

Inter-process communication (IPC)

Kartik Gopalan

Chapter 2 of Tanenbaum's book

Chapter 4 and 5 of OSTEP book

In this lecture, we cover

- Pipes
 - Uni-directional (if used cleanly)
 - ‘ps -aux | more’
- Signals
 - Event notification from one process to another
- Shared Memory
 - Common piece of read/write memory.
 - Needs synchronization for access

Other forms of IPC

- Parent-child

- Command-line arguments,
- `wait(...)`, `waitpid(...)`
- `exit(...)`

- Reading/modifying common files

- Servers commonly use 'pid' file to determine other active servers.

- Semaphores

- Locking and event signaling mechanism between processes

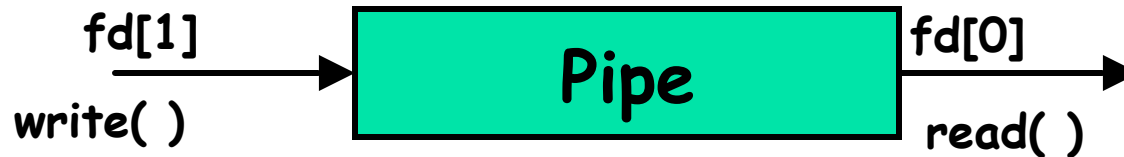
- Sockets

- Bi-directional
- Not just across the network, but also between processes.

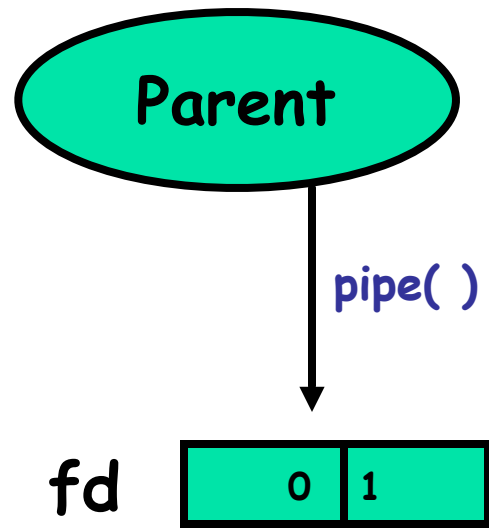
Pipes

Pipe Abstraction

- Write to one end, read from another
- `pipe()`



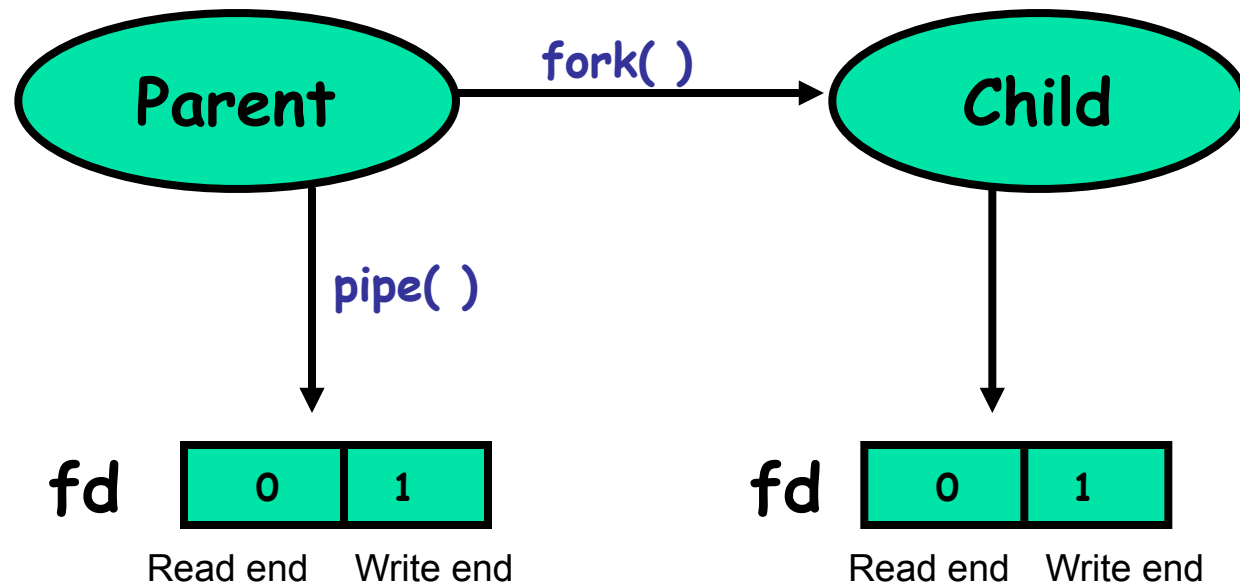
Parent-child communication using pipe



Here's an example.

<https://oscourse.github.io/examples/pipe1.c>

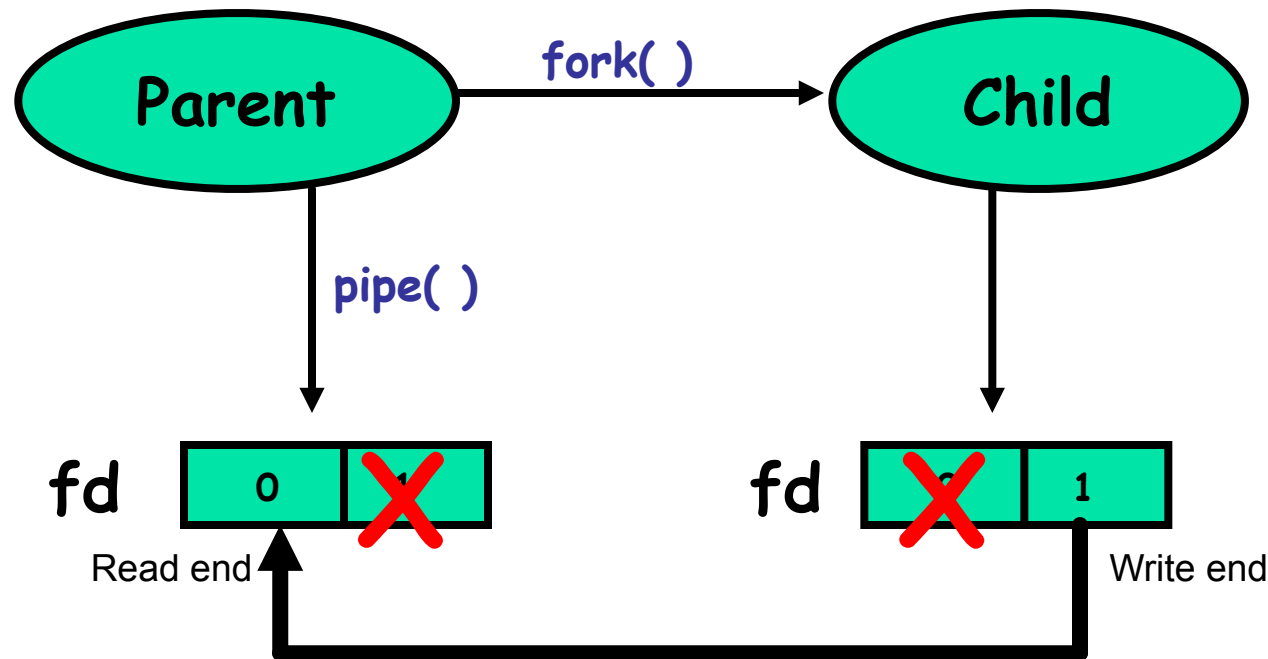
Parent-child communication using pipe



Here's an example.

<https://oscourse.github.io/examples/pipe1.c>

Parent-child communication using pipe

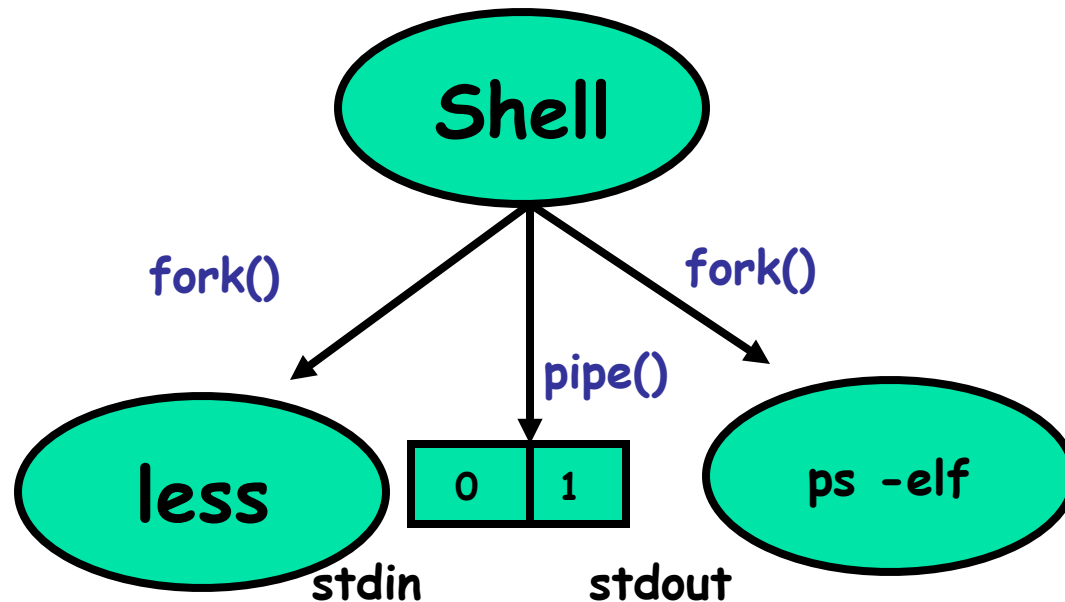


Here's an example.

<https://oscourse.github.io/examples/pipe1.c>

Filters in shell command-line

`ps -elf | less`

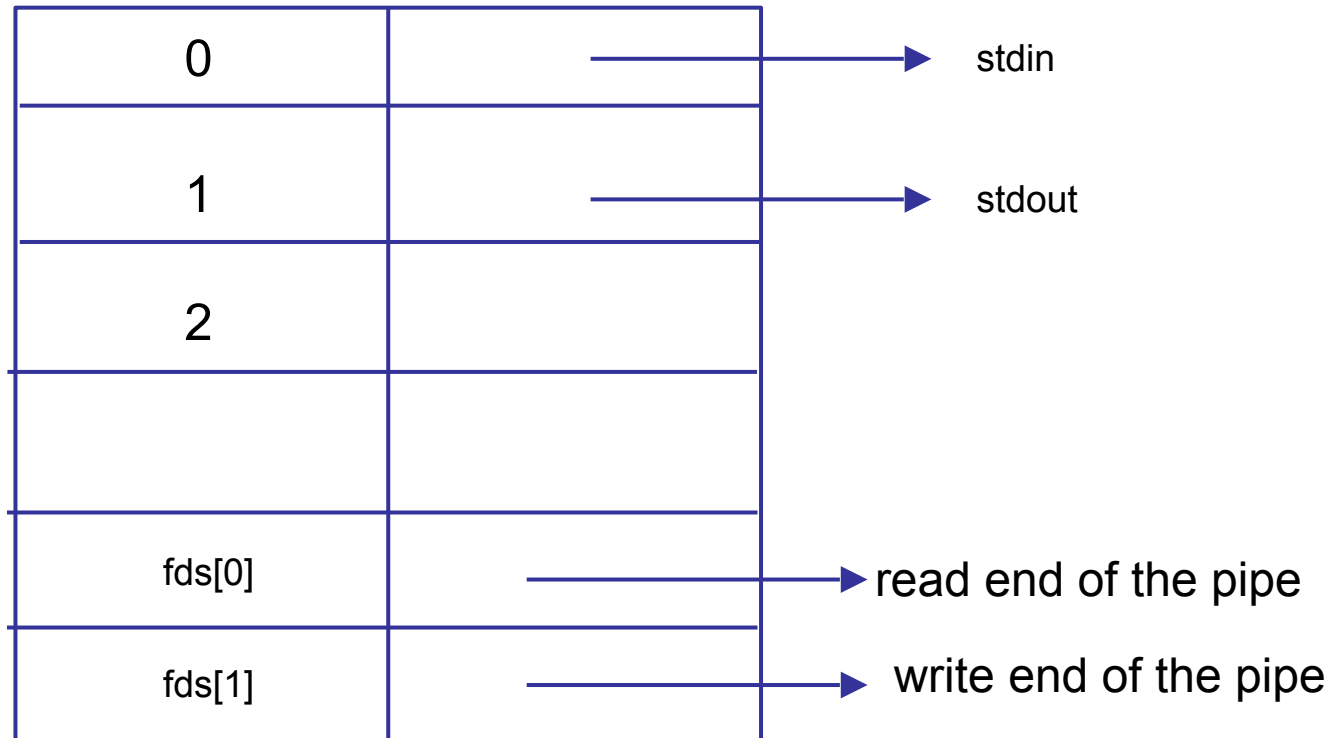


Here's an example.

<https://oscourse.github.io/examples/pipe2.c>

File-Descriptor Table

- Each process has a file-descriptor table
- One entry for each open file
- “File” = regular files, stdin, stdout, pipes, I/O devices etc.



Handling long chain of filters

— Recursive approach

- create a pipe
- fork a child
- redirect stdin and/or stdout as necessary
- fork another child for next level of recursion with a shorter command
- exec the command for the current level

Pipe provides a byte-stream abstraction

- You can read and write at arbitrary byte boundaries.
 - E.g. Byte lengths sequence written
 - 10, 10, 10, 10
 - byte lengths sequence read
 - 5, 15, 15, 5
- As opposed to **message abstraction**, which provides explicit message boundaries.
 - E.g. network packets

Being careful with read()/write()

- `read(fds[0], buf, 6);`

- Doesn't mean read will return with 6 bytes of data!
- It could be less. Why?

- Some reasons

- `read()` could reach end of input stream (EOF).
- Other endpoint may abruptly close the connection
- `read()` could return on a signal.

- So you MUST incorporate error handling with every I/O call (actually with any system call)

Error handling...

You **must**

- First check the return value of **every** read(...)/write(...) system call.
- Then either...
- Wait to read/write more data
OR
- Handle any error conditions

More convenient to write a wrapper function

/* Write "n" bytes to a descriptor. */

ssize_t **written**(int fd, const void *vptr, size_t n)

{

size_t nleft;

size_t nwritten;

const char *ptr;

ptr = vptr;

nleft = n;

while (nleft > 0) {

if ((nwritten = **write**(fd, ptr, nleft)) <= 0) {

if (errno == EINTR)

nwritten = 0; /* call write() again */

else return(-1); /* error */

}

nleft -= nwritten;

ptr += nwritten;

}

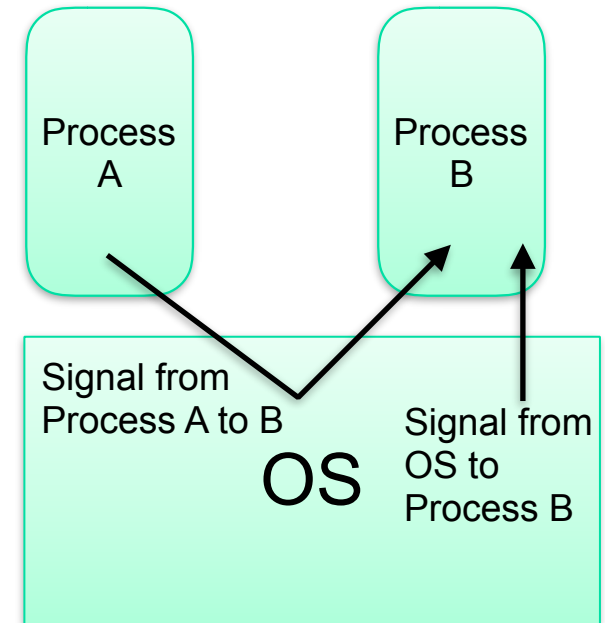
return(n);

}

Signals

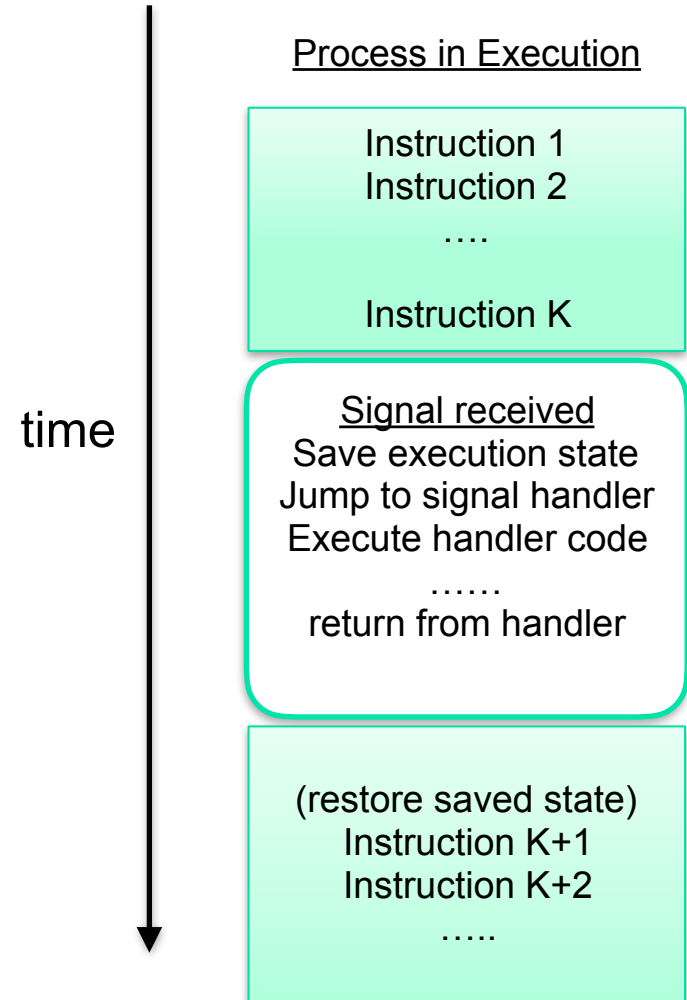
Signals Overview

- Signal is a notification to a process that an event has occurred.
 - Could come from another process or from the OS
- Type of event determined by type of signal
- Try listing all signal types using
 - `% kill -l`
- Some interesting signals
 - `SIGCHLD`, `SIGKILL`, `SIGSTOP`



Handling Signals

- Signals can be caught – i.e. an action (or handler) can be associated with them
 - SIGKILL and SIGSTOP cannot be caught.
- Actions can be customized using
 - `sigaction(...)`
 - which associates a signal handler with the signal.
- Default action for most signals is to terminate the process
 - Except SIGCHLD and SIGURG are ignored by default.
- Unwanted signals can be ignored
 - Except SIGKILL or SIGSTOP
- Here's an example.
 - https://oscourse.github.io/examples/signals_ex.c



More on SIGCHLD

- Sent to parent when a child process terminates or stops.
- If `act.sa_handler` is `SIG_IGN`
 - `SIGCHLD` will be ignored (default behavior)
- If `act.sa_flags` is `SA_NOCLDSTOP`
 - `SIGCHLD` won't be generated when children stop
- `act.sa_flags` is `SA_NOCLDWAIT`
 - children of the calling process will not be transformed into zombies when they terminate.
- These need to be set in `sigaction()` before parent calls `fork()`

Handling child's exit without blocking on wait()

- Parent could install a signal handler for SIGCHLD
- Call `wait(...)` / `waitpid(...)` inside the signal handler

```
void handle_sigchld(int signo) {  
    pid_t pid;  
    int stat;  
  
    pid = wait(&stat); //returns without  
    blocking  
  
    printf("child %d terminated\n", pid);  
}
```

- Here's an example.

• <https://oscourse.github.io/examples/sigchld.c>

More information...

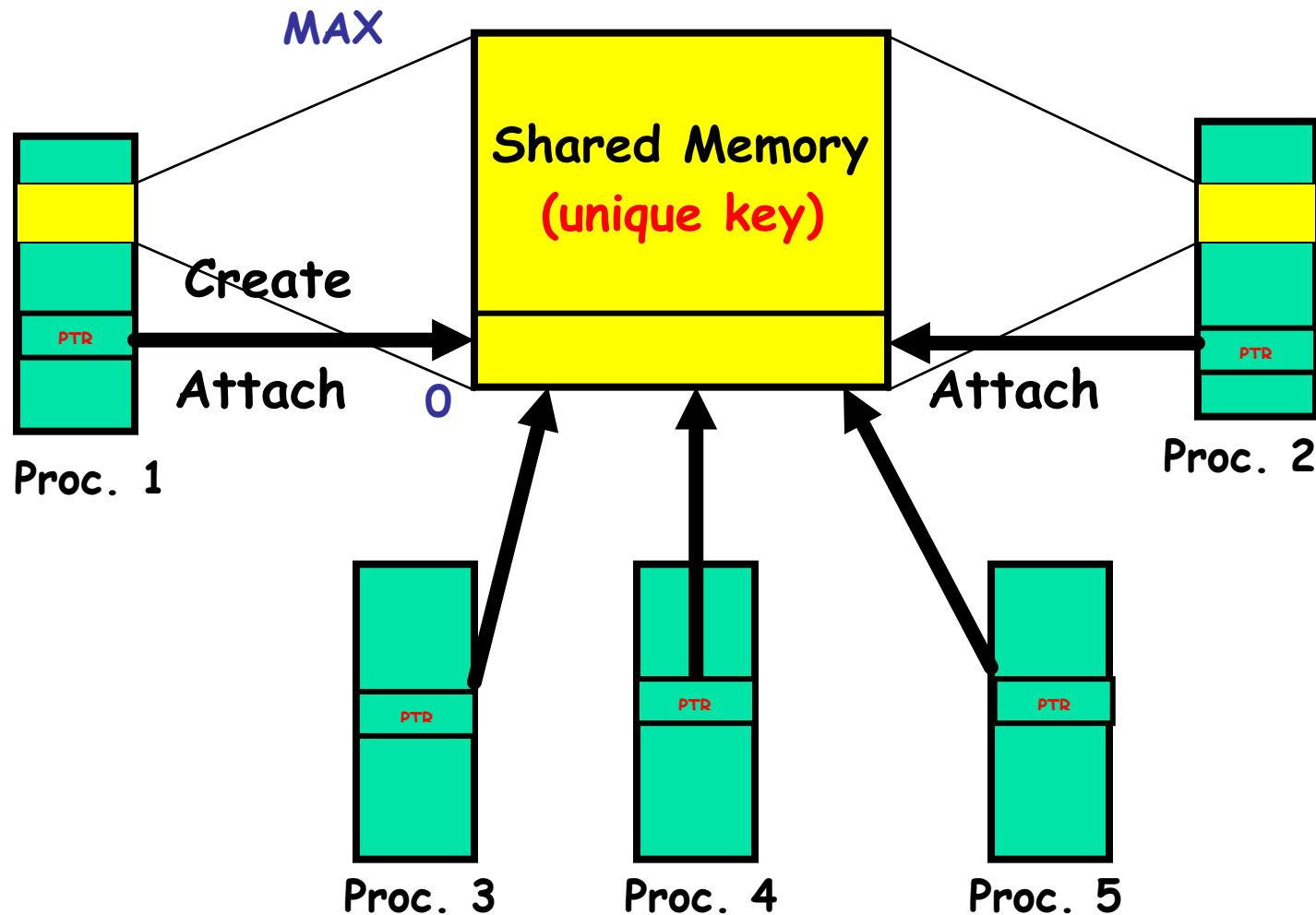
- Check ‘man sigaction(...)’
- Understand what happens when signal is delivered in the middle of a system call?
 - Different OSes have different behavior.
- Google for keywords “Unix Signals”
 - Tons of useful links

Shared Memory, Semaphores

- Man pages : shmget, shmat, shmdt, shmctl, semget, semop, semctl

Shared Memory

Common chunk of read/write memory among processes



Creating Shared Memory

```
int shmget(key_t key, size_t size, int shmflg);
```

Example:

```
key_t key;  
int shmid;
```

```
key = ftok("<somefile>", 'A');
```

```
shmid = shmget(key, 1024, 0644 | IPC_CREAT);
```

Here's an example.

https://oscourse.github.io/examples/shm_create.c

Attach and Detach Shared Memory

```
void *shmat(int shmid, void *shmaddr, int shmflg);  
int shmdt(void *shmaddr);
```

Example:

```
key_t key;  
int shmid;  
char *data;  
key = ftok("<somefile>", 'A');  
shmid = shmget(key, 1024, 0644);  
data = shmat(shmid, (void *)0, 0);  
// read or write something to data here.  
shmdt(data);
```

Here's an example.

https://oscourse.github.io/examples/shm_attach.c

Deleting Shared Memory

```
int shmctl(int shmid, int cmd, struct shmid_ds *buf);
```

```
shmctl(shmid, IPC_RMID, NULL);
```

Example:

https://oscourse.github.io/examples/shm_delete.c

Command-line IPC control

- **ipcs**

- Lists all IPC objects owned by the user

- **ipcrm**

- Removes specific IPC object

References

- Unix man pages
- “Advanced Programming in Unix Environment”
by Richard Stevens
 - <http://www.kohala.com/start/apue.html>