Client-Server Lab
Part 1
Processes

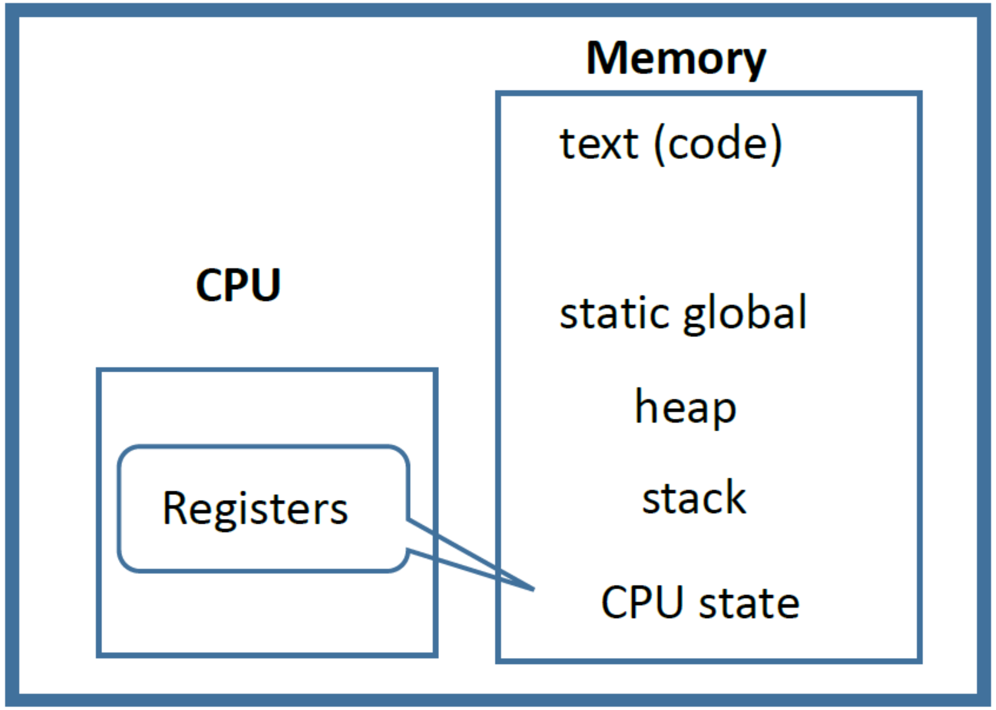
Outline

- What is a process
- Managing processes
- Launching programs from a process
- Communicating processes: pipes
- I/O redirection: dup2

What is a Process

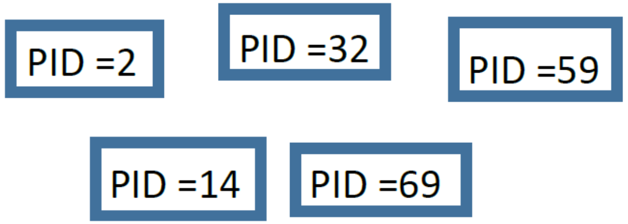
Process:
An instance of a program running in a computer

Computer Model



You can have multiple processes running in a computer
Time sharing: CPU running multiple programs
Multi-core computers

General Purpose Computers run multiple processes
(e.g., Windows, Android, Apple OS, Linux)
Each process has its own unique Process ID (PID)



Processes are created over time, successive processes getting higher PIDs

Processes run in “parallel” and independently.
Processes are created/destroyed by the operating system

```
ps -a

PID    TTY     TIME        CMD
24538  pts/4   00:00:00    bash
24570  pts/4   00:00:00    ps
```

Managing Processes

Create, terminate, wait for a process to terminate

Create

Parent

Computation flow

```
main( )
{
pid = fork( );
if (pid < 0) { /* error */
  indicate an error occured
}
if (pid== 0) { /* child */
   processing for the child
}
else { /* parent */
   processing for the parent
}
}
```

fork():

1 Creates a child process, which is identical to the parent process

2 Returns

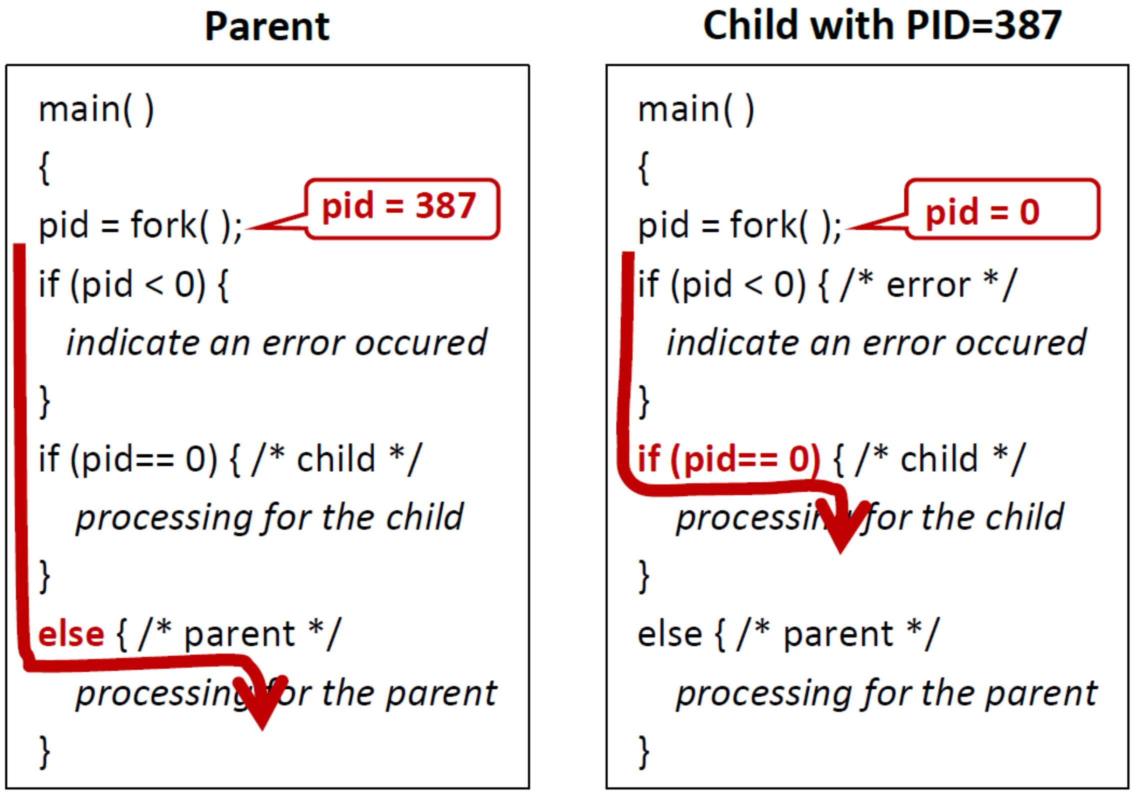
  1 To the parent, the PID of the child

  2 To the child, the value 0

The returned value indicates if the program is a parent or child

See fork.c

Managing Processes: Create, wait, exit



Parent

```
main( )
{
pid = fork( );
if (pid < 0) {
  indicate an error occured
}
if (pid== 0) { /* child */
   processing for the child
}
else { /* parent */
   processing for the parent
}
```

pid = 387

Child with PID=387

```
main( )
{
pid = fork( );
if (pid < 0) { /* error */
  indicate an error occured
}
if (pid== 0) { /* child */
   processing for the child
}
else { /* parent */
   processing for the parent
}
```

pid = 0

The parent and child are running “concurrently”,
either on different CPU cores or by time sharing or both

Exiting (terminating) a process:

exit(EXIT_SUCCESS);   -- exiting after success
exit(EXIT_FAILURE);   -- exiting due to failure

wait and waitpid:

int status;
wait(&status); -- wait until a child terminates
waitpd(pid, &status, 0);
     -- wait until the child with pid terminates

See wait.c

Launching Processes: exec()

```
aloha.c:
void main( )
{
printf(“Aloha world!\n”);
}
```

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>   /* Necessary for ‘execlp’ */

void main()
{
printf(“Start of program ‘launch’\n”);
execlp(“./aloha”,”./aloha”, (char *) NULL);
printf(“End of program ‘launch’\n”);
}
```

Path to the program

The command to launch the program

Terminates the command line

```
execlp( input 0, input 1, input 2, input 3, ..., input 20, (char *) NULL);
```

```
execlp(“\bin\ls”, “ls”, “-l”, (char*) NULL);
```

```
ls -l
```

The process is completely replaced by the “aloha” process

```
Start of program ‘launch’
Aloha world!
```

See exec.c

Launching Processes: program launching a program

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

void main()
{
if (fork()) {
      execlp(“./aloha”, “./aloha”, (char *) NULL);
      exit(EXIT_FAILURE);
}
< Code for main() >
}
```

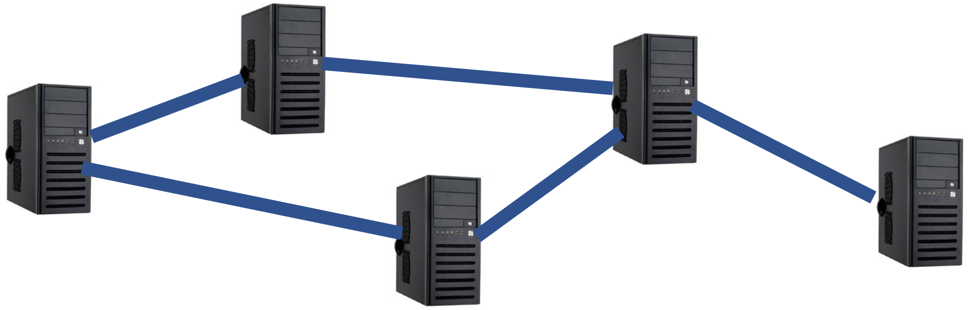
Now we have two processes

Issue:
Processes can run independently like virtual computers running programs; isolated from each other

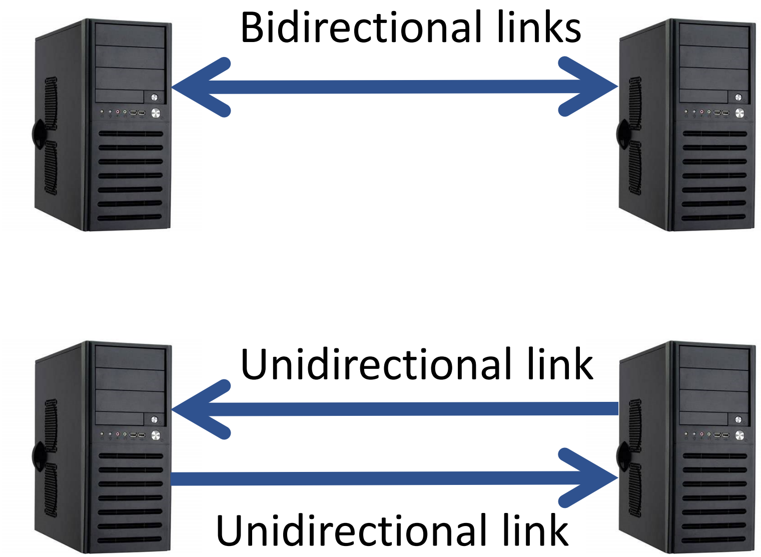
Process:
Virtual computer
running a program

How can we get them to work together?

We can set up communication links



Communication Links



ID of queue

data to transfer

bytes to transfer

ssize_t write(fd, buffer1, count); Nonblocking

Returns # bytes actually transferred

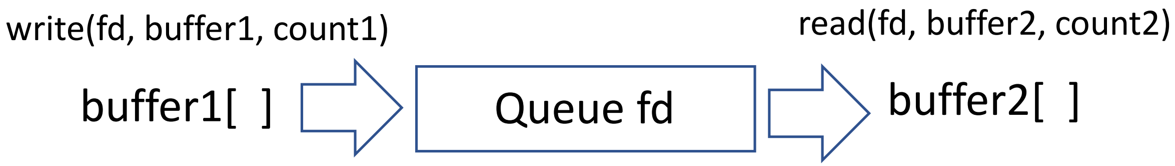
ID of queue

data to transfer

bytes to transfer

ssize_t read(fd, buffer2, count); Nonblocking

Returns # bytes actually transferred



write(fd, buffer1, count1)

read(fd, buffer2, count2)

buffer1[ ]

Queue fd

buffer2[ ]

Links: Pipes

```
int  fd[2];

pipe(fd);          Create a pipe
```

fd[0]: file descriptor of the read-end of the pipe
        the output of the pipe
fd[1]: file descriptor of the write-end of the pipe
        the input of the pipe

You send data from process 1 to process 2:

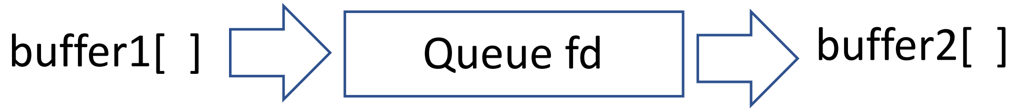
Create a pipe(fd)

Then create the processes

Process 1 writes to the pipe
Process 2 reads from the pipe

write(fd[1], buffer1, count1)

read(fd[0], buffer2, count2)



buffer1[ ]

Queue fd

buffer2[ ]

close(fd[1]);

close(fd[0]);

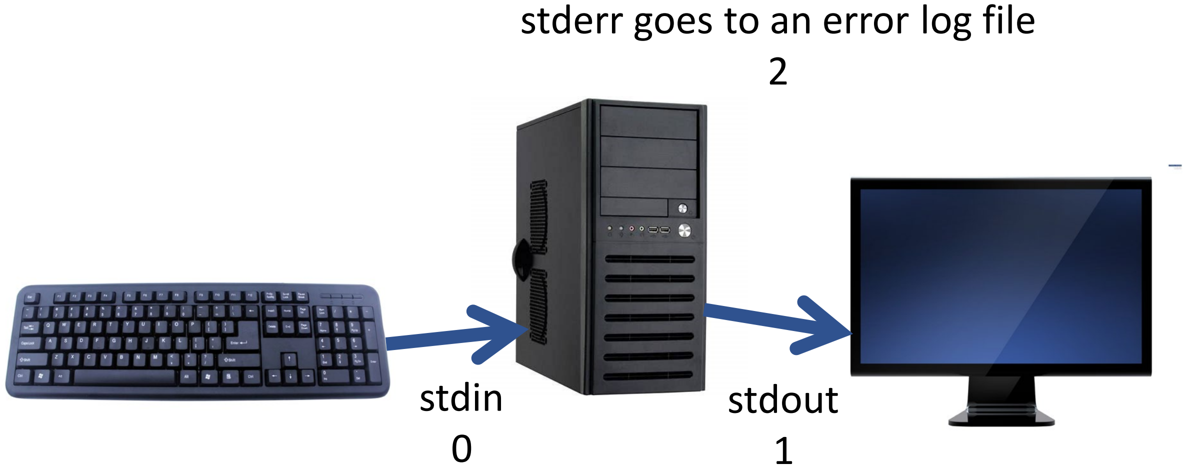
Redirecting I/O: dup2

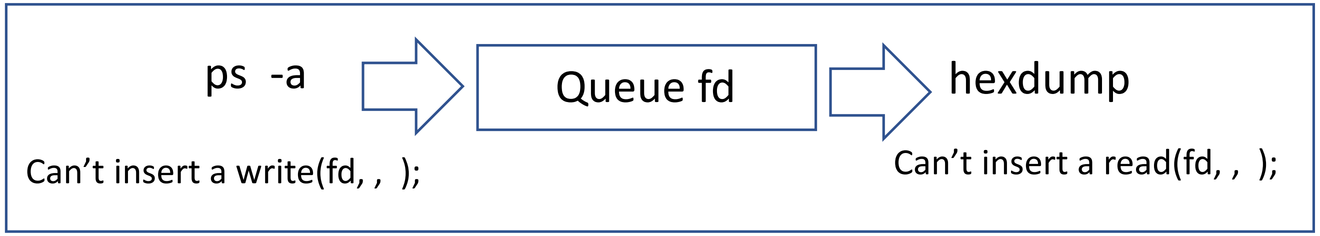
You send data from process 1 to process 2:

Create a pipe(fd)

Then create the processes, which are launced programs, e.g., ps –a, hexdump

Programs such as ps-a or hexdump will read and write data through stdin and stdout




ps -a

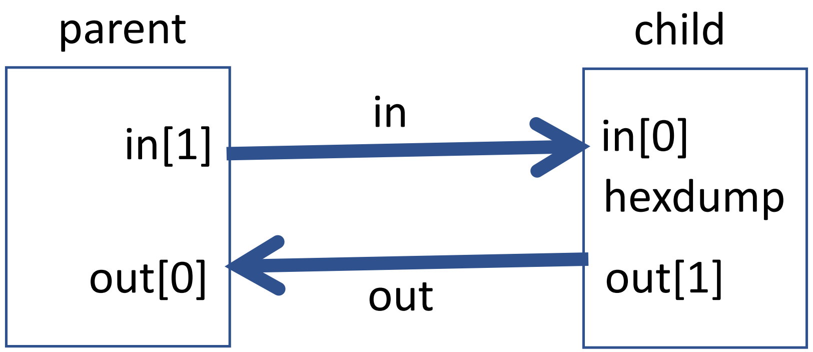
Queue fd

hexdump

Can’t insert a write(fd, ,);

Can’t insert a read(fd, ,);

Example

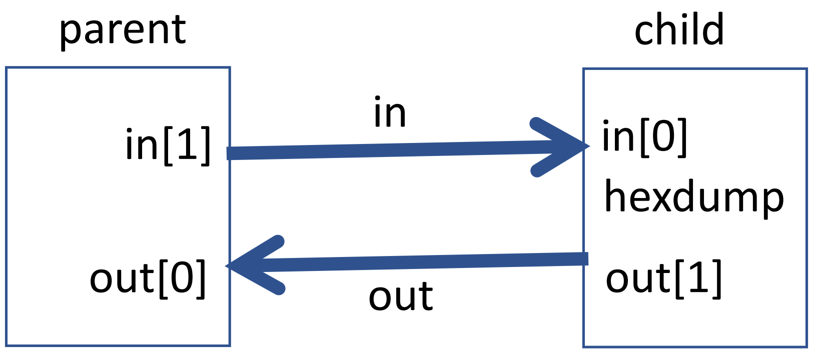


```
int in[2], out[2], n, pid;
char buf[255];

if (pipe(in) < 0) error("pipe in");  /* Create pipe ‘in’ */
if (pipe(out) < 0) error("pipe out"); /* Create pipe ‘out’ */
if ((pid=fork()) == 0) { /* Child */
  close(0); /* Close stdin, stdout, stderr */
  close(1);
  close(2);
  dup2(in[0],0); /* Redirect stdin, stdout, and stderr to/from pipes */
  dup2(out[1],1);
  dup2(out[1],2);
  close(in[1]); /* Close unused ends of pipes */
  close(out[0]); /* Then when the other end is closed the processes get EOF */
  execl("/usr/bin/hexdump", "hexdump", "-C", (char *)NULL);
  error("Could not exec hexdump");
}
```

Child

Example



parent

child

in[1]

in

in[0]

hexdump

out[0]

out

out[1]

Parent

```
/*  Parent process */
printf("Spawned 'hexdump -C' as a child process at pid %d\n", pid);
close(in[0]); /* Close unused end of pipes */
close(out[1]);
printf("String sent to child: %s\n\n", data);
write(in[1], data, strlen(data)); /* Parent sends string to hexdump */
close(in[1]); /* This will for an EOF to be sent to child */
n = read(out[0], buf, 250); /* Read back any output from hexdump */
buf[n] = 0;
printf("This was received by the child: %s",buf);
exit(0);
```