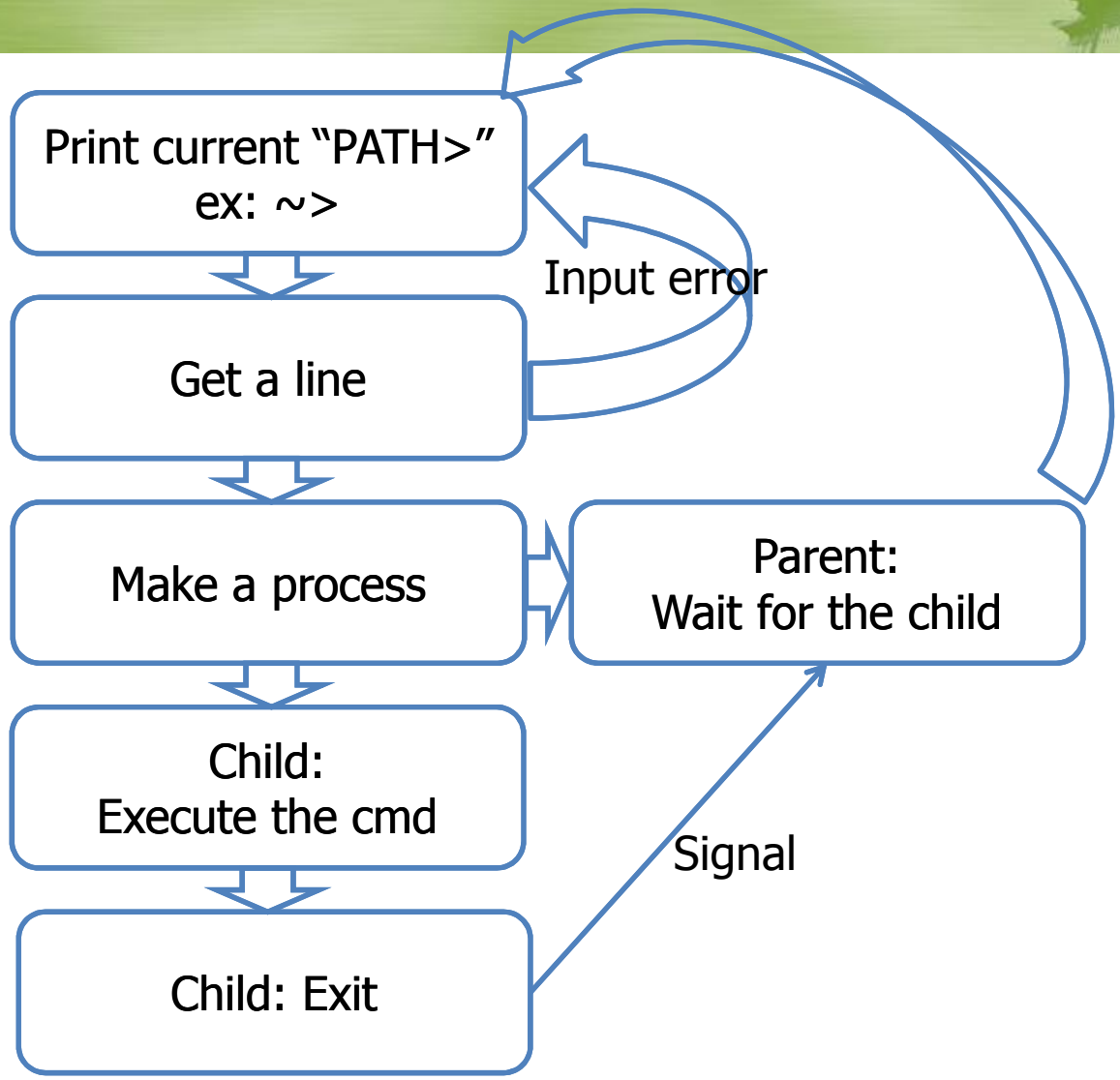
- **A shell program executing following commands**
  - An application program that runs programs on behalf of the user

Command	Description	Original command
cd	Change directory	cd
cls	Clear the terminal screen	clear
dir	List directory contents	ls
copy	Copy files and directories	cp
move	Move files and directories	mv
delete	Delete files and directories	rm
exit	Exit the shell	exit

- **How to make it?**

Mini Shell


Print current "PATH>"
ex: ~>
Input error
Get a line
Make a process
Parent:
Wait for the child
Child:
Execute the cmd
Signal
Child: Exit

Processes

- **An instance of a program in execution.**
  - One of the most profound ideas in computer science.
  - Not the same as "program" or "processor".
- **Process provides each program with two key abstractions:**
  - Logical control flow
    - Each program seems to have exclusive use of the CPU.
  - Private address space
    - Each program seems to have exclusive use of main memory.
- **How are these illusions maintained?**
  - Process executions interleaved (multitasking).
  - Address space managed by virtual memory system.

Creating a New Process

- **pid_t fork(void)** <unistd.h>
  - Creates a new process (child process) that is identical to the calling process (parent process)
  - Returns 0 to the child process
  - Returns child's **pid** to the parent process

```
if (fork() == 0) {
   printf("hello from child\n");
} else {
   printf("hello from parent\n");
}
```

Fork is interesting (and often confusing) because it is called *once* but returns *twice*

Fork Example (1)

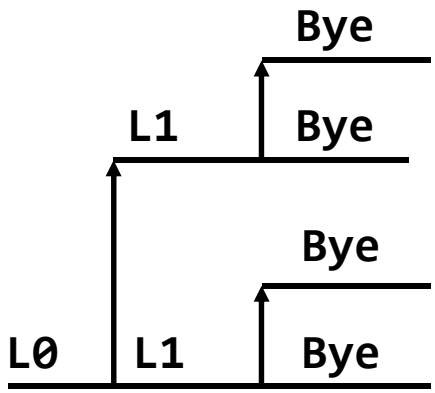
- **Key points**
  - Parent and child both run same code.
    - Distinguish parent from child by return value from **fork()**
  - Start with same state, but each has private copy.
    - Share file descriptors, since child inherits all open files.

```
void fork1() {
    int x = 1;
    pid_t pid = fork();
    if (pid == 0) {
       printf("Child has x = %d\n", ++x);
    } else {
       printf("Parent has x = %d\n", --x);
    }
    printf("Bye from process %d with x = %d\n", getpid(), x);
}
```

Fork Example (2)

- **Key points**
  - Both parent and child can continue forking.

```
void fork2()
{
    printf("L0\n");
    fork();
    printf("L1\n");
    fork();
    printf("Bye\n");
}
```



Destroying a Process

- **void exit (int status)** <stdlib.h>
  - Exits a process.
    - Normally returns with status 0
  - **atexit()** registers functions to be executed upon exit.

```
void cleanup(void) {
   printf("cleaning up\n");
}

void fork6() {
   atexit(cleanup);
   fork();
   exit(0);
}
```

Zombies (1)

- **Idea**
  - When a process terminates, still consumes system resources.
    - Various tables maintained by OS
  - Called a "zombie"
    - Living corpse, half alive and half dead
- **Reaping**
  - Performed by parent on terminated child.
  - Parent is given exit status information.
  - Kernel discards the terminated process.
- **What if parent doesn't reap?**
  - If any parent terminates without reaping a child, then child will be reaped by init process.
  - Only need explicit reaping for long-running processes.
    - e.g. shells and servers

Zombies (2)

```
void fork7()
{
  if (fork() == 0) {
    /* Child */
    printf("Terminating Child, PID = %d\n",
           getpid());
    exit(0);
  } else {
    printf("Running Parent, PID = %d\n",
           getpid());
    while (1); /* Infinite loop */
  }
}
```

```
linux> ./forks 7 &
[1] 6639
Running Parent, PID = 6639
linux> ps
  PID TTY          TIME CMD
 6585 ttyp9    00:00:00 tcsh
 6639 ttyp9    00:00:03 forks
 6641 ttyp9    00:00:00 ps
linux> kill 6639
[1]    Terminated
linux> ps
  PID TTY          TIME CMD
 6585 ttyp9    00:00:00 tcsh
 6642 ttyp9    00:00:00 ps
```

- **ps** shows child processes as "defunct"
- Killing parent allows child to be reaped

Synchronizing with Children

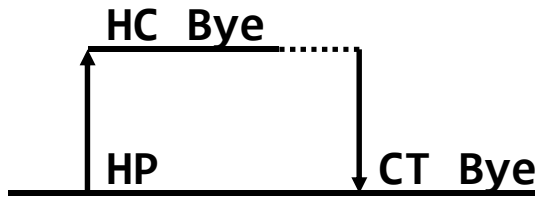
- **pid_t wait (int *status)**
  - suspends current process until one of its children terminates.
  - return value is the **pid** of the child process that terminated.
  - if **status != NULL**, then the object it points to will be set to a status indicating why the child process terminated.

- **pid_t waitpid (pid_t pid, int *status, int options)**
  - Can wait for specific process
  - Various options

Wait Example (1)

```
void fork9() {
   int child_status;

   if (fork() == 0) {
      printf("HC: hello from child\n");
   }
   else {
      printf("HP: hello from parent\n");
      wait(&child_status);
      printf("CT: child has terminated\n");
   }
   printf("Bye\n");
   exit();
}
```



Wait Example (2)

- **If multiple children completed,**
  - will take in arbitrary order.
  - Can use macros **WIFEXITED** and **WEXITSTATUS** to get information about exit status.

```
void fork10() {
    pid_t pid[N];
    int i, child_status;
    for (i = 0; i < N; i++)
        if ((pid[i] = fork()) == 0)
            exit(100+i); /* Child */
    for (i = 0; i < N; i++) {
        pid_t wpid = wait(&child_status);
        if (WIFEXITED(child_status))
            printf("Child %d terminated with exit status %d\n",
                   wpid, WEXITSTATUS(child_status));
        else
            printf("Child %d terminate abnormally\n", wpid);
    }
}
```

Waitpid Example

```
void fork11()
{
    pid_t pid[N];
    int i;
    int child_status;
    for (i = 0; i < N; i++)
        if ((pid[i] = fork()) == 0)
            exit(100+i); /* Child */
    for (i = 0; i < N; i++) {
        pid_t wpid = waitpid(pid[i], &child_status, 0);
        if (WIFEXITED(child_status))
            printf("Child %d terminated with exit status %d\n",
                   wpid, WEXITSTATUS(child_status));
        else
            printf("Child %d terminated abnormally\n", wpid);
    }
```

Running New Programs (1)

- **int execl (char *path, char *arg0, ..., NULL)**
  - loads and runs executable at **path** with arguments **arg0**, **arg1**, ...
    - **path** is the complete path of an executable
    - **arg0** becomes the name of the process
      - » Typically **arg0** is either identical to **path**, or else it contains only the executable filename from path.
    - – "real" arguments to the executable start with **arg1**, etc.
    - – list of args is terminated by a **(char *)** 0 argument.
  - returns –1 if error, otherwise doesn't return!
- **int execv (char *path, char *argv[])**
  - argv : null terminated pointer arrays

Running New Programs (3)

- Example: running /bin/ls

```
main() {
    if (fork() == 0) {
        execl("/bin/ls", “ls", “/", 0);
    }
    wait(NULL);
    printf("completed\n");
    exit();
}
```

```
main() {
    char *args[] = {“ls”, “/”, NULL};
    if (fork() == 0) {
        execv("/bin/ls", args);
    }
    wait(NULL);
}
```

Shell

- **Definition**
  - An application program that runs programs on behalf of the user
    - sh: Original Unix Bourne Shell
    - csh: BSD Unix C Shell
    - tcsh: Enhanced C Shell
    - bash: Bourne-Again Shell

Execution is a sequence of read/evaluate steps

```
int main()
{
    char cmdline[MAXLINE];

    while (1) {
        /* read */
        printf("> ");
        fgets(cmdline, MAXLINE,
              stdin);
        if (feof(stdin))
            exit(0);

        /* evaluate */
        eval(cmdline);
    }
}
```

Simple Shell Example (1)

```
void eval(char *cmdline) {
    char *argv[MAXARGS]; /* argv for execve() */
    int bg;              /* should the job run in bg or fg? */
    pid_t pid;           /* process id */

    bg = parseline(cmdline, argv);
    if (!builtin_command(argv)) {
        if ((pid = fork()) == 0) {   /* child runs user job */
            if (execve(argv[0], argv, environ) < 0) {
                printf("%s: Command not found.\n", argv[0]);
                exit(0);
            }
        }
        if (!bg) {   /* parent waits for fg job to terminate */
           int status;
            if (waitpid(pid, &status, 0) < 0)
                unix_error("waitfg: waitpid error");
        }
        else         /* otherwise, don't wait for bg job */
            printf("%d %s", pid, cmdline);
    }
}
```

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- **How to make it?**

Accessing File Metadata

```
/* statcheck.c - Querying and manipulating a file's meta data */

int main (int argc, char **argv)
{
    struct stat st;
    char *type, *readok;

    stat(argv[1], &st);
    if (S_ISREG(st.st_mode)) /* file type*/
        type = "regular";
    else if (S_ISDIR(st.st_mode))
        type = "directory";
    else
        type = "other";
    if ((st.st_mode & S_IRUSR)) /* OK to read?*/
        readok = "yes";
    else
        readok = "no";

    printf("type: %s, read: %s\n", type, readok);
    exit(0);
}
```

```
bass> ./statcheck statcheck.c
type: regular, read: yes
bass> chmod 000 statcheck.c
bass> ./statcheck statcheck.c
type: regular, read: no
```