

lab6

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由于操作系统H课要求我写一个shell，其中要求了信号处理，我认为该实验有助于我更深入理解shell信号处理知识，故提前完成shell lab。

一.实验准备

阅读csapp教材第八章，理解并发、信号处理

- `eval`: Main routine that parses and interprets the command line. [70 lines]
- `builtin_cmd`: Recognizes and interprets the built-in commands: `quit`, `fg`, `bg`, and `jobs`. [25 lines]
- `do_bgfg`: Implements the `bg` and `fg` built-in commands. [50 lines]
- `waitfg`: Waits for a foreground job to complete. [20 lines]
- `sigchld_handler`: Catches `SIGCHLD` signals. 80 lines]
- `sigint_handler`: Catches `SIGINT` (`ctrl-c`) signals. [15 lines]
- `sigstp_handler`: Catches `SIGTSTP` (`ctrl-z`) signals. [15 lines]

如上图要求，可以看到有对前后台要求和信号处理。

Hints • Read every word of Chapter 8 (Exceptional Control Flow) in your textbook

谢谢提醒。

二.实验流程

1.eval

解析输入命令，对应csapp书(中文版)P525页

```

lab-handout / C / sh.c
Sigfillset(&mask_all);
Sigemptyset(&mask_one);
Sigaddset(&mask_one, SIGCHLD); //信号阻塞处理
//-----
bg = parseline(cmdline, argv);
isbackground = bg? BG:FG;
if (argv[0] == NULL)
    return; //忽略空

if (!builtin_cmd(argv)) {
    //fork之前阻塞SIGCHLD, 防止竞争 ~P543
    Sigprocmask(SIG_BLOCK, &mask_one, &prev_one);
    if ((pid = fork()) == 0) { //子进程
        //解除阻塞
        Sigprocmask(SIG_SETMASK, &prev_one, NULL);
        Setpgid(0, 0); //设置进程组ID
        Execve(argv[0], argv, environ);
    }
    //父进程,判断前后台问题
    Sigprocmask(SIG_BLOCK, &mask_all, NULL);
    addjob(jobs, pid, isbackground, cmdline);
    if (isbackground == FG) {
        //阻塞保护级操作--wait前台运行
        Sigprocmask(SIG_SETMASK, &mask_one, NULL);
        waitfg(pid);
    }
}

终端 调试控制台 端口
3378-fengli-ics:~/csapp/lab6/shlab-handout$ & sleep 5
近期的记录 "0" 附近有语法错误

```

如图实现sigchld信号的阻塞，用于回收僵死进程

2.builtin_cmd

实现一下quit等内置命令即可，fg、bg、job都是调用函数。

3.do_bgfg

前后台进程调度

bg : 通过向 对应的作业发送SIGCONT信号来使它重启并放在后台运行

fg : 通过向 对应的作业发送SIGCONT信号来使它重启并放在前台运行

用kill来发送信号，用sigchld_handler接收信号，用fg、bg命令区分该任务应该放在前台还是后台，同时用指针修改jobs的值。

4.waitfg

前台运行信号的阻塞，书P545页。由于并发竞争问题，可以使用sleep或sigsuspend函数，这里使用sigsuspend，等价于

```
sigprocmask(SIG_SETMASK, &mask, &prev);
pause();//原子版
sigprocmask(SIG_SETMASK, &prev, NULL);
```

使用信号锁解决问题。

5.sigchld_handler

解决收到chld信号，即子进程执行完毕时，要回收所有僵死进程的操作。

对应书P543页,核心是安全的、阻塞所有信号时，进行jobs的更新(防止在jobs将要更新时，传来一个中断信号，导致进程回收失败，造成进程僵死)。

6.sigint_handler

INT是接收ctrl+c的信号，用kill来向前台进程组的所有进程传递该信号，注意需要阻塞所有信号安全操作

7.sigstsp_handler

tstp信号是来自终端的停止信号，ctrl+z。操作同INT

三.测试

在函数填写完成后，手动测试16个测试代码，make test01；make rtest01然后比较两者，这里放两张图片。所有测试程序均已经运行完毕，程序正确无误。

```
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test01
./sdriver.pl -t trace01.txt -s ./tsh -a "-p"
#
# trace01.txt - Properly terminate on EOF.
#
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make
rtest01
./sdriver.pl -t trace01.txt -s ./tshref -a "-p"
#
# trace01.txt - Properly terminate on EOF.
#
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test02
./sdriver.pl -t trace02.txt -s ./tsh -a "-p"
#
# trace02.txt - Process builtin quit command.
#
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest02
./sdriver.pl -t trace02.txt -s ./tshref -a "-p"
#
# trace02.txt - Process builtin quit command.
#
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test03
./sdriver.pl -t trace03.txt -s ./tsh -a "-p"
#
# trace03.txt - Run a foreground job.
#
tsh> quit
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest03
./sdriver.pl -t trace03.txt -s ./tshref -a "-p"
#
# trace03.txt - Run a foreground job.
#
tsh> quit
```

```
[1] (2553718) ./myspin 1 &
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest04
./sdriver.pl -t trace04.txt -s ./tshref -a "-p"
#
# trace04.txt - Run a background job.
#
tsh> ./myspin 1 &
[1] (2558556) ./myspin 1 &
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test05
./sdriver.pl -t trace05.txt -s ./tsh -a "-p"
#
# trace05.txt - Process jobs builtin command.
#
tsh> ./myspin 2 &
[1] (2568627) ./myspin 2 &
tsh> ./myspin 3 &
[2] (2568635) ./myspin 3 &
tsh> jobs
[1] (2568627) Running ./myspin 2 &
[2] (2568635) Running ./myspin 3 &
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest05
./sdriver.pl -t trace05.txt -s ./tshref -a "-p"
#
# trace05.txt - Process jobs builtin command.
#
tsh> ./myspin 2 &
[1] (2575749) ./myspin 2 &
tsh> ./myspin 3 &
[2] (2575753) ./myspin 3 &
tsh> jobs
[1] (2575749) Running ./myspin 2 &
[2] (2575753) Running ./myspin 3 &
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$
```

```
# trace06.txt - Forward SIGINT to foreground job.
#
tsh> ./myspin 4
Job [1] (2624488) terminated by signal 104
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest06
./sdriver.pl -t trace06.txt -s ./tshref -a "-p"
#
# trace06.txt - Forward SIGINT to foreground job.
#
tsh> ./myspin 4
Job [1] (2631544) terminated by signal 2
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test07
./sdriver.pl -t trace07.txt -s ./tsh -a "-p"
#
# trace07.txt - Forward SIGINT only to foreground job.
#
tsh> ./myspin 4 &
[1] (2652623) ./myspin 4 &
tsh> ./myspin 5
Job [2] (2652626) terminated by signal 82
tsh> jobs
[1] (2652623) Running ./myspin 4 &
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest07
./sdriver.pl -t trace07.txt -s ./tshref -a "-p"
#
# trace07.txt - Forward SIGINT only to foreground job.
#
tsh> ./myspin 4 &
[1] (2660579) ./myspin 4 &
tsh> ./myspin 5
Job [2] (2660583) terminated by signal 2
tsh> jobs
[1] (2660579) Running ./myspin 4 &
```

```
Job [2] (2660583) terminated by signal 2
tsh> jobs
[1] (2660579) Running ./myspin 4 &
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test08
./sdriver.pl -t trace08.txt -s ./tsh -a "-p"
#
# trace08.txt - Forward SIGTSTP only to foreground job.
#
tsh> ./myspin 4 &
[1] (2708648) ./myspin 4 &
tsh> ./myspin 5
Job [2] (2708650) stopped by signal 84
tsh> jobs
[1] (2708648) Running ./myspin 4 &
[2] (2708650) Stopped ./myspin 5
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test09
./sdriver.pl -t trace09.txt -s ./tsh -a "-p"
#
# trace09.txt - Process bg builtin command
#
tsh> ./myspin 4 &
[1] (2736084) ./myspin 4 &
tsh> ./myspin 5
Job [2] (2736087) stopped by signal 191
tsh> jobs
[1] (2736084) Running ./myspin 4 &
[2] (2736087) Stopped ./myspin 5
tsh> bg %2
[2] (2736087) ./myspin 5
tsh> jobs
[1] (2736084) Running ./myspin 4 &
[2] (2736087) Running ./myspin 5
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest08
./sdriver.pl -t trace08.txt -s ./tshref -a "-p"
#
# trace08.txt - Forward SIGTSTP only to foreground job.
#
tsh> ./myspin 4 &
[1] (2722953) ./myspin 4 &
tsh> ./myspin 5
Job [2] (2722956) stopped by signal 20
tsh> jobs
[1] (2722953) Running ./myspin 4 &
[2] (2722956) Stopped ./myspin 5
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest09
./sdriver.pl -t trace09.txt -s ./tshref -a "-p"
#
# trace09.txt - Process bg builtin command
#
tsh> ./myspin 4 &
[1] (2744420) ./myspin 4 &
tsh> ./myspin 5
Job [2] (2744423) stopped by signal 20
tsh> jobs
[1] (2744420) Running ./myspin 4 &
[2] (2744423) Stopped ./myspin 5
tsh> bg %2
[2] (2744423) ./myspin 5
tsh> jobs
[1] (2744420) Running ./myspin 4 &
[2] (2744423) Running ./myspin 5
• ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$
```

```
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test10
./sdriver.pl -t trace10.txt -s ./tsh -a "-p"
#
# trace10.txt - Process fg builtin command.
#
tsh> ./myspin 4 &
[1] (2792621) ./myspin 4 &
tsh> fg %1
Job [1] (2792621) stopped by signal 156
tsh> jobs
[1] (2792621) Stopped ./myspin 4 &
tsh> fg %1
tsh> jobs

ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test11
./sdriver.pl -t trace11.txt -s ./tsh -a "-p"
#
# trace11.txt - Forward SIGINT to every process in foreground process group
#
tsh> ./mysplit 4
Job [1] (2814308) terminated by signal 100
tsh> /bin/ps a
  PID TTY          STAT       TIME COMMAND
  137 pts/0      Ss+        0:00 /sbin/agetty -o -p -- \u --noclear --keep-
-baud console 115200,38400,9600 linux
  138 pts/1      Ss+        0:00 /sbin/agetty -o -p -- \u --noclear --keep-
-baud tty1 115200,38400,9600 linux
  139 pts/2      Ss+        0:00 /sbin/agetty -o -p -- \u --noclear --keep-
-baud tty2 115200,38400,9600 linux
  673 pts/4      Ss+        0:00 /bin/bash --init-file /home/ubuntu/.vscode
-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/ser
ver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration-ba
sh.sh

server/lib/vscode/out/vs/workbench/contrib/terminal/browser/media/shellI
ntegration-bash.sh
2267126 pts/11  Ss        0:00 /usr/bin/bash --init-file /opt/vlab/code-s
erver/lib/vscode/out/vs/workbench/contrib/terminal/browser/media/shellI
ntegration-bash.sh
2290667 pts/11  T         0:00 ./shell
2300834 pts/11  Z+        0:00 [sleep] <defunct>
2460837 pts/16  Ss+       0:00 /bin/bash --init-file /home/ubuntu/.vscode
-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/ser
ver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration-ba
sh.sh
2697163 pts/18  Ss+       0:00 /usr/bin/bash --init-file /home/ubuntu/.vs
code-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/ser
ver/out/vs/workbench/contrib/terminal/browser/media/shellIntegratio
n-bash.sh
2923636 pts/17  S+        0:00 make test12
2923638 pts/17  S+        0:00 /bin/sh -c ./sdriver.pl -t trace12.txt -s
./tsh -a "-p"
2923640 pts/17  S+        0:00 /usr/bin/perl ./sdriver.pl -t trace12.txt
-s ./tsh -a -p
2923642 pts/17  S+        0:00 ./tsh -p
2923674 pts/17  T         0:00 ./mysplit 4
2923676 pts/17  T         0:00 ./mysplit 4
2926002 pts/17  R         0:00 /bin/ps a
3006420 pts/17  Ss        0:00 /bin/bash --init-file /home/ubuntu/.vscode
-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/ser
ver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration-ba
sh.sh
3951719 pts/14  Ss+       0:00 /bin/bash --init-file /home/ubuntu/.vscode
-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/ser
ver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration-ba
sh.sh
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest10
./sdriver.pl -t trace10.txt -s ./tshref -a "-p"
#
# trace10.txt - Process fg builtin command.
#
tsh> ./myspin 4 &
[1] (2798332) ./myspin 4 &
tsh> fg %1
Job [1] (2798332) stopped by signal 20
tsh> jobs
[1] (2798332) Stopped ./myspin 4 &
tsh> fg %1
tsh> jobs

ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest11
./sdriver.pl -t trace11.txt -s ./tshref -a "-p"
#
# trace11.txt - Forward SIGINT to every process in foreground process group
#
tsh> ./mysplit 4
Job [1] (2809898) terminated by signal 2
tsh> /bin/ps a
  PID TTY          STAT       TIME COMMAND
  137 pts/0      Ss+        0:00 /sbin/agetty -o -p -- \u --noclear --keep
-baud console 115200,38400,9600 linux
  138 pts/1      Ss+        0:00 /sbin/agetty -o -p -- \u --noclear --keep
-baud tty1 115200,38400,9600 linux
  139 pts/2      Ss+        0:00 /sbin/agetty -o -p -- \u --noclear --keep
-baud tty2 115200,38400,9600 linux
  673 pts/4      Ss+        0:00 /bin/bash --init-file /home/ubuntu/.vsco
e-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/s
erver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration
-bash.sh

server/lib/vscode/out/vs/workbench/contrib/terminal/browser/media/shel
lIntegration-bash.sh
2267126 pts/11  Ss        0:00 /usr/bin/bash --init-file /opt/vlab/code-
server/lib/vscode/out/vs/workbench/contrib/terminal/browser/media/shel
lIntegration-bash.sh
2290667 pts/11  T         0:00 ./shell
2300834 pts/11  Z+        0:00 [sleep] <defunct>
2460837 pts/16  Ss+       0:00 /bin/bash --init-file /home/ubuntu/.vsco
e-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/s
erver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration
-bash.sh
2697163 pts/18  Ss        0:00 /usr/bin/bash --init-file /home/ubuntu/.v
scode-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d
39/server/out/vs/workbench/contrib/terminal/browser/media/shellIntegra
tion-bash.sh
2927474 pts/18  S+        0:00 make rtest12
2927475 pts/18  S+        0:00 /bin/sh -c ./sdriver.pl -t trace12.txt -s
./tshref -a "-p"
2927477 pts/18  S+        0:00 /usr/bin/perl ./sdriver.pl -t trace12.txt
-s ./tshref -a -p
2927507 pts/18  S+        0:00 ./tshref -p
2927511 pts/18  T         0:00 ./mysplit 4
2927513 pts/18  T         0:00 ./mysplit 4
2929339 pts/18  R         0:00 /bin/ps a
3006420 pts/17  Ss+       0:00 /bin/bash --init-file /home/ubuntu/.vsco
e-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/s
erver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration
-bash.sh
3951719 pts/14  Ss+       0:00 /bin/bash --init-file /home/ubuntu/.vsco
e-server/cli/servers/Stable-e170252f762678dec6ca2cc69aba1570769a5d39/s
erver/out/vs/workbench/contrib/terminal/browser/media/shellIntegration
-bash.sh
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$
```



```

ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test14
./sdriver.pl -t trace14.txt -s ./tsh -a "-p"
#
# trace14.txt - Simple error handling
#
tsh> ./bogus
./bogus: Command not found.
tsh> ./myspin 4 &
[1] (1023014) ./myspin 4 &
tsh> fg
fg command requires PID or %jobid argument
tsh> bg
bg command requires PID or %jobid argument
tsh> fg a
fg: argument must be a PID or %jobid
tsh> bg a
bg: argument must be a PID or %jobid
tsh> fg 9999999
(9999999): No such process
tsh> bg 9999999
(9999999): No such process
tsh> fg %2
%2: No such job
tsh> fg %1
Job [1] (1023014) stopped by signal 156
tsh> bg %2
%2: No such job
tsh> bg %1
[1] (1023014) ./myspin 4 &
tsh> jobs
[1] (1023014) Running ./myspin 4 &
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

tsh> jobs
[1] (1023014) Running ./myspin 4 &
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test15
./sdriver.pl -t trace15.txt -s ./tsh -a "-p"
#
# trace15.txt - Putting it all together
#
tsh> ./bogus
./bogus: Command not found.
tsh> ./myspin 10
Job [1] (1037940) terminated by signal 116
tsh> ./myspin 3 &
[1] (1040256) ./myspin 3 &
tsh> ./myspin 4 &
[2] (1040261) ./myspin 4 &
tsh> jobs
[1] (1040256) Running ./myspin 3 &
[2] (1040261) Running ./myspin 4 &
tsh> fg %1
Job [1] (1040256) stopped by signal 223
tsh> jobs
[1] (1040256) Stopped ./myspin 3 &
[2] (1040261) Running ./myspin 4 &
tsh> bg %3
%3: No such job
tsh> bg %1
[1] (1040256) ./myspin 3 &
tsh> jobs
[1] (1040256) Running ./myspin 3 &
[2] (1040261) Running ./myspin 4 &
tsh> fg %1
tsh> quit
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

tsh> quit
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make test16
./sdriver.pl -t trace16.txt -s ./tsh -a "-p"
#
# trace16.txt - Tests whether the shell can handle SIGTSTP and SIGINT
#
# signals that come from other processes instead of the terminal.
#
tsh> ./mystop 2
Job [1] (1091850) stopped by signal 169
tsh> jobs
[1] (1091850) Stopped ./mystop 2
tsh> ./myint 2
Job [2] (1095420) terminated by signal 124
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

tsh> quit
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest14
./sdriver.pl -t trace14.txt -s ./tshref -a "-p"
#
# trace14.txt - Simple error handling
#
tsh> ./bogus
./bogus: Command not found
tsh> ./myspin 4 &
[1] (1005238) ./myspin 4 &
tsh> fg
fg command requires PID or %jobid argument
tsh> bg
bg command requires PID or %jobid argument
tsh> fg a
fg: argument must be a PID or %jobid
tsh> bg a
bg: argument must be a PID or %jobid
tsh> fg 9999999
(9999999): No such process
tsh> bg 9999999
(9999999): No such process
tsh> fg %2
%2: No such job
tsh> fg %1
Job [1] (1005238) stopped by signal 20
tsh> bg %2
%2: No such job
tsh> bg %1
[1] (1005238) ./myspin 4 &
tsh> jobs
[1] (1005238) Running ./myspin 4 &
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

tsh> jobs
[1] (1005238) Running ./myspin 4 &
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest15
./sdriver.pl -t trace15.txt -s ./tshref -a "-p"
#
# trace15.txt - Putting it all together
#
tsh> ./bogus
./bogus: Command not found
tsh> ./myspin 10
Job [1] (1059959) terminated by signal 2
tsh> ./myspin 3 &
[1] (1062149) ./myspin 3 &
tsh> ./myspin 4 &
[2] (1062151) ./myspin 4 &
tsh> jobs
[1] (1062149) Running ./myspin 3 &
[2] (1062151) Running ./myspin 4 &
tsh> fg %1
Job [1] (1062149) stopped by signal 20
tsh> jobs
[1] (1062149) Stopped ./myspin 3 &
[2] (1062151) Running ./myspin 4 &
tsh> bg %3
%3: No such job
tsh> bg %1
[1] (1062149) ./myspin 3 &
tsh> jobs
[1] (1062149) Running ./myspin 3 &
[2] (1062151) Running ./myspin 4 &
tsh> fg %1
tsh> quit
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

tsh> quit
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$ make rtest16
./sdriver.pl -t trace16.txt -s ./tshref -a "-p"
#
# trace16.txt - Tests whether the shell can handle SIGTSTP and SIGINT
#
# signals that come from other processes instead of the terminal.
#
tsh> ./mystop 2
Job [1] (1096252) stopped by signal 20
tsh> jobs
[1] (1096252) Stopped ./mystop 2
tsh> ./myint 2
Job [2] (1099452) terminated by signal 2
ubuntu@VM8378-fengli-ics:~/csapp/lab6/shlab-handout$

```

如上图。值得一提的是在测试test14时曾发现了bug，原因是在execve之后，我认为该函数会直接接管程序，所以子进程中，该函数之后的部分应该全部无效，所以在execve之后没有写exit终止错误进程。而test14应该含有了这样的错误，导致我的程序运行了两次。


```
193     if (!builtin_cmd(argv)) {
194         //fork之前阻塞SIGCHLD, 防止竞争 ~P543
195         Sigprocmask(SIG_BLOCK, &mask_one, &prev_one);
196         if ((pid=fork()) == 0) { //子进程
197             //解除阻塞
198             Sigprocmask(SIG_SETMASK, &prev_one, NULL);
199             Setpgid(0, 0); //设置进程组ID
200             Execve(argv[0], argv, environ);
201             exit(0);
202         }
203         //父进程,判断前后台问题
204         Sigprocmask(SIG_BLOCK, &mask_all, NULL);
205         addjob(jobs, pid, isbackground, cmdline);
206         if (isbackground == FG) {
207             //阻塞保护级操作--wait前台运行
208             Sigprocmask(SIG_SETMASK, &mask_one, NULL);
209             waitfg(pid);
```

如上图，201行应该添加exit，以防止错误发生。

四.总结

相比于操作系统H上的shell，这个shell要显得简陋很多，<https://osh-2024.github.io/lab2/>上有我们的要求。在信号方面，我们要求ctrlc能丢弃指令，中断运行，甚至在嵌套shell里也能运行。虽然我拼拼凑凑得到了一个符合要求勉强能运行的shell，但是自学完这一章后我感觉受益良多，对并发信号的安全性有了更深层次的理解，对进程间信号传递，前后台进程管理有了更深层的认识，这样的实验时有意义的。用这样一本通用教科书来学习信号，比盲人摸象、七拼八凑的操作系统实验要专业、安全的多。

在lab6中附上操作系统实验的shell作为对比。