Computer Network Programming

UNIX Processes

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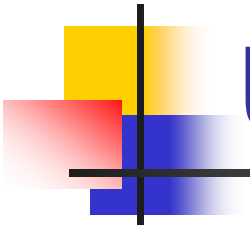
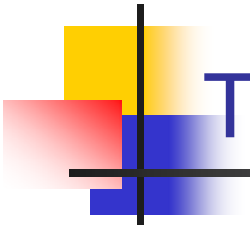


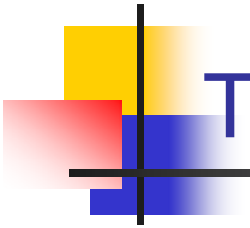
UNIX Processes

- Process Model
- Process Creation
- Process Termination
- Zombie Process
- Orphaned Process
- Race Conditions
- Process Attributes
- Kernel Data Structures
- Context of a Process
- Process Execution



Typical Memory Layout of a Process (1/3)

- Text segment
  - For instructions.
- Data segment
  - Initialized data segment.
  - Uninitialized data segment.
    - BSS (***b***lock ***s***tarted by ***s***ymbol)
- Stack
  - For function calls.



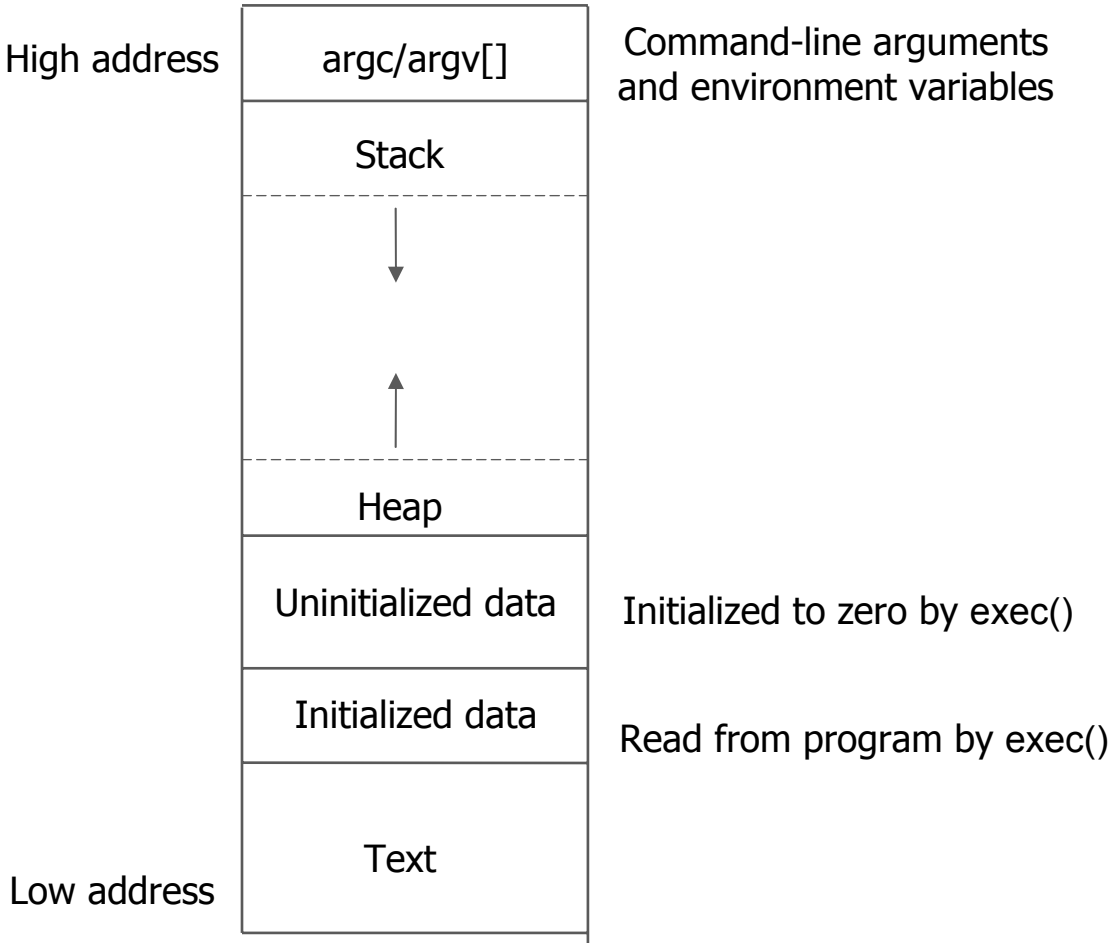
Typical Memory Layout of a Process (2/3)

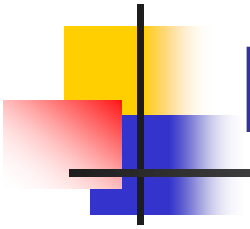
- Heap
  - For dynamic memory allocations.
- Command-line arguments

  argc/argv[]/envp[]
- Environment vairables

  *extern char **environ*

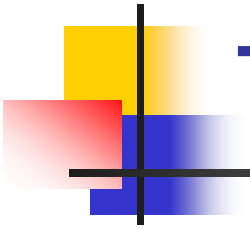
Typical Memory Layout of a Process (3/3)





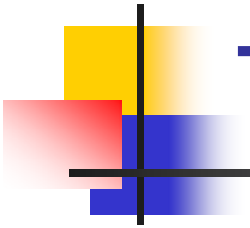
Processes

- A process is a program in execution.
- Each has a unique PID.
  - A non-negative integer: 0 ~ PID_MAX
- Created by *fork()*/*vfork()* system calls.
- Some special PIDs:
  - 0: scheduler
  - 1: init
  - 2: pagedaemon



The *fork()* System Call (1/3)

- Only way to create processes
  - Except for 0, 1, …
- Parent/child relationship
  - The child is a copy of the parent.
    - It inherits the parent's data, heap and stack.
  - COW (copy-on-write) in most current implementations.
    - Only the page that gets modified is copied, typically in a virtual memory system.

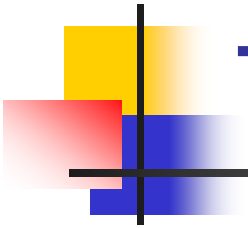


The *fork()* System Call (2/3)

- Often the parent and the child share the text segment,
  - If it is read-only.
- Never know whether the parent or child will start executing first.
  - All file descriptors that are open in the parent are duplicated in the child.
    - Parent/child also share the same file offset (Files opened after *fork()* are not shared).

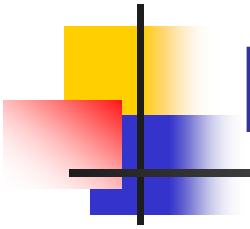
The *fork()* System Call (3/3)

- Two normal cases for handling the descriptors after a *fork()*:
  - Parent waits.
  - Parent and child go their own way.
- *fork()* may fail if it,
  - Exceeds user limit, or
  - Exceeds total system limit.
- Two uses (reasons) for *fork()*:
  - Each can execute a different sections of the code at the same time.
  - One process can execute a different program.



The *vfork()* System Call

- A BSD variant of *fork*(), now supported by SVR4.
- Similar to *fork*(); however, is used to *exec* a new program only.
- Child running in the parent address space until it calls *exec*()/*exit*().
- Not fully copying the address space of the parent into the child.
- *vfork*() guarantees that the child runs first until it calls *exec*()/*exit*( ).
- Deadlock is possible if the child needs information from the parent.

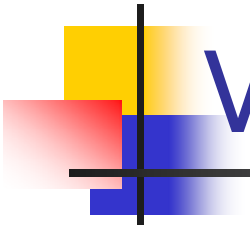


Process Termination

- Normal termination
  - Return from main().
  - Calling *exit()*.
  - Calling *_exit()*.
- Abnormal termination
  - Calling *abort()*.
  - Terminated by a signal.

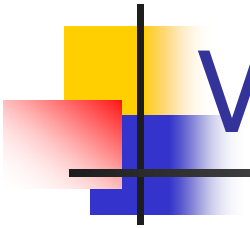
The *exit()*/*_exit()* System Calls

- *exit()*
  - Performs a standard I/O cleanup.
    - Executes all registered *exit handlers*.
    - Flushes all C output buffers.
    - Closes all open streams.
  - Terminates the calling process.
- *_exit()*
  - Terminates the calling process without performing a standard I/O cleanup.



Various *wait()* System Calls (1/3)

- *wait()* is used to wait for a child to terminate.
- *waitpid()* is used to wait for a specific child to terminate, plus some options.
- *wait3()/wait4()* will further collect resource usage information.



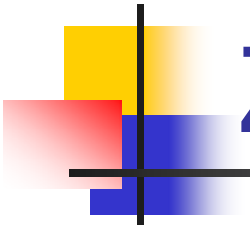
Various *wait()* System Calls (2/3)

- When a process terminates, the following are reported/returned to its parent via a *wait()* system call:
  - Exit/termination status.
  - Resource utilization
    - CPU time
    - Memory
    - Etc.

Various *wait()* System Calls (3/3)

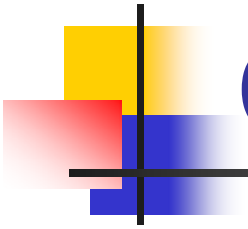
Function	pid	options	rusage	POSIX.1	SVR4	4.4BSD
wait()				•	•	•
waitpid()	•	•		•	•	•
wait3()		•	•		•	•
wait4()	•	•	•			•

Arguments supported by various *wait()* functions on different systems.



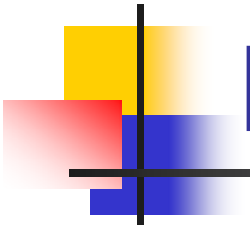
Zombie Process

- A process that no longer exists, but still ties up a slot in the system process table.
  - A process that has terminated, but whose parent exists and has not waited or acknowledged the child's termination.
- Zombies are to be avoided.
  - To wait for the child to finish.
  - To catch SIGCHLD in the parent.
  - To have the child orphaned (not encouraged).



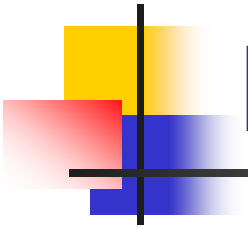
Orphaned Process (orphan)

- A process whose parent has exited.
- An orphaned process can never become a zombie process.
- Its slot in the process table is immediately released when an orphan terminates.
- Orphaned processes are inherited by *init()*.



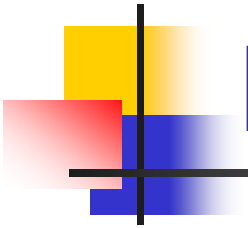
Race Conditions

- A race condition occurs when multiple processes are competing for the same system resource(s).
  - The final outcome depends on the order in which the processes run.
- Problems due to race conditions are hard to debug.
  - Programs tend to work "most of the time."
- Needs to have process synchronization.



Process Attributes (1/2)

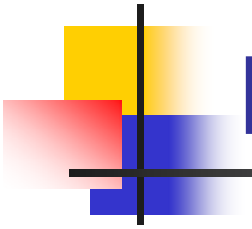
- A process has the following Ids:
  - Process ID.
  - Parent Process ID.
  - Process group ID.
  - Session ID.
  - User ID of the process.
  - Group ID of the process.
  - Effective user ID.
  - Effective group ID.



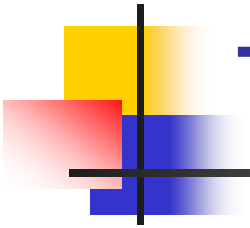
Process Attributes (2/2)

- Some other properties:
  - Controlling terminal.
  - Current working directory.
  - Root directory.
  - Open files descriptors.
  - File mode creation mask.
  - Resource limits.
  - Process times.

Two Kernel Data Structures Pertinent to a Process

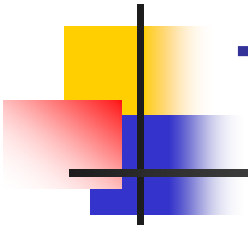


- The process table entry and user (u) area.
  - They contain administrative information for a process.
  - One each per process.
- Process table entry
  - It keeps information always needed.
- User area
  - It keeps information needed when running.



The Context of a Process

- User address space.
- Relevant kernel data structures:
  - Process table entry + u area.
- Contents in hardware registers.

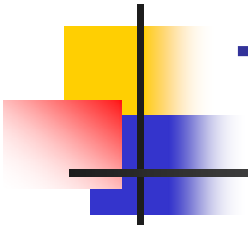


The *exec()* System Call (1/5)

- Only way to execute processes.

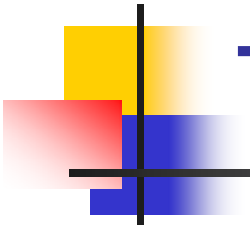
  In the UNIX system, fork() *creates processes and* exec() *executes processes. These two system calls are very closely related. Without* exec(), *no process can be executed. No* fork(), *no process can be created. They make a good team achieving most of the UNIX system operations.*

- Will replace the calling process with a new program and start execution.



The *exec()* System Call (2/5)

- Brand new text, data, heap and stack segments.
  - Inherits most of the process attributes of the calling process, such as
  - PID and PPID.
  - The real and effective UID and GID that aren't SUID or SGID.
  - Open files, except those with the *close-on-exec* flag set, are passed to the new program.
  - The file mode creation mask (umask) is passed to the new program.



The *exec()* System Call (3/5)

- Controlling terminal.
- Current working directory
- Root directory.
- File locks.
- Signal mask.
- Pending signals.
- Resource limits
- CPU times.

The *exec()* System Call (4/5)

- Is a family name for six like functions virtually doing the same thing, only slightly different in syntax:
  - *execl()*, *execv()*, *execle()*, *execve()*, *execlp(),* and *execvp()*.
    - Only *execve()* is a system call.
  - Meaning of different letters:

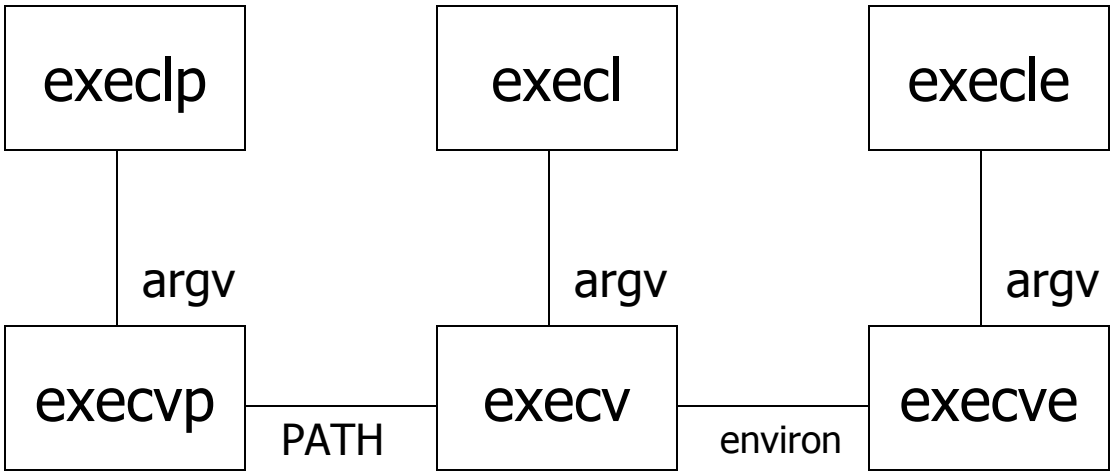
    l: needs a list of arguments.

    v: needs an *argv[]* vector (*l* and *v* are mutually exclusive).

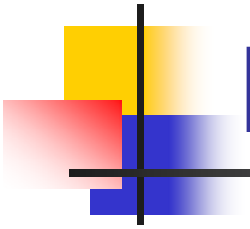
    e: needs an *envp[]* array.

    p: needs the PATH variable to find the executable file.

The *exec()* System Call (5/5)



Relationship of the *exec()* functions.



Recommended Reading

- Read Chapters 7-8, *Advanced Programming in the UNIX Environment*, by W. Richard Stevens.