CSGE602055 Operating Systems
CSF2600505 Sistem Operasi
Week 05: Virtual Memory

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

REV189 07-Feb-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	23-30 Mar 2019 (tba)	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	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	18-25 May 2019 (tba)	Final (UAS)	This schedule is subject to change.
Extra	27 Jun 2019	Extra assignment confirmation	

The Weekly Check List

- **Resources**: `https://os.vlsm.org/`
  - **(THIS) Slides** — `https://github.com/UI-FASILKOM-OS/SistemOperasi/tree/master/pdf/`
  - **Demos** — `https://github.com/UI-FASILKOM-OS/SistemOperasi/tree/master/demos/`
  - **Extra** — `BADAK.cs.ui.ac.id:///extra/`
  - **Problems** — `https://rms46.vlsm.org/2/`: `195.pdf` (Week 00), `196.pdf` (Week 01), `197.pdf` (Week 02), `198.pdf` (Week 03), `199.pdf` (Week 04), `200.pdf` (Week 05), `201.pdf` (Week 06), `202.pdf` (Week 07), `203.pdf` (Week 08), `204.pdf` (Week 09), `205.pdf` (Week 10).
- **Text Book**: any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10^{th} Edition, 2018.
- Encode your **QRC** with size upto 7cm x 7cm (ca. 400x400 pixels): **"OS182 CLASS ID SSO-ACCOUNT Your-Full-Name"**
- Write your Memo (with QRC) **every week**.
- Login to `badak.cs.ui.ac.id` via `kawung.cs.ui.ac.id` for at least **10 minutes** every week. Copy the weekly demo files to your own home directory.
  Eg. (Week00): `cp -r /extra/Week00/W00-demos/ W00-demos/`

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

[1] Source: ACM IEEE CS Curricula 2013

Week 05 Virtual Memory: Learning Outcomes[1]

- 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]

[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

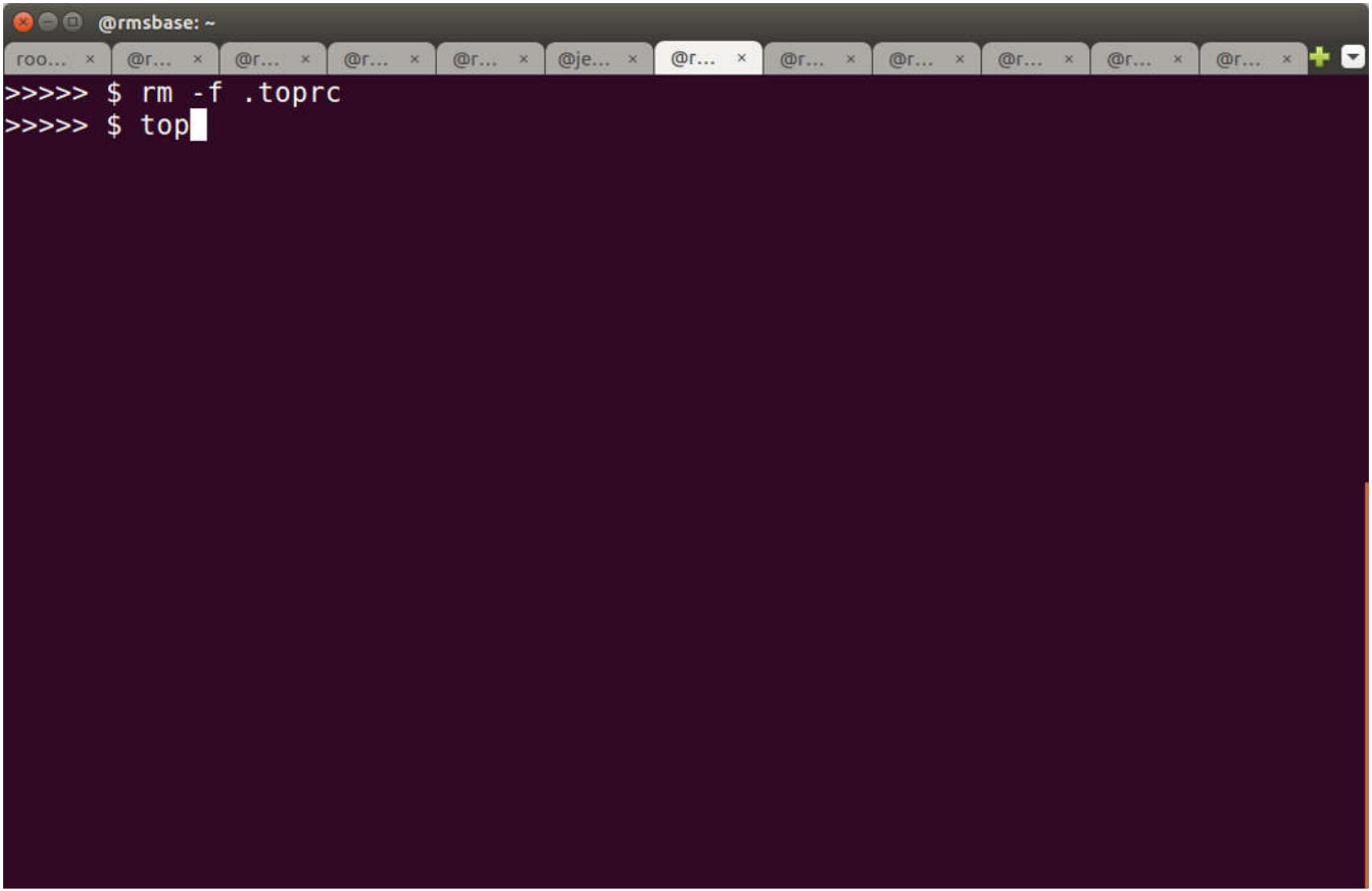

Figure: top

TOP (2)

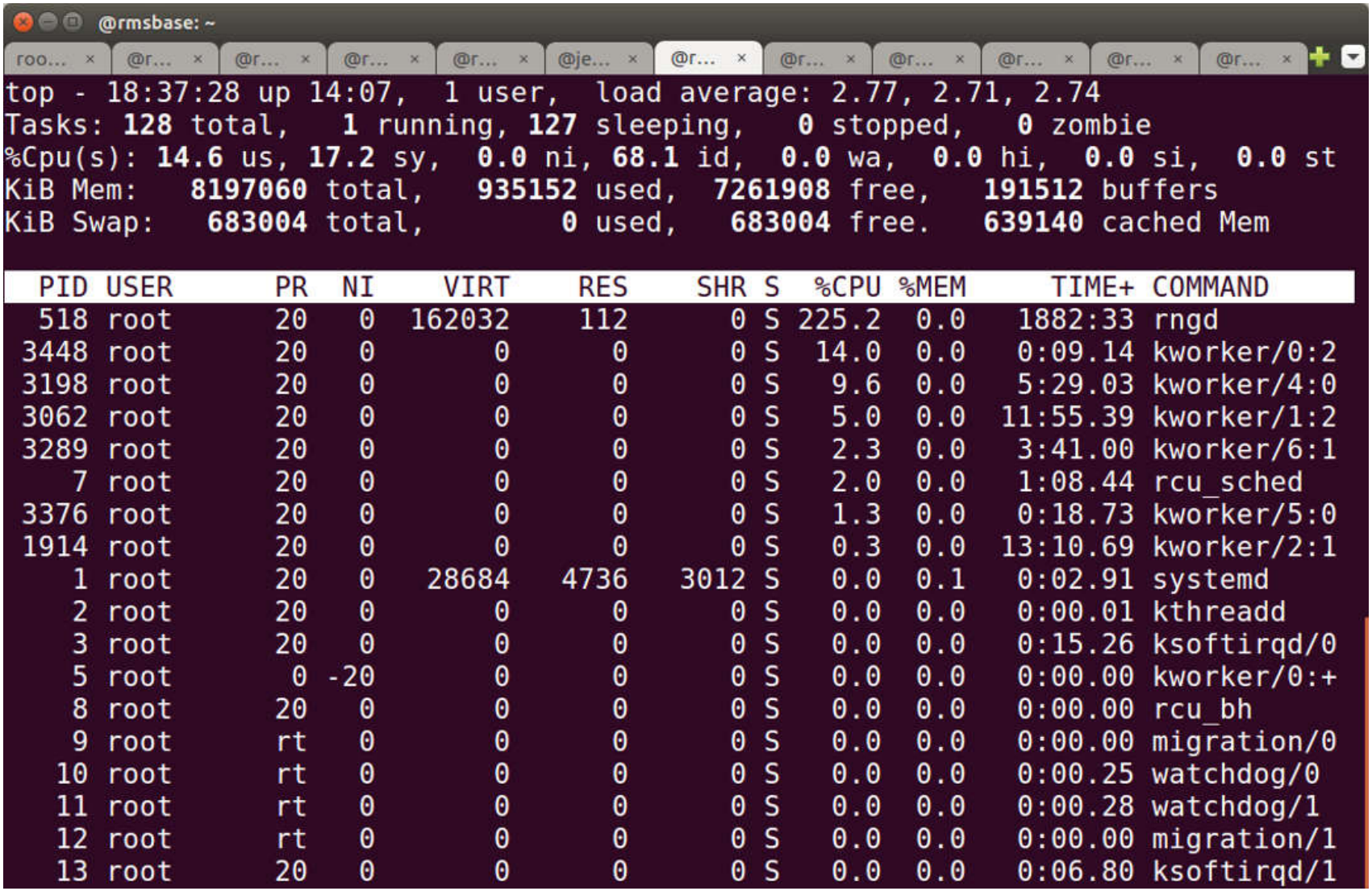

Figure: "h" = help

TOP (3)

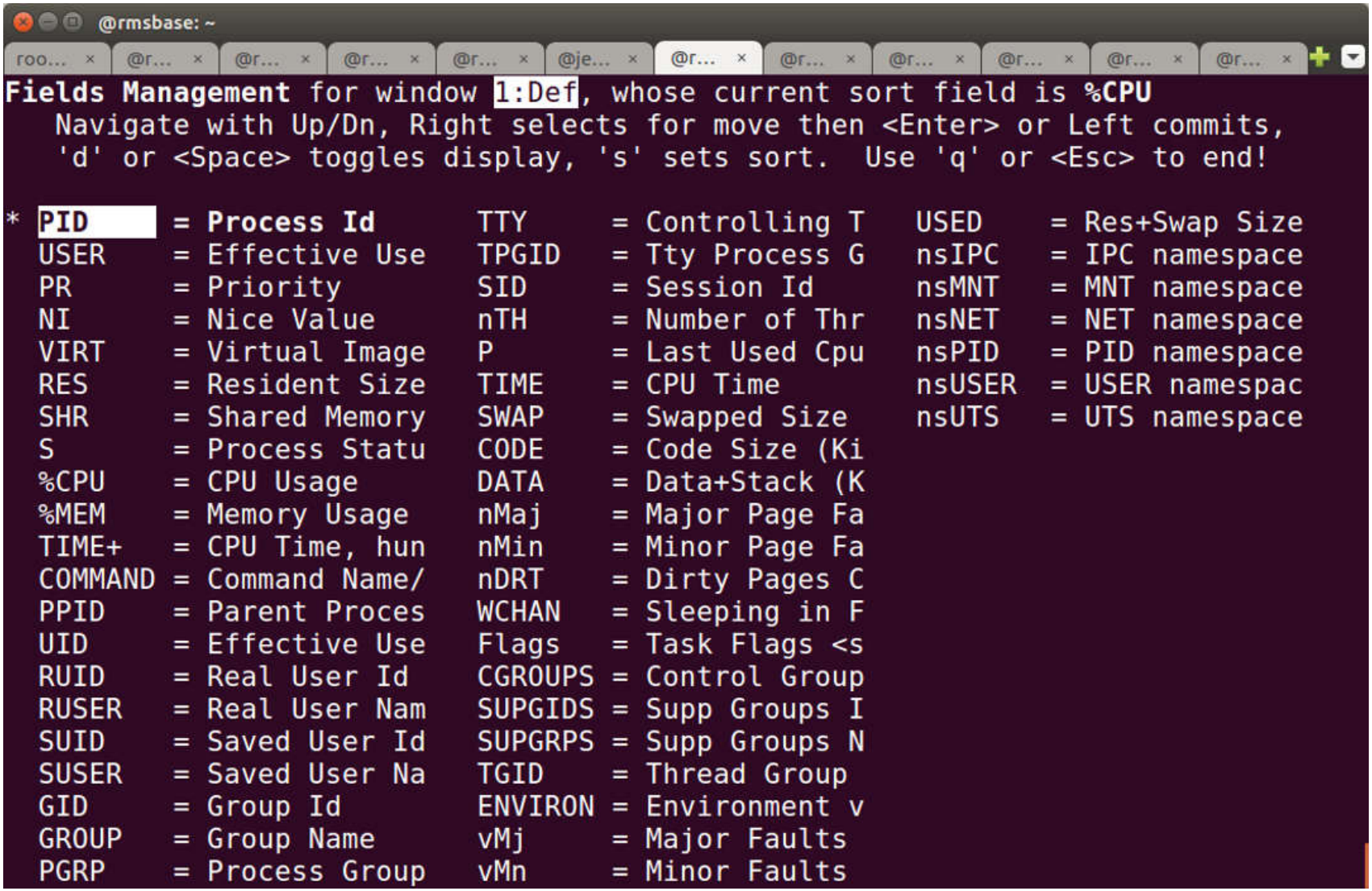

Figure: Moving Fields: "f"

TOP (4)

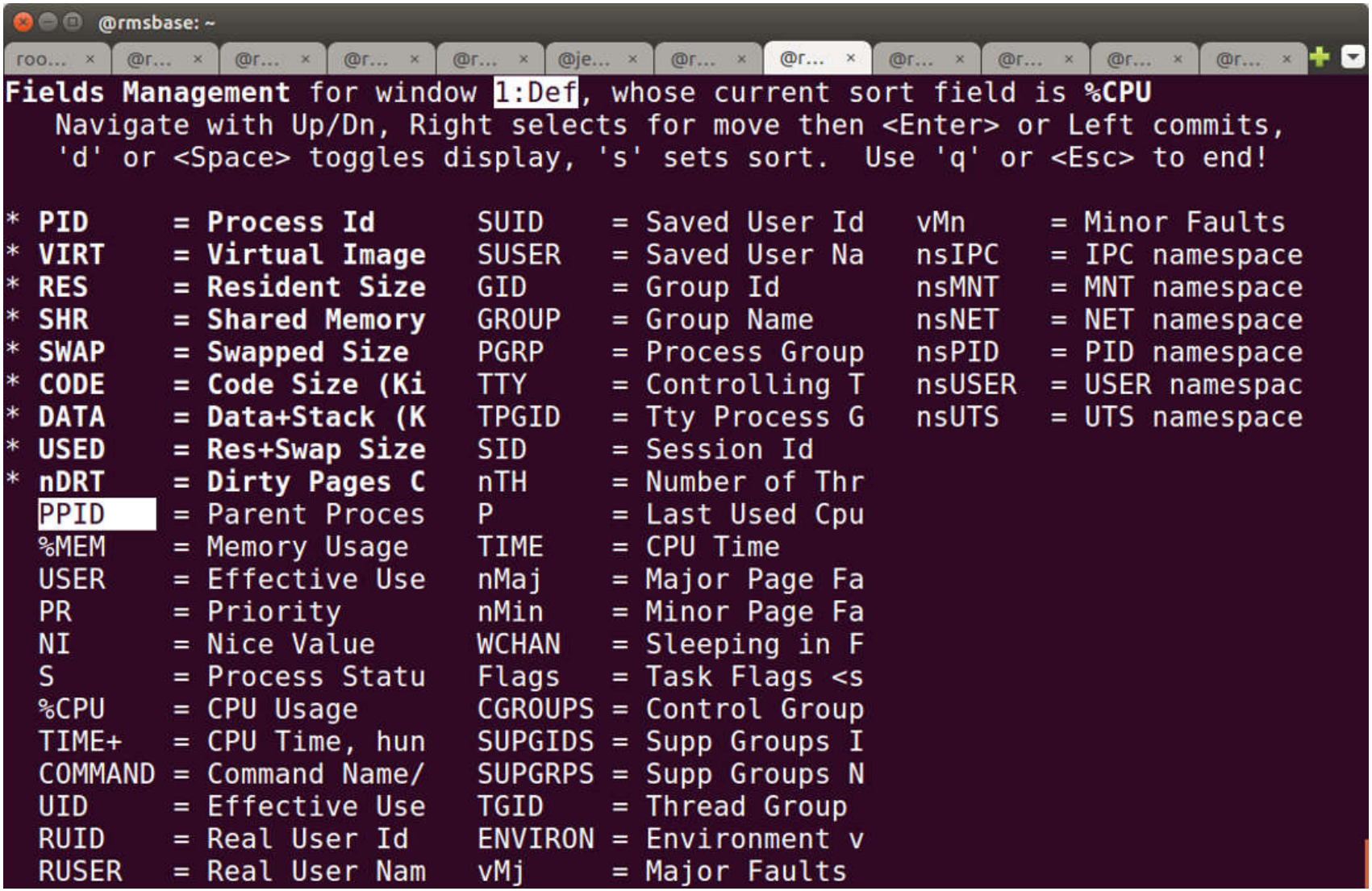

Figure: Moving Fields

TOP (5)

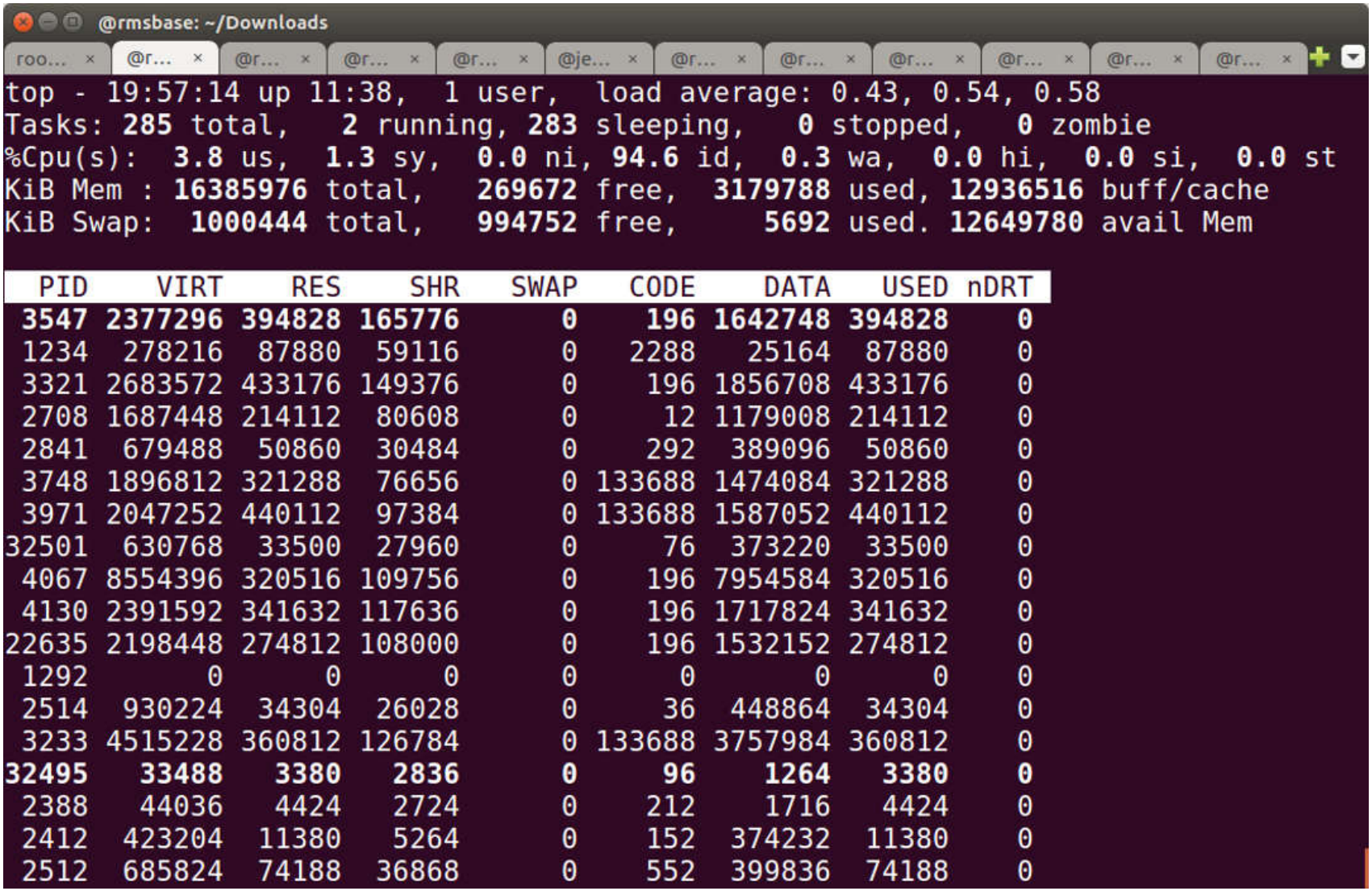

Figure: Write Configuration .toprc: "W"

06-memory

```
/* 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);
}
```

06-memory (2)

```
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 (2)

```
>>>>> $ ./06-memory
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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]
```

06-memory (3)

```
 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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