Chapter 10

Review and Conclusions

What have you learned? What else could you still learn?

Print Version of Lectures Notes of *Operating Systems*

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Purpose and Contents

The purpose of this chapter

1. review subjects presented during the OS course (this semester)
2. draw some conclusions
3. presents future OS-related courses 10.2

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1 OS Subject Review

OS Definition, Role, Architecture

- system software placed between hardware and user software (applications)
- roles
  - virtual machine provider (hide hardware and provide abstractions)
  - resource manager
- every resource access / need must be required from OS
  - by calling SO services, i.e. system calls
- OS protects itself from user applications based on different CPU execution modes
  - privileged: kernel mode
  - non-privileged: user mode
- architectures
  - monolith
  - micro-kernel 10.4

Practice: OS Definition Related Questions

- When is the OS code executed on an uni-processor system? Give examples of at least two situations.
- How is the system call mechanism implemented?
- Which software is run in kernel and user mode respectively in the following two cases?
  - monolithic OS
  - micro-kernel OS

10.5

OS Shell

- provides the user interface to the OS
- usually a simple application
- takes user requests and translated them in system calls
- two types
  - graphical
  - text, named command interpreter
- command interpreter functionality
  - get user's command line
  - split it in tokens, i.e. command line and arguments
  - create a new process to execute the specified command
  - waits for created child process' termination
- command line
  - a string of characters separated by spaces
  - first item: command name, actually an executable path
    * searched in directories from PATH
    * security: trust user-established environment (e.g. PATH)
  - other items: command line arguments
  - special characters, like STDIN/OUT redirection, pipe etc.

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Practice: Shell Related Questions

Which is the effect of the following commands?

- ls > file
- read n < file
- ls -R / 1>good 2>err
- cat dict.txt | sort

10.7

File System (FS)

- file concept
  - basic unit of data allocation
  - unstructured stream of bytes
  - file contents managed by user applications, not by OS
  - components: data and meta-data
  - security: too much permissions vulnerability
- directory concept
  - used for organizing the file system space
  - impose file system hierarchy
  - paths: absolute and relative
  - security: path traversal vulnerability

- FS system calls
  - file: open, read, write, lseek, close
  - directory: opendir, readdir, stat, unlink, link
- allocation aspects
  - contiguous allocation ⇒ external fragmentation
  - any-free-block allocation ⇒ internal fragmentation
  - i-nodes, directory entries, links, files with holes

10.8

Practice: FS Related Questions

- How is usually the file provided like to the user applications?
- Which of the following extensions usually correspond to text and binary files respectively: html, pdf, c, zip?
- What is an i-node in Linux?
- What does 0640 means in terms of permission rights in Linux?
- Which is the most probable file descriptor returned (and displayed) by the following Linux program? Explain your answer.

```
main()
{
    int fd = open ("/etc/passwd", O_RDONLY);
    printf("fd = %d\n", fd);
}
```

- Write in one line the C code to read a text line from a file, whose file descriptor is given.
- Write the C code to read an integer from offset 16 from a file, whose file descriptor is given.

10.9

Process and Thread Management

- process
  - models execution: abstractizes the machine (CPU, memory)
  - describe execution and resources needed for that execution
  - isolates (separates) resources / executions
  - states: running, ready, blocked, terminated
- thread
  - models execution in a process
  - more threads = more concurrent executions in the same process
  - threads of a process share all resources of that process
  - threads useful and effective when
    * logical parallelism exist in the application
    * enough hardware resources available
- scheduling
  - decides who runs and for how long
  - preemptive vs. non-preemptive
    * preemptiveness based on timer interrupt
  - first-come first-served (FCFS), shortest job first (SJB), round-robin (RR), priority-based

10.10

Practice: Process Related Questions

- How many times is each message in the code below displayed on the screen? Explain your answer.

```
int fd[2];
pipe(fd);
printf("Step 1\n");
fork();
fork();
fork();
printf("Step 2\n");
```

- How many readers and writers, respectively, will exist in the system for the created pipe after the execution of the given code, supposing no process is terminated at that moment?
- Which is the optimum number of threads that should be created by an application to get the best performance (i.e. execution time) when running on a uni-process system and copying a file from one disk to another disk, by encrypting the file contents during the copy operation?

10.11

Synchronization Mechanisms

- problem: race conditions of concurrent threads sharing resources
- synchronization means imposing access rules
  - leads to waiting (blocking) ⇒ reduce parallelism
- synchronization needs OS and hardware support to get atomicity
- synchronization mechanisms
  - lock ⇒ mutual exclusion
  - semaphore
    - generalized lock
    - event counter
  - condition variable
    - specialized waiting mechanism in mutual exclusion area
- classical patterns
  - producers-consumers, readers-writers, rendez-vous (barrier)

10.12

Practice: Synchronization Related Questions

- Use semaphores to allow just 10 threads run simultaneously a given function's body.
- Rendezvous: synchronize threads executing functions `boy()` and `girl()` respectively, such that to allow them returning from that functions only in pairs of a "boy" and a "girl".
- Synchronize two concurrent threads executing the two functions below respectively, such that to make them display on the screen the message "*Life is wonderful, isn't is?*"

```
thread_1()
{
    printf("Life ");
    printf("wonderful, ");
}
```

```
thread_2()
{
    printf("is ");
    printf("isn't it?");
}
```

10.13

Memory Management

- memory addresses: physical vs. virtual
  - address space
  - virtual address space structure: code, data, heap, stack
- memory binding / translation
  - compile-time (very limited), load-time, run-time (most flexible)
  - need translation tables
- contiguous allocation
  - simple, efficient
  - leads to external fragmentation

– base and limit registers

- segmentation
  – one contiguous area for each segment (area)
  – segment table
- paging
  – allocates memory in fixed-size chunks ⇒ internal fragmentation
  – virtual pages and physical frames
  – page tables and page table entries
  – page sharing, memory mapped files

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Practice: Memory Mng Related Questions

- Which is the size in bytes of a process' virtual address space on a system using 64 bits for a memory address?
- How may page table entries must be used by such a system to map a process VAS, supposing the page size to be 4MB?
- Illustrate on such a system the part of a process' VAS and page table (entries) used for mapping the memory required be the following code:

```
unsigned int *p = malloc(4*4*1024*1024);
printf("p=%u\n", p);      // displays p = 1000*4*1024*1024
```

- Which page does the following instruction refer to? Could it be executed successfully or not?

```
p[4*1024*1024] = 10;
```

10.15

Security Aspects

- untrusted application environment
  – untrusted PATH variable
- file system
  – too much permissions
  – path traversal
- memory-related: bad / wrong memory accesses
  – NULL-pointer usage
  – use-after free
  – buffer overflow

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2 Conclusions

2.1 Past

What did we talk about?

- OS's place and role (and definition), relative to hardware and other software
- OS structure
- Shell, i.e. command interpreter
- File System
- Process Management
- Memory Management
- Security Aspects

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What have we learned?

- basic concepts like
  - process, thread — execution, resources, isolation, scheduling
  - file: storage, sequence of bytes (no format), meta-data (i-node), links, fragmentation, open files
  - directory: organization, file tree, collection of directory entries
  - synchronization: locks (mutex), semaphores, condition variables, producers/consumers, readers/writers, barrier
  - memory: address space, virtual/physical memory addresses, ELF, paging
  - IPC mechanisms: pipes, shared memory
  - fragmentation: external (contiguous allocation, best-fit, worst-fit), internal
  - basic security issues: buffer overflow, path traversal
- system calls to access various OS (Linux) services
- write C programs to have access to Linux system calls

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What can we do?

- explain OS functionality and concepts
- understand better applications functionality, their relationship with the OS and some of their crash reasons
- write (if needed) C programs to access low-level OS services
- choose the appropriate OS for a particular purpose
- tune better an OS for particular applications/context/purposes

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2.2 Future

Will I need OS knowledge?

- all the time: understand, explain, evaluate, configure

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Will I use OS system calls?

- sometimes, especially when you need a particular (efficient, lower-level) functionality
- all the time, if you work at low-level (in C, asm)

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Operating System Design

- this is (our) next step: the advanced course (UTCN, CS Dept.) regarding OS
- what about: internals of an OS, design/implementation alternatives of
  - scheduling algorithms and synchronization mechanisms
  - user processes and threads
  - system calls for open files, processes and threads
  - memory management, virtual memory, page replacement algorithms
  - file system
- practical aspects: design, implement (in C) and test an OS (*HAL9000* — UTCN; *Pintos* — Stanford, USA); learn how to debug an OS on a remote virtual machine
- practical aspects: work in team (3 members)

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Operating System Design (cont.)

- usefulness
  - an OS is a complex management software; all the management algorithms and techniques work for many other complex management software even at higher levels
  - understanding low-level mechanisms makes you understand better higher-level ones' behavior
- it is an 4th year *optional subject*
- *students' myth*: (highly) difficult
- *reality (trust me)*: just interesting and challenging, not more difficult than other subjects/projects

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Operating System Design (cont.)

- I would like you to think like this:
  - "I'd choose this subject just because I am really interested in, it sounds great and challenging, I feel I need it in my future career, I want to understand how low-level mechanisms and aspects work, it fits my aptitudes and interests, I have heard about learning useful things etc."
- I would not like to hear about you saying:
  - "I DID NOT choose that subject just because I have a job and do not have enough time for it, I've heard it takes long(er) to solve the assignments, I've heard it is (more) difficult etc."

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Security Master Program (SISC)

- many OS-related courses
  - build low-level OS layers on the 64-bit architecture
  - kernel driver development
  - build virtualization security-oriented OS (hypervisor)
- many security-related aspects
  - secure coding
  - Web security
  - mobile systems (Android) security
  - big-data and security
  - penetration testing
  - risk management
  - cryptography

10.25

Finish

That's all folks! So long, folks!

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