CSGE602055 Operating Systems
CSF2600505 Sistem Operasi
Week 05: Virtual Memory

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`https://os.vlsm.org/`
Always check for the latest revision!

REV201 22-Apr-2019

Operating Systems 2019-1

A (Rm 3114) [Tu/Th 10-12] — B (Rm 3114) [Tu/Th 13-15] — C (Rm 3114) [Tu/Th 16-18] — D (Rm 2401) [Tu/Th 10-12] — E (Rm 2306) [Tu/Th 13-15]

Week	Schedule	Topic	OSC10
Week 00	07 Feb - 13 Feb 2019	Overview 1, Virtualization & Scripting	Ch. 1, 2, 18.
Week 01	14 Feb - 20 Feb 2019	Overview 2, Virtualization & Scripting	Ch. 1, 2, 18.
Week 02	21 Feb - 27 Feb 2019	Security, Protection, Privacy, & C-language	Ch. 16, 17
Week 03	28 Feb - 06 Mar 2019	File System & FUSE	Ch. 13, 14, 15
Week 04	12 Mar - 18 Mar 2019	Addressing, Shared Lib, & Pointer	Ch. 9
Week 05	19 Mar - 25 Mar 2019	Virtual Memory	Ch. 10
Mid-Term	Tue, 26 Mar 2019	13:00 - 15:30 — MidTerm (UTS)	
Week 06	02 Apr - 08 Apr 2019	Concurency: Processes & Threads	Ch. 3, 4
Week 07	09 Apr - 15 Apr 2019	Synchronization & Deadlock	Ch. 6, 7, 8
Week 08	16 Apr - 22 Apr 2019	Scheduling + W06/W07	Ch. 5
Week 09	23 Apr - 29 Apr 2019	Storage, BIOS, Loader, & Systemd	Ch. 11
Week 10	30 Apr - 06 May 2019	I/O & Programming	Ch. 12
Reserved	07 May - 17 May 2019		
Final	Tue, 21 May 2019	13:00 - 15:00 — Final (UAS)	This schedule is
Extra	27 Jun 2019	Extra assignment confirmation	subject to change.

STARTING POINT — https://os.vlsm.org/

- ☐ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018. See also http://codex.cs.yale.edu/avi/os-book/OS10/.
- ☐ **Weekly**
  - ☐ Encode your **QRC** with size about 5cm x 5cm (ca. 400x400 pixels): **"OS191 CLASS ID SSO-ACCOUNT Your-Full-Name"** Write your Memo (with QRC) **every week**.

    See also Assignment#0: Generate your QR Code.
  - ☐ Login to badak.cs.ui.ac.id via kawung.cs.ui.ac.id for at least **10 minutes** every week. Copy all weekly demo folders into your own badak home directory.

    Eg.: cp -r /extra/Demos/* ~/mydemos/
- ☐ **Resources**
  - ☐ **All In One** — BADAK.cs.ui.ac.id:///extra/ (**FASILKOM only!**).
  - ☐ **Download Slides and Demos from GitHub.com** https://github.com/UI-FASILKOM-OS/SistemOperasi/
  - ☐ **Problems** — https://rms46.vlsm.org/2/: 195.pdf (W00), 196.pdf (W01), 197.pdf (W02), 198.pdf (W03), 199.pdf (W04), 200.pdf (W05), 201.pdf (W06), 202.pdf (W07), 203.pdf (W08), 204.pdf (W09), 205.pdf (W10).

Week 05: Memory

Week 05 Virtual Memory: Topics[1]

- Review of physical memory and memory management hardware
- Virtual Memory
- Caching
- Memory Allocation
- Memory Performance
- Working sets and thrashing

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[1]Source: ACM IEEE CS Curricula 2013

- Explain memory hierarchy and cost-performance trade-offs. [Familiarity]
- Summarize the principles of virtual memory as applied to caching and paging. [Familiarity]
- Describe the reason for and use of cache memory (performance and proximity, different dimension of how caches complicate isolation and VM abstraction). [Familiarity]
- Defend the different ways of allocating memory to tasks, citing the relative merits of each. [Assessment]
- Evaluate the trade-offs in terms of memory size (main memory, cache memory, auxiliary memory) and processor speed. [Assessment]
- Discuss the concept of thrashing, both in terms of the reasons it occurs and the techniques used to recognize and manage the problem. [Familiarity]

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[1]Source: ACM IEEE CS Curricula 2013

Virtual Memory

- Reference: (OSC10-ch10 demo-w05)
- Virtual Memory: Separation Logical from Physical.
- Virtual Address Space: logical view.
- Demand Paging
- Page Flags: Valid / Invalid
- Page Fault
- Demand Paging Performance
- Copy On Write (COW)
- Page Replacement Algorithm
  - Reference String
  - First-In-First-Out (FIFO)
  - Belady Anomaly
  - Optimal Algorithm
  - Least Recently Used (LRU)
  - LRU Implementation
  - Lease Frequently Used (LFU)
  - Most Frequently Used (MFU)

Allocation Algorothm

- Page-Buffering Algorithms
- Allocation of Frames
- Fixed Allocation
- Priority Allocation
- Global vs. Local Allocation
- Non-Uniform Memory Access (NUMA)
- Thrashing
- Working-Set Model
- Shared Memory via Memory-Mapped I/O
- Kernel
    - Buddy System Allocator
    - Slab Allocator

TOP

Figure: top

TOP (2)

Figure: "h" = help

TOP (3)

Figure: Moving Fields: "f"

TOP (4)

Figure: Moving Fields

TOP (5)

Figure: Write Configuration .toprc: "W"

```
/* Copyright (C) 2016-2018 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 * REV04 Mon Mar 12 17:33:30 WIB 2018
 * START Mon Oct  3 09:26:51 WIB 2016
 */
#define MSIZE0 0x10000
#define MSIZE1 0x10008
#define MSIZE2 0x10009
#define MSIZE3 0x1000A
#define MSIZE4 0x20978
#define MSIZE5 0x20979
#define MSIZE6 0x2097A
#define MSIZE7 0xF0000
#define MSIZE8 0x10000
#define MSIZE9 0x1000
#define LINE    75
#define MAXSTR 80
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <string.h>
#include <sys/types.h>

void printLine(int line) {
    while(line-- > 0) putchar('x');
    putchar('\n');
    fflush(NULL);
}
```

```
void main (void) {
    int   msize[] = {MSIZE0, MSIZE1, MSIZE2, MSIZE3, MSIZE4,
                     MSIZE5, MSIZE6, MSIZE7, MSIZE8, MSIZE9};
    int   ii, jj;
    int   myPID  = (int) getpid();
    char  strSYS1[MAXSTR], strOUT[MAXSTR];
    char* chrStr  = strSYS1;
    char* chrPTR;

    printLine(LINE);
    sprintf(strSYS1, "top -b -n 1 -p%d | tail -5", myPID);
    system (strSYS1);
    sprintf(strSYS1, "top -b -n 1 -p%d | tail -1", myPID);
    for (ii=0; ii< (sizeof(msize)/sizeof(int)); ii++){
        chrStr = malloc(msize[ii]);
        fgets(strOUT, sizeof(strOUT)-1, popen(strSYS1, "r"));
        strOUT[(int) strlen(strOUT)-1]='\0';
        printf("%s [%X]\n", strOUT, msize[ii]);
        free(chrStr);
    }
    for (ii=0; ii< (sizeof(msize)/sizeof(int)); ii++){
        chrPTR = chrStr = malloc(msize[ii]);
        for (jj=0;jj<msize[ii];jj++)
            *chrPTR++='x';
        fgets(strOUT, sizeof(strOUT)-1, popen(strSYS1, "r"));
        strOUT[(int) strlen(strOUT)-1]='\0';
        printf("%s [%X]\n", strOUT, msize[ii]);
        free(chrStr);
    }
}
```

```
>>>>> $ ./06-memory
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
KiB Mem:   8197060 total,   957928 used,  7239132 free,    192520 buffers
KiB Swap:   683004 total,        0 used,   683004 free.   660108 cached
    Mem

  PID    VIRT    RES    SHR   SWAP   CODE    DATA   USED nDRT
 4362    4172    640    564      0      4     320    640    0
 4362    4172    640    564      0      4     320    640    0 [10000]
 4362    4172    640    564      0      4     320    640    0 [10008]
 4362    4308    640    564      0      4     456    640    0 [10009]
 4362    4244   1176   1068      0      4     392   1176    0 [1000A]
 4362    4244   1176   1068      0      4     392   1176    0 [20978]
 4362    4376   1176   1068      0      4     524   1176    0 [20979]
 4362    4376   1192   1068      0      4     524   1192    0 [2097A]
 4362    5340   1192   1068      0      4    1488   1192    0 [F0000]
 4362    4376   1200   1068      0      4     524   1200    0 [10000]
 4362    4376   1200   1068      0      4     524   1200    0 [1000]
```

```
4362    4376    1200    1068    0    4     524    1200    0 [1000]
4362    4376    1200    1068    0    4     524    1200    0 [10000]
4362    4376    1276    1068    0    4     524    1276    0 [10008]
4362    4376    1276    1068    0    4     524    1276    0 [10009]
4362    4376    1284    1068    0    4     524    1284    0 [1000A]
4362    4376    1284    1068    0    4     524    1284    0 [20978]
4362    4376    1352    1068    0    4     524    1352    0 [20979]
4362    4376    1352    1068    0    4     524    1352    0 [2097A]
4362    5340    2144    1068    0    4    1488    2144    0 [F0000]
4362    5340    2324    1068    0    4    1488    2324    0 [10000]
4362    5340    2324    1068    0    4    1488    2324    0 [1000]
>>>>> $
```

The End

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