

# SYSTEM PROGRAMMING

## WEEK 1: INTRODUCTION TO SYSTEM PROGRAMMING

---

Seongjin Lee

Updated: 2016-09-07

01-intro

[insight@hanyang.ac.kr](mailto:insight@hanyang.ac.kr)

<http://esos.hanyang.ac.kr>

Esos Lab. Hanyang University

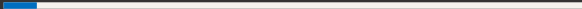


# Table of contents

1. Nutshell
2. History
3. The UNIX Basics
4. The Editors
  - 4.1 Vim
  - 4.2 Emacs



# NUTSHELL





Ken Thompson and Dennis Ritchie at PDP-11 in 1971 (Photo: Courtesy of Bell Labs)



# What we are going to learn

- Familiarize with UNIX
- Experience systems programming
- Understand fundamental OS concepts
  - Multi-user concepts
  - Basic and advanced I/O
  - Process
  - Interprocess communication



# Why do we have to?

- UNIX gives you insights on how other OS works
- You can only catch the tiger by going into the tiger's den
- It is the basis for most other programming and understanding of the system
- It in C helps you understand the general programming concepts



# How are going to do?

```
1  /*
2   * welcome file
3   */
4
5  #include <stdio.h>
6  #include <unistd.h>
7
8  int
9  main(int argc, char **argv) {
10     printf("Welcome to System Programming, %s!\n", getlogin());
11 }
```

## How to compile

\$ cc -Wall -g -o welcome welcome.c



# Errors and Warnings

```
1  $ gcc -Wall -g -o welcome welcome.c
2  welcome.c:6:81: warning: implicit declaration of function 'getlogin'
3      is invalid in C99 [-Wimplicit-function-declaration]
4      printf("Welcome to System Programming, %s!\n", getlogin())
5                                          ^
6  welcome.c:6:81: warning: format specifies type 'char *' but the
7      argument has type 'int' [-Wformat]
8      printf("Welcome to System Programming, %s!\n", getlogin())
9                                          ~~      ^~~~~~
10                                         %d
11  welcome.c:6:92: error: expected ';' after expression
12      printf("Welcome to System Programming, %s!\n", getlogin())
13                                                         ^
14                                                         ;
15  2 warnings and 1 error generated.
```





# About this class

## Textbook

- “Advanced Programming in the UNIX Environment”, by W. Richard Stevens, Stephen A. Rago (3rd Edition)

## Assistant

- Yeonjin Noh (nygo813@gmail.com)
- FTC #804

## Grading:

- Attendance 5%
- Assignments 30%
- Quiz 5%
- Midterm Exam 30%
- Final Exam 30%
- Level test on editors



# Syllabus

Week 1 09-07 Introduction to system  
programming & Shell Survival  
Kit

Week 2 09-14 (추석)

Week 3 09-21 Files IO & ctag/etag

Week 4 09-28 Files and Directories

Week 5 10-05 Standard I/O Library

Week 6 10-12 Process Environment

Week 7 10-19 Process Control

Week 8 10-26 (중간고사)

Week 9 11-02 Signals

Week 10 11-09 Threads

Week 11 11-16 Thread Control

Week 12 11-23 Advanced I/O

Week 13 11-30 Interprocess  
Communication I

Week 14 12-07 Interprocess  
Communication II

Week 15 12-14 Network IPC Week 16  
12-21 (기말고사)



# HISTORY

---

# The UNIX History

For more info : [http://www.unix.org/what\\_is\\_unix/history\\_timeline.html](http://www.unix.org/what_is_unix/history_timeline.html)

- Originally developed in 1969 at Bell Labs by Ken Thompson and Dennis Ritchie.
- 1973, Rewritten in C. This made it portable and changed the history of OS
- 1974: Thompson, Joy, Haley and students at Berkeley develop the **Berkeley Software Distribution (BSD)** of UNIX
- two main directions emerge: BSD and what was to become "System V"



# UNIX History

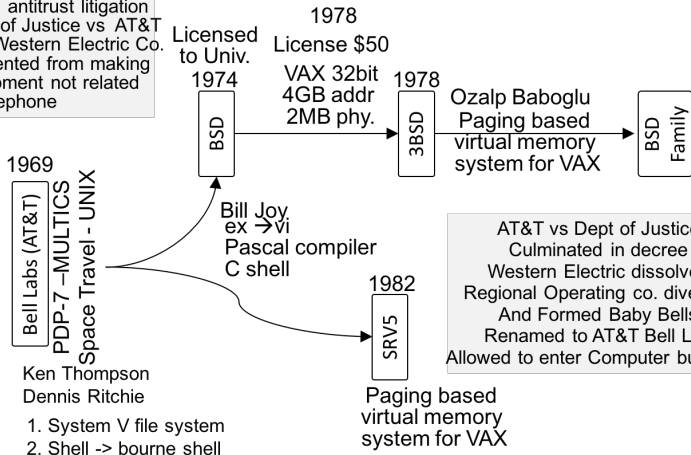
- 1984 4.2BSD released (TCP/IP)
- 1986 4.3BSD released (NFS)
- 1991 Linus Torvalds starts working on the Linux kernel
- 1993 Settlement of USL vs. BSDi; NetBSD, then FreeBSD are created
- 1994 Single UNIX Specification introduced
- 1995 4.4BSD-Lite Release 2 (last CSRG release); OpenBSD forked off NetBSD
- 2000 Darwin created (derived from NeXT, FreeBSD, NetBSD)
- 2003 Xen; SELinux
- 2005 Hadoop; DTrace; ZFS; Solaris Containers
- 2006 AWS ("Cloud Computing" comes full circle)
- 2007 iOS; KVM appears in Linux
- 2008 Android; Solaris open sourced as OpenSolaris

list from [www.cs.stevens.edu/~jschauma/631A/](http://www.cs.stevens.edu/~jschauma/631A/)



# History

1956, antitrust litigation  
Dept of Justice vs AT&T  
and Western Electric Co.  
Prevented from making  
Equipment not related  
to telephone



Ken Thompson  
Dennis Ritchie

1. System V file system
2. Shell → bourne shell

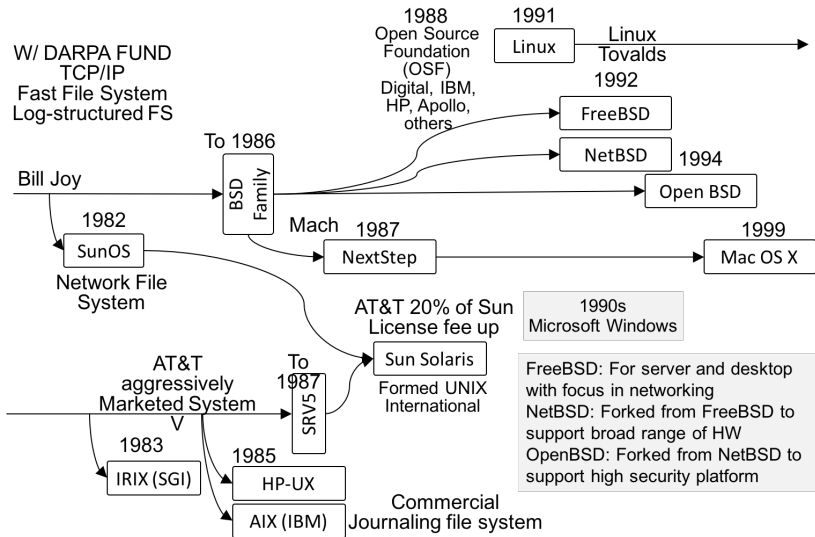
1971 Nov. R&T – UNIX programmer's Manual

1973 Feb. UNIX v3 included cc – rewritten in C

1973 Oct. ACM SOSP – The UNIX Time Sharing System



# History



# Some UNIX Versions

## More UNIX (some generic, some trademark, some just unix-like):

1BSD	2BSD	3BSD	4BSD	4.4BSD Lite 1
4.4BSD Lite 2	386 BSD	A/UX	Acorn RISC iX	AIX
AIX PS/2	AIX/370	AIX/6000	AIX/ESA	AIX/RT
AMiX	AOS Lite	AOS Reno	ArchBSD	ASV
Atari Unix	BOS	BRL Unix	BSD Net/1	BSD Net/2
BSD/386	BSD/OS	CB Unix	Chorus	Chorus/MiX
Coherent	CTIX	Darwin	Debian GNU/Hurd	DEC OSF/1 ACP
Digital Unix	DragonFly BSD	Dynix	Dynix/ptx	ekkoBSD
FreeBSD	GNU	GNU-Darwin	HPBSD	HP-UX
HP-UX BLS	IBM AOS	IBM IX/370	Interactive 386/ix	Interactive IS
IRIX	Linux	Lites	LSX	Mac OS X
Mac OS X Server	Mach	MERT	MicroBSD	Mini Unix
Minix	Minix-VMD	MIPS OS	MirBSD	Mk Linux
Monterey	more/BSD	mt Xinu	MVS/ESA OpenEdition	NetBSD
NeXTSTEP	NonStop-UX	Open Desktop	Open UNIX	OpenBSD
OpenServer	OPENSTEP	OS/390 OpenEdition	OS/390 Unix	OSF/1
PC/IX	Plan 9	PWB	PWB/UNIX	QNX
QNX RTOS	QNX/Neutrino	QUNIX	ReliantUnix	Rhapsody
RISC iX	RT	SCO UNIX	SCO UnixWare	SCO Xenix
SCO Xenix System V/386	Security-Enhanced Linux	Sinix	Sinix ReliantUnix	Solaris
SPIX	SunOS	Tru64 Unix	Trusted IRIX/B	Trusted Solaris
Trusted Xenix	TS	UCLA Locus	UCLA Secure Unix	Ultrix
Ultrix 32M	Ultrix-11	Unicos	Unicos/mk	Unicox-max
UNICS	UNIX 32V	UNIX Interactive	UNIX System III	UNIX System IV
UNIX System V	UNIX System V Release 2	UNIX System V Release 3	UNIX System V Release 4	UNIX System V/286
UNIX System V/386	UNIX Time-Sharing System	UnixWare	UNSW	USG
Venix	Wollogong	Xenix OS	Xinu	xMach

adopted from <http://www.cs.stevens.edu/~jschauma/631A/>

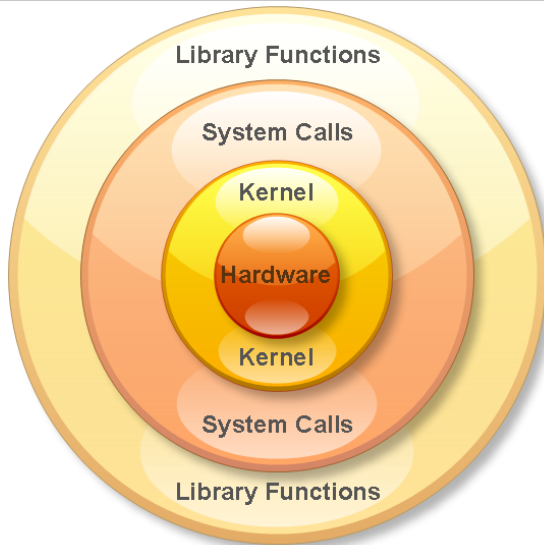




# THE UNIX BASICS

---

# The UNIX Basics: Architecture



applications > shell



# System Calls and Library Calls

## System calls

They are entry points into kernel code where their functions are implemented. Documented in section 2 of the manual (e.g. `write(2)` or `$man 2 write`).

## Library Calls

They are transfers to user code which performs the desired functions. Documented in section 3 of the manual (e.g. `printf(3)`).



# Error Handling: ANSI C

## ○ Important ANSI C Features:

- function prototypes
- generic pointers (void \*)
- abstract data types (e.g. pid\_t, size\_t)

## ○ Error Handling:

- meaningful return values
- errno variable
- look up constant error values via two functions:

```
1 #include <string.h>
2 char *strerror(int errnum) // returns pointer to message string
```

```
1 #include <stdio.h>
2 void perror(const char *msg)
```



# Principles

[https://en.wikipedia.org/wiki/Unix\\_philosophy](https://en.wikipedia.org/wiki/Unix_philosophy)

- Small is beautiful.
- Make each program do one thing well.
- Build a prototype as soon as possible.
- Choose portability over efficiency.
- Store data in flat text files.
- Use software leverage to your advantage.
- Use shell scripts to increase leverage and portability.
- Avoid captive user interfaces.
- Make every program a filter.



## THE EDITORS

---

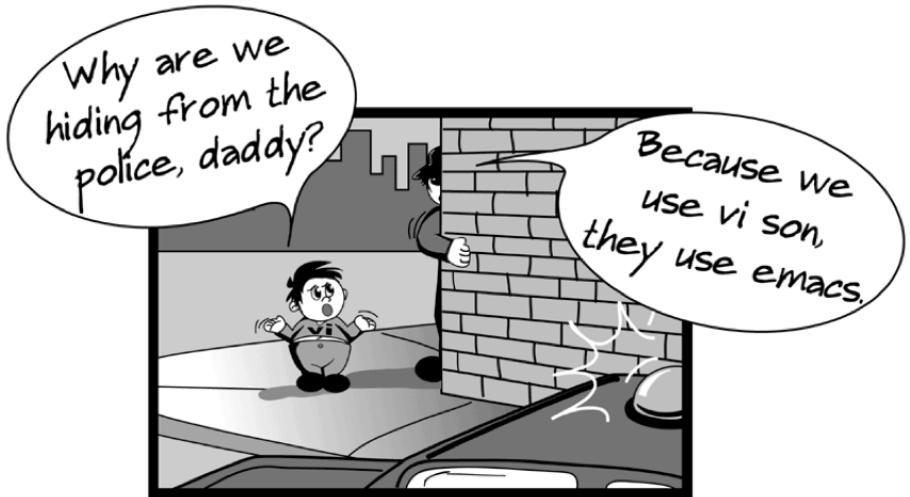


Image from [http://michael-prokop.at/computer/tools\\_vim\\_en.html](http://michael-prokop.at/computer/tools_vim_en.html)



# What is Vi(m)

**Vi** is a visual screen text editor developed by Bill Joy, who later becomes co-founder of Sun Micro Systems

- It is visual version of **ex**, a Unix line editor
- Vi is available on most Unix Systems
- Works with a variety of terminals
- Allows **ex** command from **vi**



*"I got tired of people complaining that it was too hard to use UNIX because the editor was too complicated."*

*Bill Joy*





# What is Vim

VIM is acronym for **Vi** **iM**proved, developed by Bram Moolenaar, a extended version of vi and some of enhancements include

- Completion, comparison, and merging of files
- Split and tabbed windows
- Command histories



All editing session before saving is done in buffer area

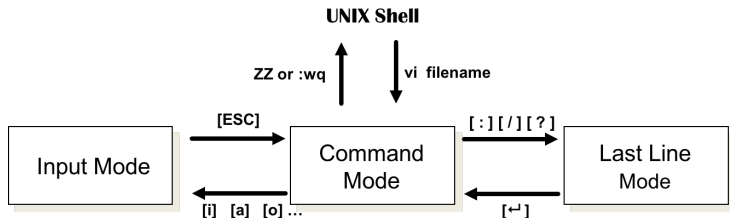
- Nothing is saved as hard data, until you save it



# Modes of vi

There are three mode in vi

- **Command Mode** – A default mode in vi
  - Everything is command before you enter into other modes
- **Input Mode** – What you type is what you see
  - Anything typed in this mode is considered as data
  - Pressing [ESC] always leads to Command mode
- **Last Line Mode** – Only can be accessed from Command mode
  - Three ways to enter Last Line Mode – : (Colon) / (Back Slash) ? (Question Mark)



# Moving Around

VI uses four characters to move around, and each character is mapped to a direction



Moving by units of word, sentence, paragraph

- E.g., 3w moves to three words after the current cursor



next word



previous word



Beginning of sentence



end of sentence



Beginning of paragraph



end of paragraph



# Deleting

Deleting a character, words, sentence, line, and paragraph

- `x` erases a character
- Combination of direction commands with `d` erases a word, sentence, and paragraph.
  - E.g., `dw` erases a word before the cursor
- `dd` erases a line
- `D` to delete rest of line
- `X` to delete before the cursor
- `Xp` to transpose



# Searching and Replacing

Searching in vi is done in last line mode

- **/** lets you search a character, word, and words
  - E.g., **/abc** moves the cursor to the location of the pattern
- Search pattern in forward direction: **n**, backward direction: **keystrokeN**
- Regular expressions can be also used in searching

**r** replaces a character

- Suppose the cursor is on **b**, and by **r** **p** we can change it to “preview”

breview → preview



## Substituting in vi is done in last line mode

Find i and substitute with X once

<code>:s/i/X</code>	→	This is preview.	→	ThXs is preview.
		How it is done		How it is done

Find i and substitute with X in the same line


<code>:s/i/X/g</code>	→	This is preview.	→	ThXs is prevXew.
		How it is done		How it is done



Find i and substitute with X in all the lines

<code>:%s/i/X/g</code>	→	This is preview.	→	ThXs is prevXew.
		How it is done		How Xt Xs done




# Undo and Redo

Undo in vi is done by 

- Or to do in last line mode you could type in 
-  undo all latest changes on one line

Redo in vi is done by  

- Or to do in last line mode you could type in 



# Simple Tutorial: From Start to quit

This simple tutorial illustrates how to write, delete, copy, paste, replace, save, and quit. Start vi by `vi newfile.txt` and type the following

i This is how we write `esc` o and copy lines `esc` k y y j  
p k y 3 w j ) a space bar `esc` p o ummm `esc` b  
x r E l r N l r D : w q `enter`

This will produce following and goes back to command prompt

```
and copy lines
This is how we write and copy lines
END
```





# Simple Tutorial: From Start to quit

i This is how we write `esc` o and copy lines `esc` k y y j  
p k y 3 w j ) a space bar `esc` p o ummm `esc` b  
x r E l r N l r D : w q enter

## The command in the tutorial

i insert `esc` back to command mode o add new line after  
current line k move cursor up yy copy a line j move cursor  
down p paste after cursor point y3w copy three words ) move to  
end of sentence a append b move cursor to previous word x  
erase a character r replace a character l move cursor right :wq  
write to a file and quit



# Learn by experience

```
1 The five boxing wizards jump quickly.  
2 See the quick brown fox jump over the lazy dog.  
3 A mad boxer shot a quick, gloved jab to the jaw of his dizzy opponent.  
4 We promptly judged antique ivory buckles for the next prize.  
5 A quart jar of oil mixed with zinc oxide makes a very bright paint.  
6 The job requires extra pluck and zeal from every young wage earner.
```

Complete all tasks with minimum number of retyping, but with commands

- Substitute all j's to z and all z's to j
- Copy lines 1, 3, 5, and 6, and make new paragraph with those lines
- Delete three words "requires extra pluck," and type in "need lot of money" in the place
- Add "caps" at the end of all words with "w", e.g., wizards to "wizardscaps"



# Vi Configurations

Place `.vimrc` to your home direcotry

Have a look at the sample file

https:

[//github.com/resourceful/lecture\\_sysprog/blob/master/01-intro/misc/.vimrc](https://github.com/resourceful/lecture_sysprog/blob/master/01-intro/misc/.vimrc)



# References

## Graphical cheat sheet of Vi and VIM

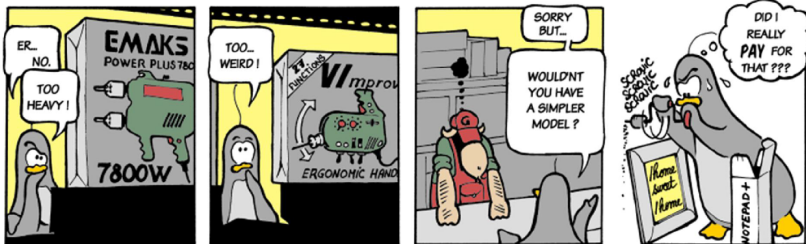
- [http://www.viemu.com/a\\_vi\\_vim\\_graphical\\_cheat\\_sheet\\_tutorial.html](http://www.viemu.com/a_vi_vim_graphical_cheat_sheet_tutorial.html)

## Cursor movement Commands

- <http://www.kcomputing.com/vi.html>

## List of Commands

- <http://www.smashingmagazine.com/2010/05/03/vi-editor-linux-terminal-cheat-sheet-pdf/>





# What is Emacs

Emacs (Editor MACroS) is the extensible, customizable, self-documenting, real-time display editor

Richard Stallman is the author of Emacs; the author of GCC and GDB

Runs on LISP engines + lots of LISP libraries



**Richard Stallman**  
**The founder of GNU**

<http://www.theregister.co.uk/>



# What is Emacs and why use it? (cont'd)

It is not the only good choice, there are options like VI, VIM Works on many platforms and independent of GUI

Extremely powerful

vi often does things with fewer keystrokes, but emacs easily surpass vi when it comes to searching and replacing and using macros



# What is Emacs and why use it? (cont'd)

Some of assumptions of Emacs are

- No mouse! – Much more reliable and much faster for experienced user
- No particular keyboard; No particular GUI environment
- Runs through telnet (as well as directly)





emac@like-DAVID

File Edit Options **Buffers** Tools Help

temp -- (/home/james/  
 \*scratch\*  
 \*Messages\* \*  
 \*GNU Emacs\* %  
 \*Buffer List\* %

Next Buffer C-x <C-right>  
 Previous Buffer C-x <C-left>  
 Select Named Buffer... C-x b  
 List All Buffers C-x C-b

Shortcut key

Pop up a window listing all Emacs buffers

Edit modes  
 -Not modified  
 ★ modified  
 % read-only

Buffer Name

WINDOWS

Window Display position

Line Number

Buffer major/minor

MODE name

Modeline

MINIBUFFER

CRM	Buffer	Size	Mode	File
	temp	0	Fundamental	~/temp
	*scratch*	191	Lisp Interaction	
	* *Messages*	1428	Fundamental	
	% *GNU Emacs*	679	Fundamental	
















-U:-- temp All 1 (Fundamental Ovrwt)-----




-U:%%- \*Buffer List\* All 11 (Buffer Menu)-----



# Emacs Preliminaries

In the emacs documentation, key sequences described as:

- C-e – This is -
- C-x C-b – This is - -
- $\wedge$ b - this is -
- C-x b – This is - 
- M-e – This is - or -

On the PC, you can use the  key or -release to substitute  key

When you press a valid key sequence, emacs executes a command associated with the key



# Moving Around

Emacs uses the control keys to move in the four directions



To move by units of word, sentence, and paragraph



# Deleting

Delete a word, line, and sentence

**Ctrl** - **d** Delete a character   **Meta** - **d** Delete a word   **Ctrl** - **k** Delete a line  
**Meta** - **k** Delete a sentence

## When in Doubt

Use “GET ME OUT OF HERE” command **Ctrl** - **g**



# Searching

- asks for search pattern

- - to search next pattern

- - to search previous pattern

- Regular expressions can be also used in searching with -









# Substitution

`Meta` - `%` to replace or `Meta` -replace-string

- Requests for search pattern; press enter for substituting pattern
- Replacing the substituting pattern this once `SPC`
- Skipping to the next without replcacing `DEL`
- Replace all remaining matches `!`
- Exiting replace command by `RET`



# Undo and Redo

Undo an unwanted change is done by  -  Redo is reverse of undo,  
undo direction is reversed by  -  and  - 



Macros are useful for repeatable key sequences that may be include commands.

## Common macro commands

- `Ctrl-x` - `(` – begin macro definition (after this, type whatever actions you would like repeated and stored)
- `Ctrl-x` - `)` – end macro definition
- `Ctrl-x` - `e` – execute stored macro
- `Ctrl-u5` `Ctrl-e` – execute stored macro 5 times (Note: `Ctrl-u5` can prefix any emacs cmd, even a non-cmd)





# Simple Tutorial: From Start to quit

One can type without having to use complex commands but ....

This is how we write

Ctrl - a  
Ctrl - qj  
Ctrl - u3  
Return  
Ctrl - x-s

ummm

Ctrl - spc  
Ctrl - y  
Meta - f  
Ctrl - x-c

Ctrl - qj

Ctrl - e

Ctrl - p

Meta - w

Ctrl - a

and copy lines

Meta - w

Ctrl - a

Meta - }

Ctrl - u4

SPC

Ctrl - d

Ctrl - p

Meta - }

Ctrl - SPC

Ctrl - y

END

This will produce following and goes back to command prompt

and copy lines

This is how we write and copy lines

END



# Simple Tutorial: From Start to quit

This is how we write

Ctrl - spc  
Ctrl - p  
Meta - }  
Ctrl - d

Ctrl - e  
Ctrl - a  
SPC  
END

Ctrl - qj  
Meta - w  
Ctrl - SPC  
Return  
Ctrl - y  
Ctrl - x-s

and copy lines

Meta - }  
Ctrl - u3  
ummm  
Ctrl - x-c

Ctrl - p  
Ctrl - qj  
Meta - f  
Ctrl - a

Ctrl - a  
Ctrl - y  
Meta - w  
Ctrl - u4

## Explaining the commands in the tutorial

Ctrl - qj Add a new line   Ctrl - p Move to previous line   Ctrl - a Move to beginning of the sentence   Ctrl - spc Start highlighting   Ctrl - e Move to end of sentence   Meta - w Copy highlighted   Meta - } Move to end of the paragraph   Ctrl - y Paste copied text   Ctrl - u3 Repeat command with following number   Meta - f Move to next word   Ctrl - d Delete a character   Ctrl - x-s Save the document   Ctrl - x-c Quit



# Learn by experience

```
1 The five boxing wizards jump quickly.  
2 See the quick brown fox jump over the lazy dog.  
3 A mad boxer shot a quick, gloved jab to the jaw of his dizzy opponent.  
4 We promptly judged antique ivory buckles for the next prize.  
5 A quart jar of oil mixed with zinc oxide makes a very bright paint.  
6 The job requires extra pluck and zeal from every young wage earner.
```

Complete all tasks with minimum number of retyping, but with commands

- Substitute all j's to z and all z's to j
- Copy lines 1, 3, 5, and 6, and make new paragraph with those lines
- Delete three words "requires extra pluck," and type in "need lot of money" in the place
- Add "caps" at the end of all words with "w", e.g., wizards to "wizardscaps"



# emacs Configurations

Place .emacs to your home direcotry

Have a look at the sample file

https:

[//github.com/resourceful/lecture\\_sysprog/blob/master/01-intro/misc/.emacs](https://github.com/resourceful/lecture_sysprog/blob/master/01-intro/misc/.emacs)



# References

Reference card with most commands you'll ever need

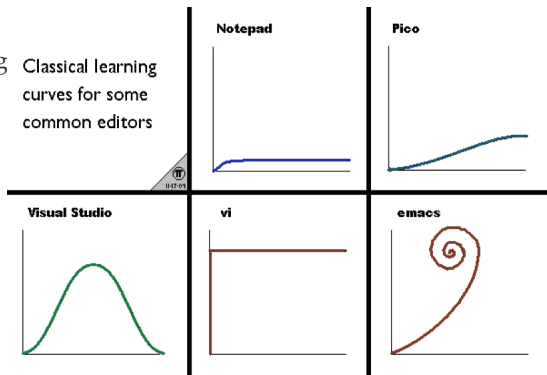
- <http://home.uchicago.edu/~gan/file/emacs.pdf>

Official GNU emacs site

- <http://www.gnu.org/software/emacs/>

An emacs HowTo

- <https://www.emacswiki.org> Classical learning curves for some common editors



# Homework

- Read up to chapter 3 File I/O — There will be a pop quiz on chapter 3
- Download source code for F2FS file system in advance, we will going to learn how to use ctag

