

# CSED211: ShellLab Report

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## 0. 개요

이 과제는 Job Control 기능을 지원하는 Unix Shell 프로그램인 tsh (tiny shell)을 구현하는 것을 목표로 한다. 기본 skeleton 코드가 짜여 있는 tsh.c 내의 eval, builtin\_cmd, do\_bgfg, waitfg 함수 및 3개의 signal handler 함수인 sigchld\_handler, sigint\_handler, sigtstp\_handler를 완성하여 tsh를 구현할 수 있다.

### 1. eval 함수

eval 함수는 입력한 커맨드 라인을 파싱하고, 적절한 프로세스를 생성하여 실행하는 역할을 한다. Race Condition의 방지 및 Process Group 설정에 중점을 뒀서 구현했다.

먼저 parseline으로 백그라운드 실행 여부를 파악하고 builtin\_cmd를 통해 내장 명령어가 아닌 것을 알아내면 (내장 명령어가 아닐 시 0을 반환) fork를 통해 자식 프로세스를 생성한다. 여기서 부모 프로세스가 addjob으로 작업을 목록에 추가하기 전 자식 프로세스가 먼저 종료돼 sigchld\_handler가 실행될 수 있다. (Race Condition) 따라서 이를 방지하기 위해 fork를 호출하기 직전에 sigprocmask를 사용해 SIGCHLD 시그널을 block했고, addjob을 완료한 후 다시 unblock했다.

또한 자식 프로세스 코드 내에서는 setpgid(0, 0)를 호출해 자식을 독자적인 프로세스 그룹 리더로 설정했다. 이는 터미널에서 ctrl-c나 ctrl-z를 입력했을 때 shell 자체는 종료되지 않으며 foreground 프로세스 그룹에만 signal이 전달되도록 하기 위함이다. 마지막으로 execve가 실패할 경우 "Command not found" 메시지를 출력하고 exit(0)으로 shell을 종료하도록 했다.

### 2. 내장 명령어 & Job Control 구현

#### 1) builtin\_cmd 함수

builtin\_cmd 함수는 quit, jobs, bg, fg의 4가지 내장 명령어를 strcmp를 통해 처리하도록 했다. (같은 경우 0을 반환) quit의 경우 exit(0)으로 shell을 종료하고, jobs는 listjobs 헬퍼 함수에 전역변수 jobs를 넣어 호출한다. bg와 fg의 경우 후술할 do\_bgfg 함수를 호출하도록 했다.

#### 2) do\_bgfg 함수

do\_bgfg 함수는 bg <job> 또는 fg <job>을 수행한다. 먼저 인자가 JID(%)인지 PID인지 구별해 파싱한다. 그리고 JID / PID에 따라 getjobjid / getjobpid를 통해 그것과 대응되는 job\_t를 찾은 후, kill(-(job->pid), SIGCONT)를 호출해 정지된 작업과 해당 그룹에 (-

를 붙임) SIGCONT 시그널을 보내 restart하도록 했다. 이후 bg 명령어인 경우 작업 상태 BG로 바꾸고 실행 정보를 출력 ("[jid] (pid) cmdline"), fg 명령어인 경우 작업 상태를 FG로 바꾸고 waitfg 함수를 호출해 해당 작업이 완료 또는 정지될 때까지 기다리도록 했다.

### 3) waitfg 함수

waitfg 함수는 foreground 작업이 끝날 때까지 shell을 대기시키는 함수로, waitpid를 직접 호출하지 않고 sleep(1)을 이용해 구현했다. 후술할 sigchld\_handler가 호출되면 waitpid를 통해 자식의 종료를 감지하고, 전역 jobs 배열에서 해당 작업을 삭제하거나 상태를 갱신하게 된다. 따라서 waitfg는 이 jobs 배열의 변화를 감지하기 위해 fgp\_id 함수를 루프 내에서 호출하고, handler에 의해 작업이 목록에서 사라질 때까지 대기하는 방식으로 동기화를 구현한 것이다.

## 3. Signal Handler 구현

### 1) sigchld\_handler

sigchld\_handler 함수는 자식 프로세스가 종료 또는 정지됐을 때 호출된다. while과 함께 waitpid 함수를 사용해 대기 중인 모든 zombie 프로세스를 최대한 많이 회수하도록 구현했다. waitpid의 옵션으로 WNOHANG | WUNTRACED를 사용해 아직 종료되지 않은 자식 때문에 shell이 blocking 되는 것을 막으며 정지된 자식 프로세스도 감지할 수 있도록 하였다. 여기서 WNOHANG은 종료된 자식이 없을 경우 Blocking되지 않고 즉시 0을 반환하게 하여 shell의 응답성을 유지해준다. 또한 WUNTRACED는 종료된 자식뿐만 아니라 정지 상태로 변한 자식 프로세스까지 감지하기 위해 필요하다.

정상 종료(WIFEXITED)는 자식이 정상적으로 exit한 경우이므로 deletejob을 통해 작업 목록에서 제거한다. 시그널 종료(WIFSIGNALED)는 자식이 시그널에 의해 강제 종료된 경우로, WTERMSIG 매크로를 사용해 종료를 일으킨 시그널 번호를 메시지로 출력하고 deletejob을 통해 작업 목록에서 제거한다. 작업 정지(WIFSTOPPED)는 자식이 정지된 경우로, WSTOPSIG 매크로로 정지를 유발한 시그널 번호를 확인해 출력하고, 작업 상태를 ST로 변경해 앞으로 bg / fg 명령어로 제어할 수 있도록 한다.

### 2) sigint\_handler & sigtstp\_handler

sigint\_handler 함수는 ctrl-c (SIGINT), sigtstp\_handler 함수는 ctrl-z (SIGTSTP) 입력을 처리한다. fgp\_id를 통해 현재 foreground 작업의 PID를 가져와 kill(-pid, sig)를 호출한다. (-를 붙여 프로세스 그룹 전체에 시그널 전송) 이를 통해 foreground 작업이 생성한 모든 자손 프로세스들까지 올바르게 종료되거나 정지되도록 구현했다.

## 4. 결과

이렇게 구현된 tsh.c를 writeup을 참고하여 trace01~trace16을 이용해 테스트했다. 그

결과 writeup에서 언급되었던 PID를 제외하고는 reference shell과 모두 동일한 동작과 출력을 확인할 수 있었다.

```
[cotmdgus@programming2 shlab-handout]$ make test01
./sdriver.pl -t trace01.txt -s ./tsh -a "-p"
#
# trace01.txt - Properly terminate on EOF.
#
[cotmdgus@programming2 shlab-handout]$ make rtest01
./sdriver.pl -t trace01.txt -s ./tshref -a "-p"
#
# trace01.txt - Properly terminate on EOF.
#

[cotmdgus@programming2 shlab-handout]$ make test02
./sdriver.pl -t trace02.txt -s ./tsh -a "-p"
#
# trace02.txt - Process builtin quit command.
#
[cotmdgus@programming2 shlab-handout]$ make rtest02
./sdriver.pl -t trace02.txt -s ./tshref -a "-p"
#
# trace02.txt - Process builtin quit command.
#

[cotmdgus@programming2 shlab-handout]$ make test03
./sdriver.pl -t trace03.txt -s ./tsh -a "-p"
#
# trace03.txt - Run a foreground job.
#
tsh> quit
[cotmdgus@programming2 shlab-handout]$ make rtest03
./sdriver.pl -t trace03.txt -s ./tshref -a "-p"
#
# trace03.txt - Run a foreground job.
#
tsh> quit

[cotmdgus@programming2 shlab-handout]$ make test04
./sdriver.pl -t trace04.txt -s ./tsh -a "-p"
#
# trace04.txt - Run a background job.
#
tsh> ./myspin 1 &
[1] (7133) ./myspin 1 &
[cotmdgus@programming2 shlab-handout]$ make rtest04
./sdriver.pl -t trace04.txt -s ./tshref -a "-p"
#
# trace04.txt - Run a background job.
#
tsh> ./myspin 1 &
[1] (7143) ./myspin 1 &

[cotmdgus@programming2 shlab-handout]$ make test05
./sdriver.pl -t trace05.txt -s ./tsh -a "-p"
#
# trace05.txt - Process jobs builtin command.
#
tsh> ./myspin 2 &
[1] (7252) ./myspin 2 &
tsh> ./myspin 3 &
[2] (7254) ./myspin 3 &
tsh> jobs
[1] (7252) Running ./myspin 2 &
[2] (7254) Running ./myspin 3 &
[cotmdgus@programming2 shlab-handout]$ make rtest05
./sdriver.pl -t trace05.txt -s ./tshref -a "-p"
#
# trace05.txt - Process jobs builtin command.
#
tsh> ./myspin 2 &
[1] (7266) ./myspin 2 &
tsh> ./myspin 3 &
[2] (7268) ./myspin 3 &
tsh> jobs
[1] (7266) Running ./myspin 2 &
[2] (7268) Running ./myspin 3 &

[cotmdgus@programming2 shlab-handout]$ make test06
./sdriver.pl -t trace06.txt -s ./tsh -a "-p"
#
# trace06.txt - Forward SIGINT to foreground job.
#
tsh> ./myspin 4
Job [1] (8960) terminated by signal 2
[cotmdgus@programming2 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] (8972) terminated by signal 2

[cotmdgus@programming2 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] (9065) ./myspin 4 &
tsh> ./myspin 5
Job [2] (9068) terminated by signal 2
tsh> jobs
[1] (9065) Running ./myspin 4 &
[cotmdgus@programming2 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] (9102) ./myspin 4 &
tsh> ./myspin 5
Job [2] (9104) terminated by signal 2
tsh> jobs
[1] (9102) Running ./myspin 4 &

[cotmdgus@programming2 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] (9268) ./myspin 4 &
tsh> ./myspin 5
Job [2] (9270) stopped by signal 20
tsh> jobs
[1] (9268) Running ./myspin 4 &
[2] (9270) Stopped ./myspin 5
[cotmdgus@programming2 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] (9283) ./myspin 4 &
tsh> ./myspin 5
Job [2] (9285) stopped by signal 20
tsh> jobs
[1] (9283) Running ./myspin 4 &
[2] (9285) Stopped ./myspin 5
```

```
[cotmdgus@programming2 shlab-handout]$ make test09
./sdriver.pl -t trace09.txt -s ./tsh -a "-p"
#
# trace09.txt - Process bg builtin command
#
tsh> ./myspin 4 &
[1] (10630) ./myspin 4 &
tsh> ./myspin 5
Job [2] (10632) stopped by signal 20
tsh> jobs
[1] (10630) Running ./myspin 4 &
[2] (10632) Stopped ./myspin 5
tsh> bg %2
[2] (10632) ./myspin 5
tsh> jobs
[1] (10630) Running ./myspin 4 &
[2] (10632) Running ./myspin 5
[cotmdgus@programming2 shlab-handout]$ make rtest09
./sdriver.pl -t trace09.txt -s ./tshref -a "-p"
#
# trace09.txt - Process bg builtin command
#
tsh> ./myspin 4 &
[1] (10648) ./myspin 4 &
tsh> ./myspin 5
Job [2] (10650) stopped by signal 20
tsh> jobs
[1] (10648) Running ./myspin 4 &
[2] (10650) Stopped ./myspin 5
tsh> bg %2
[2] (10650) ./myspin 5
tsh> jobs
[1] (10648) Running ./myspin 4 &
[2] (10650) Running ./myspin 5
```

```
[cotmdgus@programming2 shlab-handout]$ make test10
./sdriver.pl -t trace10.txt -s ./tsh -a "-p"
#
# trace10.txt - Process fg builtin command.
#
tsh> ./myspin 4 &
[1] (11161) ./myspin 4 &
tsh> fg %1
Job [1] (11161) stopped by signal 20
tsh> jobs
[1] (11161) Stopped ./myspin 4 &
tsh> fg %1
tsh> jobs
[cotmdgus@programming2 shlab-handout]$ make rtest10
./sdriver.pl -t trace10.txt -s ./tshref -a "-p"
#
# trace10.txt - Process fg builtin command.
#
tsh> ./myspin 4 &
[1] (11177) ./myspin 4 &
tsh> fg %1
Job [1] (11177) stopped by signal 20
tsh> jobs
[1] (11177) Stopped ./myspin 4 &
tsh> fg %1
tsh> jobs
```

```
[cotmdgus@programming2 shlab-handout]$ make test11
./sdriver.pl -t tracell.txt -s ./tsh -a "-p"
#
# tracell.txt - Forward SIGINT to every process in foreground process group
#
tsh> ./mysplit 4
Job [1] (11289) terminated by signal 2
tsh> /bin/ps a
  PID TTY          STAT TIME COMMAND
 1614 pts/17    Ss+  0:00 -bash
 1621 tty1      Ss   0:00 -bash
 1648 tty1      S    0:00 su -
 1649 tty1      S+   0:00 -bash
 1691 pts/2     S+   0:00 nano tsh.c
11083 pts/31    Ss+  0:00 -bash
11285 pts/24    S+   0:00 make test11
11286 pts/24    S+   0:00 /usr/bin/perl ./sdriver.pl -t tracell.txt -s ./tsh -a -p
11287 pts/24    S+   0:00 ./tsh -p
11294 pts/24    R    0:00 /bin/ps a
13751 pts/18    Ss   0:00 -bash
15696 pts/2     Ss   0:00 -bash
16674 pts/18    S+   0:00 ./tsh
17706 pts/5     Ss+  0:00 -bash
20856 pts/6     Ss+  0:00 -bash
22751 pts/25    Ss+  0:00 bash --rcfile /dev/fd/63
24104 pts/24    Ss   0:00 -bash
25649 pts/27    Ss+  0:00 -bash
27095 pts/23    Ss+  0:00 -bash
28379 pts/27    R    0:00 ./tsh -p
28383 pts/27    T    0:00 ./myspin 5
28546 pts/27    R    37:04 ./tsh -p
28550 pts/27    T    0:00 ./myspin 5
29270 pts/10    Ss+  0:00 -bash
31333 pts/19    Ss+  0:00 -bash
32135 pts/29    Ss+  0:00 -bash
[cotmdgus@programming2 shlab-handout]$ make rtest11
./sdriver.pl -t tracell.txt -s ./tshref -a "-p"
#
# tracell.txt - Forward SIGINT to every process in foreground process group
#
tsh> ./mysplit 4
Job [1] (11322) terminated by signal 2
tsh> /bin/ps a
  PID TTY          STAT TIME COMMAND
 1614 pts/17    Ss+  0:00 -bash
 1621 tty1      Ss   0:00 -bash
 1648 tty1      S    0:00 su -
 1649 tty1      S+   0:00 -bash
 1691 pts/2     S+   0:00 nano tsh.c
11318 pts/24    S+   0:00 make rtest11
11319 pts/24    S+   0:00 /usr/bin/perl ./sdriver.pl -t tracell.txt -s ./tshref -a -p
11320 pts/24    S+   0:00 ./tshref -p
11340 pts/24    R    0:00 /bin/ps a
13751 pts/18    Ss   0:00 -bash
15696 pts/2     Ss   0:00 -bash
16674 pts/18    Ss   0:00 ./tsh
17706 pts/5     Ss+  0:00 -bash
20856 pts/6     Ss+  0:00 -bash
22751 pts/25    Ss+  0:00 bash --rcfile /dev/fd/63
24104 pts/24    Ss   0:00 -bash
25649 pts/27    Ss+  0:00 -bash
27095 pts/23    Ss+  0:00 -bash
28379 pts/27    R    38:08 ./tsh -p
28383 pts/27    T    0:00 ./myspin 5
28546 pts/27    R    37:14 ./tsh -p
28550 pts/27    T    0:00 ./myspin 5
29270 pts/10    Ss+  0:00 -bash
31333 pts/19    Ss+  0:00 -bash
32135 pts/29    Ss+  0:00 -bash
```

```
[cotmdgus@programming2 shlab-handout]$ make test12
./sdriver.pl -t tracel2.txt -s ./tsh -a "-p"
#
# tracel2.txt - Forward SIGTSTP to every process in foreground process group
#
tsh> ./mysplit 4
Job [1] (11860) stopped by signal 20
tsh> jobs
[1] (11860) Stopped ./mysplit 4
tsh> /bin/ps a
  PID TTY          STAT TIME  COMMAND
 1614 pts/17    Ss+  0:00 -bash
 1621 tty1     Ss   0:00 -bash
 1648 tty1     S    0:00 su -
 1649 tty1     S+   0:00 -bash
 1691 pts/2    S+   0:00 nano tsh.c
 11632 pts/31 Ss   0:00 -bash
 11663 pts/31 S+   0:00 ssh hyjang@programming2.postech.ac.kr -p2022
 11670 pts/32 Ss+  0:00 -bash
 11843 pts/29 S+   0:00 vim tshref.out
 11856 pts/24 S+   0:00 make test12
 11857 pts/24 S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel2.txt -s ./tsh -a -p
 11858 pts/24 S+   0:00 ./tsh -p
 11860 pts/24 T    0:00 ./mysplit 4
 11861 pts/24 T    0:00 ./mysplit 4
 11868 pts/24 R    0:00 /bin/ps a
 13751 pts/18 Ss   0:00 -bash
 15696 pts/2   Ss   0:00 -bash
 16674 pts/18 S+   0:00 ./tsh
 17706 pts/5   Ss+  0:00 -bash
 20856 pts/6   Ss+  0:00 -bash
 22751 pts/25 Ss+  0:00 bash --rcfile /dev/fd/63
 24104 pts/24 Ss   0:00 -bash
 25649 pts/27 Ss+  0:00 -bash
 27095 pts/23 Ss+  0:00 -bash
 28379 pts/27 R    40:25 ./tsh -p
 28383 pts/27 T    0:00 ./myspin 5
 28546 pts/27 R    39:32 ./tsh -p
 28550 pts/27 T    0:00 ./myspin 5
 29270 pts/10 Ss+  0:00 -bash
 31333 pts/19 Ss+  0:00 -bash
 32135 pts/29 Ss   0:00 -bash
```

```
[cotmdgus@programming2 shlab-handout]$ make rtest12
./sdriver.pl -t tracel2.txt -s ./tshref -a "-p"
#
# tracel2.txt - Forward SIGTSTP to every process in foreground process group
#
tsh> ./mysplit 4
Job [1] (13605) stopped by signal 20
tsh> jobs
[1] (13605) Stopped ./mysplit 4
tsh> /bin/ps a
  PID TTY          STAT TIME  COMMAND
 1621 tty1     Ss   0:00 -bash
 1648 tty1     S    0:00 su -
 1649 tty1     S+   0:00 -bash
 1691 pts/2    S+   0:00 nano tsh.c
 11632 pts/31 Ss   0:00 -bash
 11663 pts/31 S+   0:00 ssh hyjang@programming2.postech.ac.kr -p2022
 11670 pts/32 Ss+  0:00 -bash
 12832 pts/17 Ss+  0:00 -bash
 13564 pts/29 S+   0:00 ./tsh
 13601 pts/24 S+   0:00 make rtest12
 13602 pts/24 S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel2.txt -s ./tshref -a -p
 13603 pts/24 S+   0:00 ./tshref -p
 13605 pts/24 T    0:00 ./mysplit 4
 13606 pts/24 T    0:00 ./mysplit 4
 13611 pts/24 R    0:00 /bin/ps a
 13751 pts/18 Ss   0:00 -bash
 15696 pts/2   Ss   0:00 -bash
 16674 pts/18 S+   0:00 ./tsh
 20856 pts/6   Ss+  0:00 -bash
 22751 pts/25 Ss+  0:00 bash --rcfile /dev/fd/63
 24104 pts/24 Ss   0:00 -bash
 25649 pts/27 Ss+  0:00 -bash
 27095 pts/23 Ss+  0:00 -bash
 28379 pts/27 R    44:54 ./tsh -p
 28383 pts/27 T    0:00 ./myspin 5
 28546 pts/27 R    44:00 ./tsh -p
 28550 pts/27 T    0:00 ./myspin 5
 29270 pts/10 Ss+  0:00 -bash
 31333 pts/19 Ss+  0:00 -bash
 32135 pts/29 Ss   0:00 -bash
```

```
[cotmdgus@programming2 shlab-handout]$ make test13
./sdriver.pl -t tracel3.txt -s ./tsh -a "-p"
#
# tracel3.txt - Restart every stopped process in process group
#
tsh> ./mysplit 4
Job [1] (15025) stopped by signal 20
tsh> jobs
[1] (15025) Stopped ./mysplit 4
tsh> /bin/ps a
  PID TTY          STAT TIME  COMMAND
 1621 tty1     Ss   0:00 -bash
 1648 tty1     S    0:00 su -
 1649 tty1     S+   0:00 -bash
 11632 pts/31 Ss   0:00 -bash
 11663 pts/31 S+   0:00 ssh hyjang@programming2.postech.ac.kr -p2022
 11670 pts/32 Ss+  0:00 -bash
 13751 pts/18 Ss   0:00 -bash
 14105 pts/5   Ss+  0:00 -bash
 14920 pts/17 Ss+  0:00 -bash
 15014 pts/2   S+   0:00 /usr/bin/perl ./sdriver.pl -t trace09.txt -s ./tsh -a -p
 15015 pts/2   S+   0:00 [tsh] <defunct>
 15017 pts/2   S    0:00 ./myspin 4
 15019 pts/2   S    0:00 ./myspin 5
 15021 pts/24 S+   0:00 make test13
 15022 pts/24 S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel3.txt -s ./tsh -a -p
 15023 pts/24 S+   0:00 ./tsh -p
 15025 pts/24 T    0:00 ./mysplit 4
 15026 pts/24 T    0:00 ./mysplit 4
 15046 pts/24 R    0:00 /bin/ps a
 15696 pts/2   Ss   0:00 -bash
 16674 pts/18 S+   0:00 ./tsh
 20856 pts/6   Ss+  0:00 -bash
 22751 pts/25 Ss+  0:00 bash --rcfile /dev/fd/63
 24104 pts/24 Ss   0:00 -bash
 25649 pts/27 Ss+  0:00 -bash
 27095 pts/23 Ss+  0:00 -bash
 28379 pts/27 R    0:00 -bash
 28383 pts/27 T    0:00 ./myspin 5
 28546 pts/27 R    50:17 ./tsh -p
 28550 pts/27 T    0:00 ./myspin 5
 29270 pts/10 Ss+  0:00 -bash
 31333 pts/19 Ss+  0:00 -bash
 32135 pts/29 Ss+  0:00 -bash
tsh> fg %1
tsh> /bin/ps a
  PID TTY          STAT TIME  COMMAND
 1621 tty1     Ss   0:00 -bash
 1648 tty1     S    0:00 su -
 1649 tty1     S+   0:00 -bash
 11632 pts/31 Ss   0:00 -bash
 11663 pts/31 S+   0:00 ssh hyjang@programming2.postech.ac.kr -p2022
 11670 pts/32 Ss+  0:00 -bash
 13751 pts/18 Ss   0:00 -bash
 14105 pts/5   Ss+  0:00 -bash
 14920 pts/17 Ss+  0:00 -bash
 15021 pts/24 S+   0:00 make test13
 15022 pts/24 S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel3.txt -s ./tsh -a -p
 15023 pts/24 S+   0:00 ./tsh -p
 15055 pts/2   S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel0.txt -s ./tsh -a -p
 15056 pts/2   S+   0:00 ./tsh -p
 15058 pts/2   S    0:00 ./myspin 4
 15060 pts/24 R    0:00 /bin/ps a
 15696 pts/2   Ss   0:00 -bash
 16674 pts/18 S+   0:00 ./tsh
 20856 pts/6   Ss+  0:00 -bash
 22751 pts/25 Ss+  0:00 bash --rcfile /dev/fd/63
 24104 pts/24 Ss   0:00 -bash
 25649 pts/27 Ss+  0:00 -bash
 27095 pts/23 Ss+  0:00 -bash
 28379 pts/27 R    49:00 ./tsh -p
 28383 pts/27 T    0:00 ./myspin 5
 28546 pts/27 T    48:01 ./tsh -p
 28550 pts/27 T    0:00 ./myspin 5
 29270 pts/10 Ss+  0:00 -bash
 31333 pts/19 Ss+  0:00 -bash
 32135 pts/29 Ss+  0:00 -bash
```

```
[cotmdgus@programming2 shlab-handout]$ make rtest13
./sdriver.pl -t tracel3.txt -s ./tshref -a "-p"
#
# tracel3.txt - Restart every stopped process in process group
#
tsh> ./mysplit 4
Job [1] (16037) stopped by signal 20
tsh> jobs
[1] (16037) Stopped ./mysplit 4
tsh> /bin/ps a
  PID TTY          STAT TIME  COMMAND
 1621 tty1     Ss   0:00 -bash
 1648 tty1     S    0:00 su -
 1649 tty1     S+   0:00 -bash
 11632 pts/31 Ss   0:00 -bash
 11663 pts/31 S+   0:00 ssh hyjang@programming2.postech.ac.kr -p2022
 11670 pts/32 Ss+  0:00 -bash
 13751 pts/18 Ss   0:00 -bash
 14105 pts/5   Ss+  0:00 -bash
 14920 pts/17 Ss+  0:00 -bash
 15696 pts/2   Ss   0:00 -bash
 15978 pts/2   S+   0:00 nano tsh.c
 16033 pts/24 S+   0:00 make rtest13
 16034 pts/24 S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel3.txt -s ./tshref -a -p
 16035 pts/24 S+   0:00 ./tshref -p
 16037 pts/24 T    0:00 ./mysplit 4
 16038 pts/24 T    0:00 ./mysplit 4
 16046 pts/24 R    0:00 /bin/ps a
 16674 pts/18 S+   0:00 ./tsh
 20856 pts/6   Ss+  0:00 -bash
 22751 pts/25 Ss+  0:00 bash --rcfile /dev/fd/63
 24104 pts/24 Ss   0:00 -bash
 25649 pts/27 Ss+  0:00 -bash
 27095 pts/23 Ss+  0:00 -bash
 28379 pts/27 R    51:16 ./tsh -p
 28383 pts/27 T    0:00 ./myspin 5
 28546 pts/27 R    50:17 ./tsh -p
 28550 pts/27 T    0:00 ./myspin 5
 29270 pts/10 Ss+  0:00 -bash
 31333 pts/19 Ss+  0:00 -bash
 32135 pts/29 Ss+  0:00 -bash
tsh> fg %1
tsh> /bin/ps a
  PID TTY          STAT TIME  COMMAND
 1621 tty1     Ss   0:00 -bash
 1648 tty1     S    0:00 su -
 1649 tty1     S+   0:00 -bash
 11632 pts/31 Ss   0:00 -bash
 11663 pts/31 S+   0:00 ssh hyjang@programming2.postech.ac.kr -p2022
 11670 pts/32 Ss+  0:00 -bash
 13751 pts/18 Ss   0:00 -bash
 14105 pts/5   Ss+  0:00 -bash
 14920 pts/17 Ss+  0:00 -bash
 15696 pts/2   Ss   0:00 -bash
 15978 pts/2   S+   0:00 nano tsh.c
 16033 pts/24 S+   0:00 make rtest13
 16034 pts/24 S+   0:00 /usr/bin/perl ./sdriver.pl -t tracel3.txt -s ./tshref -a -p
 16035 pts/24 S+   0:00 ./tshref -p
 16050 pts/24 R    0:00 /bin/ps a
 16674 pts/18 S+   0:00 ./tsh
 20856 pts/6   Ss+  0:00 -bash
 22751 pts/25 Ss+  0:00 bash --rcfile /dev/fd/63
 24104 pts/24 Ss   0:00 -bash
 25649 pts/27 Ss+  0:00 -bash
 27095 pts/23 Ss+  0:00 -bash
 28379 pts/27 R    51:19 ./tsh -p
 28383 pts/27 T    0:00 ./myspin 5
 28546 pts/27 R    50:18 ./tsh -p
 28550 pts/27 T    0:00 ./myspin 5
 29270 pts/10 Ss+  0:00 -bash
 31333 pts/19 Ss+  0:00 -bash
 32135 pts/29 Ss+  0:00 -bash
```

```
[cotmdgus@programming2 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] (17396) ./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] (17396) stopped by signal 20
tsh> bg %2
%2: No such job
tsh> bg %1
[1] (17396) ./myspin 4 &
tsh> jobs
[1] (17396) Running ./myspin 4 &
[cotmdgus@programming2 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] (17423) ./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] (17423) stopped by signal 20
tsh> bg %2
%2: No such job
tsh> bg %1
[1] (17423) ./myspin 4 &
tsh> jobs
[1] (17423) Running ./myspin 4 &
```

```
[cotmdgus@programming2 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] (17890) terminated by signal 2
tsh> ./myspin 3 &
[1] (17893) ./myspin 3 &
tsh> ./myspin 4 &
[2] (17895) ./myspin 4 &
tsh> jobs
[1] (17893) Running ./myspin 3 &
[2] (17895) Running ./myspin 4 &
tsh> fg %1
Job [1] (17893) stopped by signal 20
tsh> jobs
[1] (17893) Stopped ./myspin 3 &
[2] (17895) Running ./myspin 4 &
tsh> bg %3
%3: No such job
tsh> bg %1
[1] (17893) ./myspin 3 &
tsh> jobs
[1] (17893) Running ./myspin 3 &
[2] (17895) Running ./myspin 4 &
tsh> fg %1
tsh> quit
[cotmdgus@programming2 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] (17936) terminated by signal 2
tsh> ./myspin 3 &
[1] (17947) ./myspin 3 &
tsh> ./myspin 4 &
[2] (17949) ./myspin 4 &
tsh> jobs
[1] (17947) Running ./myspin 3 &
[2] (17949) Running ./myspin 4 &
tsh> fg %1
Job [1] (17947) stopped by signal 20
tsh> jobs
[1] (17947) Stopped ./myspin 3 &
[2] (17949) Running ./myspin 4 &
tsh> bg %3
%3: No such job
tsh> bg %1
[1] (17947) ./myspin 3 &
tsh> jobs
[1] (17947) Running ./myspin 3 &
[2] (17949) Running ./myspin 4 &
tsh> fg %1
tsh> quit
```



```
[cotmdgus@programming2 shlab-handout]$ make test16
./sdriver.pl -t tracel6.txt -s ./tsh -a "-p"
#
# tracel6.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] (18479) stopped by signal 20
tsh> jobs
[1] (18479) Stopped ./mystop 2
tsh> ./myint 2
Job [2] (18497) terminated by signal 2
[cotmdgus@programming2 shlab-handout]$ make rtest16
./sdriver.pl -t tracel6.txt -s ./tshref -a "-p"
#
# tracel6.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] (18509) stopped by signal 20
tsh> jobs
[1] (18509) Stopped ./mystop 2
tsh> ./myint 2
Job [2] (18527) terminated by signal 2
```

make rtest\*는 reference shell, make test\*는 직접 만든 shell이다.