COMP 206: Intro to Software Systems Review

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Adapted from Joseph Vybihal's Winter 2017 COMP 206 slides.

Contents

1 Software Systems

1.1 What is a Software System?

A **system** has several parts. By themselves, not special. They cooperate together to make something. Addition of several sub-systems (programs that depend on other programs). System is the complete application that interacts directly with user.

A software system consists of a system with components (based on software) that form a part of a computer system. I.e. has separate programs, config files, documentation. Single components from a software system are usually useless without each other.

In this class, our programs will send instructions to the operating system, which will deal with sending stuff to the actual hardware.

1.2 Examples of Software Systems

Email Email clients don't know how to send email, they just send data through a wire. Keeps sending it to the next person (connected in network), until finally ISP or something else knows what to do with the email. Each piece only knows so much, all have to be together to work.

Facebook Needs Internet, ISP, PC/phone/browser and then the server/application/database. With only one thing, wouldn't be able to use Facebook.

Object oriented programming/Java Requires JVM, computer, etc. Text file → byte code converter → JVM → Libs → OS → PC →GPU or Network→Internet

Internet The Internet is the quintessential software system! Has many sub-systems, such as:
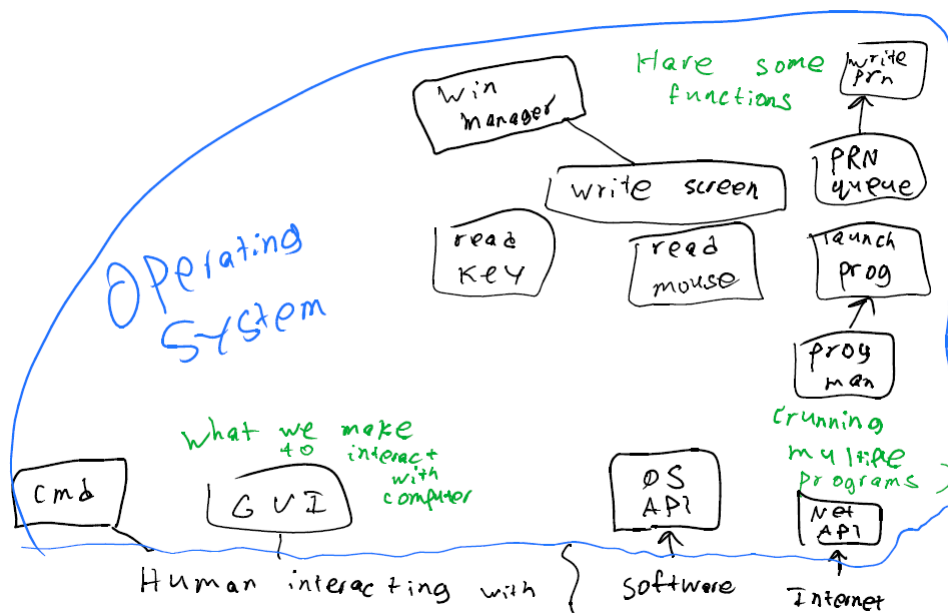
- Local PC

- Server

- Network

- Encryption

- etc.

See 1.4 For more information.

1.3   Operating Systems

Drivers   Small pieces of software, allow external devices to communicate with PC generically. So application does not have to deal separately with all different types of hardware.

What is an Operating System?   Piece of software, allows users to use computer without knowing inner workings. Main use is to manage resources, execute programs properly. Middle man between low-level hardware & users/programs. Also provides libraries.

Security
User Interface
Memory Manager
Disk / Storage Manager
Process Manager
Network Manager
Hardware Manager
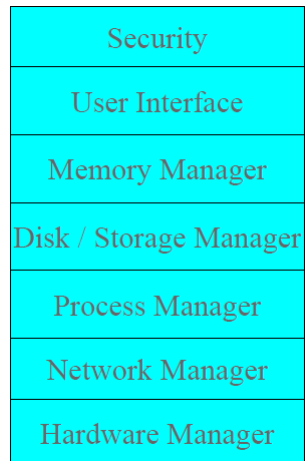
**OS Architecture**   Uses ideas from systems and subsystems.

- Security

  - Passwords

  - Encryption

  - File permissions

- User Interface

  - GUI, CLI, Shell memory

- Memory Manager

  - Find memory for programs

  - Format RAM

  - Manage cache, buffers, spools

- Storage Manager

  - Secondary Storage

  - Floppy disks

  - Hard disks

  - Memory sticks

  - etc.

- Process Manager

  - Runs programs

- – Multi-processing/multi-CPU

- – Kills programs

- – Run-time errors

- Network Manager

  - – LAN

  - – Internet

  - – etc.

- Hardware Manager

  - – Drivers

  - – Assembler & registers

  - – etc.

1.4 Internet

How does Email work?

Storage nodes...
Readability...
Security...
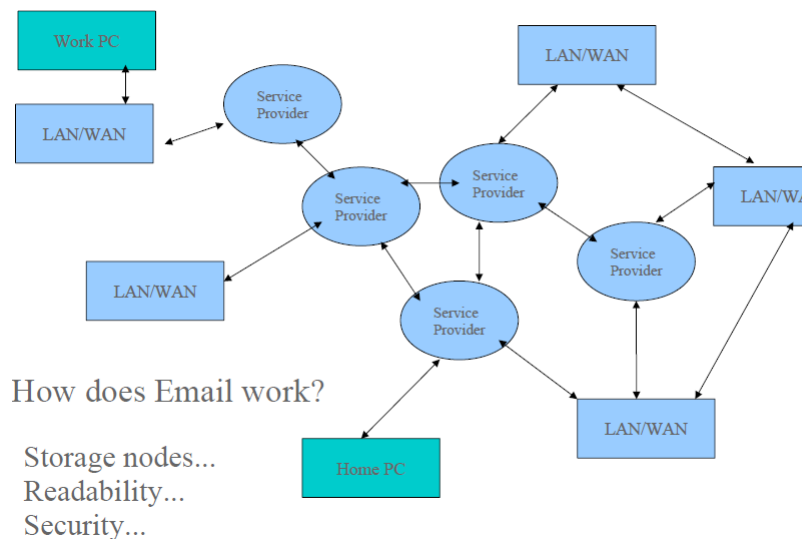
All interconnected computers around the world.

What is a Network? Wire, permits communication between computers. **LAN:** Local Area Network, computers in same room/building. **WAN:** Wide Area Network, computers in different buildings/cities, more than 1 server interconnecting big network nodes.
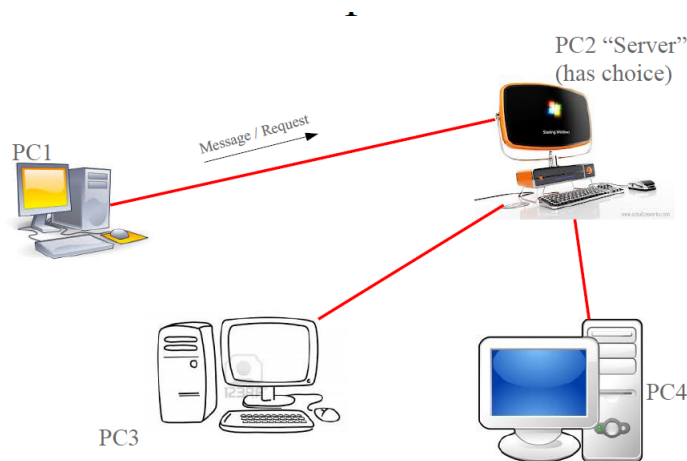
Client/Server

- Client sends request packet to server

- Server tries to find requested thing

- Server sends reply packet with data/program

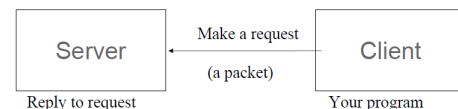- Client copies into memory and executes

Programs run on client, but programs stored on server, data is spread out. **MasterComputer/Main frame** is the opposite, programs stored & run on server, client just sees it. Additional terms: **Handshaking** consists of agreeing on packet format & passwords.

Comm-error, packet lost, resend request or time-out.

Service Providers   Special server, knows locations of other servers on the Internet. Uses this knowledge to deliver package to right destination. Internet = WAN of service providers that are connected to independent LAN & WAN networks.

Web   Subset of Internet with only interconnected ISP servers. Interacts solely with browsers.

Public_HTML   Servers connected to Internet have a directory/folder called public_html, which is public. By default, only this is accessible from Browser. The default operation for the Internet is to display folders and files at that Internet address (like a file-browser), like this. Need an index.html or other stuff to change default behavior and display a "web page".

Communicating with Other Computers   Each computer needs a unique ID, today we
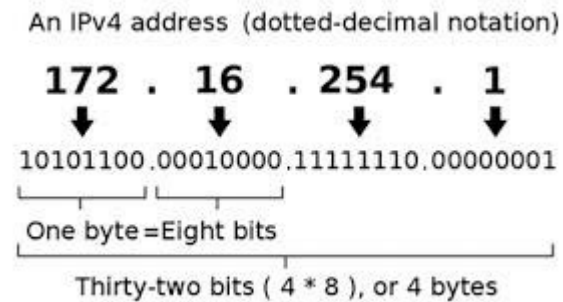
use our **IP Address** as our unique ID number.

2   Unix

2.1   About Unix

History   Failed OS by AT&T Bell Laboratories called Multics, 1st OS with 2 windows & 2 programs at the same time. Ken Thompson was working on project, writing game called *Space Travel*. Ported game to PDP-7 when project was canceled. Wrote Unix to make it easier to port. 3 types: System V UNIX (based off original), BSD UNIX (based on Berkeley Software Distribution) and UNIX-like (behave like UNIX, includes **Linux**, which we'll be using).

General Info   Unix is:

- Optimized/simple

- Password-based security

- Driven by command line

- Client-server

Unix is client/server! Companies buy one huge machine (server) and many small terminals (client). Can SSH into a SOCS machine at school.
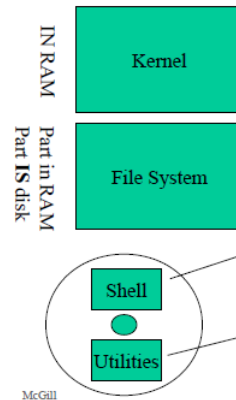
OS Components Unix is a modular OS. Several components:

- Kernel

  - In RAM

  - Handles logging in

  - Task switching

  - Manages everything

  - Basic interface

  - Drivers, run-time stack

- File System

  - How is disk drive formatted

  - FAT (File Allocation Table)

  - Data structure making files "real"

  - Everything is a "Program"

  - R/w to disk & peripherals

- Shell

  - More advanced UI

  - Global memory

  - Commands to interact with shell

- Utilities

  - Extra commands and programs

  - Drivers

Users Need an account on a Unix machine to use it. Consists of a user name and password. User gets a **home directory** ($\sim$). Accounts are members of at least one group. Groups used for permission purposes. Every Unix machine has a **root** account, with ALL permissions.

Passwords Since all Unix security is based on passwords, important to have a good password. Breach consists of someone else logging in with your password. Shouldn't use dictionary words because there are dictionary attacks. Other attacks include getting to know the user and brute force. Want a mix of upper and lower case, numbers, punctuation.

2.2 Sessions

Login prompt

$\downarrow$

Launch shell

$\downarrow$

Execute login script

$\downarrow$

rlogin   ←   Display prompt until logout or exit

slogin

ssh

$\downarrow$

Execute logout script

$\downarrow$
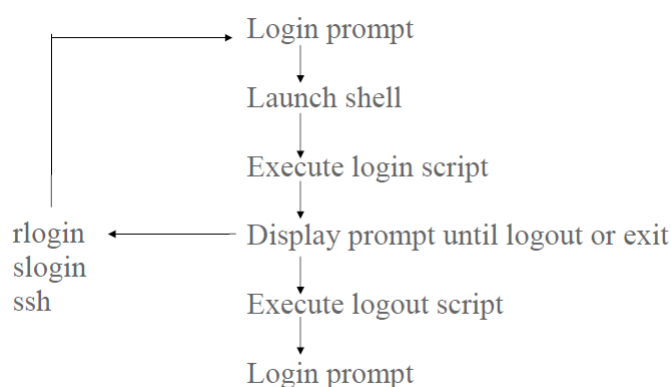
Login prompt

One session goes from login, loops the prompt many times until you logout. rlogin, slogin, ssh used to create another session within a login.

Environment Session Memory Has stuff like user name, home, shell, etc. When you start the shell, OS sets up environment, a collection of variables which can be accessed from any application launched from that environment. env & set show you current environment variables. setenv and set are not used in bash to change an environment variable in Bash, just write var=value. Echo can give you specific env variables, like echo $var.

3 Bash/Command-line

Command-line Prompt Basically a while look that keeps reading the input you give it until you logout or exit.

Syntax Program -switches arguments
Program is any command or executable. Switches are parameters that modify program's execution, arguments are fed to program.

3.1　Good Commands to Know

Command	Switches/Args	Examples	Usage
ls	-l (long output) -a (all, hidden) [file/dir]	ls ; ls -l ; ls text.txt	lists files and directories
whoami			Tells you user logged in as
who			Who is logged on server
exit			exits shell
logout			logs out of session, can logout of a nested session
finger	username@host	finger jlore	info on user
ssh	username@host	ssh jlore@mimi.cs.mcgill.ca	ssh into this user
mkdir	directoryname	mkdir test	make directory
cp	filename destination file	cp a.txt b.txt ; cp a.txt /jl	copy a file
cd	[directory] [..]	cd test ; cd .. (goes up 1 dir) ; cd (goes home)	change dir
cat	file	cat test.txt	reads text, concatenates files, can read 2 at once
rm	file	rm test.txt	removes a file
sort	-(reverse alphabetical)		sorts text alphabetically
pwd			prints working directory
rmdir	directory	rm test	removes EMPTY directory
chgrp	group file	chgrp friends test.txt	changes group of file

chmod	u(user)g(group)a(all) +(adds perm)-(removes)=(replaces) rwx 421 file (0=no perm 1=exec) (2=write 4=read)	chmod u=r test.txt (changes user to read) chmod 000 test.txt	change permissions
chown	owner file	chown jlore test.txt	changes owner of file
mv	file1 file2	mv test.txt /jlore/test.txt	moves file1 into file2
echo	text/string	echo hi	echoes string to std-out
head	[-number] file	head -2 test	display first n or first few (if no number) lines of file
tail	[-number] file	tail -2 test	display last n or last few lines of file
more	file	more test	page through file, enter advances a page
less	file	less test	navigate through paginated file, better than more
man	command/program	man ls	get manual page for a program
date	[options]		gets current date & time
du	[options] [dir/file]	du source/	shows disk space usage
hostname			Gives name of machine
uname	[option]		Prints system info

script	file	script record.txt	Records everything appearing on screen (IN/OUT) to file until exit or ctrl-D
which	command	which ls	Shows path where command is located
kill	[options] [-SIGNAL] [pid#]	kill -9 1234	Kills a process id, -9 is sigkill, aggressive/forceful kill
ps	[options] -a (all processes/users) -e (environment) -g (group leaders too) -l (long) -u (shows user, also more info like % resources) -x (includes things not run from terms) -f (full)	ps -a	Shows status of active processes
top			Monitors resource usage of active processes
tar	-c (create new) -r (update) -x (extract) -f (archive name) -v (verbose) -z (compress using gzip) (files/dir)	tar -cvf log.tar *.log ; tar -zcvf log.tgz *.log ; tar -xvf log.tar /tmp/log	Archive manipulation using tar, see 3.2
diff	[op] file1 file2	diff text text2	compares 2 files
file	[op] file	file text	What "kind" of file?
find	[op] [path] expressions	find test	Finds files matching pattern

ln	-s (soft link) source target	ln fav.txt read	Links source to target. Default is hard link, gives another name to a file. Soft/symbolic link is an indirect pointer, does not affect target file.
paste	[op] file1 file2	paste text1 text2	combines 2 files, one after other
touch	[op] [date] file	touch text	Create empty file or update access time
wc	[op] file(s)	wc text	word count
write	userid	write jlore	Sends text message to someone ^D to end, mesg -y/n to turn on/off
wall			write to all
grep	[op] -i (ignore case) -c (return only count of matches) -v (invert, display ones that don't match) -n (adds line number of match) -l (filenames of matches) string files	grep hi text	Search for occurrences of String, supports regex
sed	[op] -i (interactive, update current file) files	sed -i '1d 'text (deletes first line) ; sed -i '1iHello 'text (inserts Hello at 1st line)	stream editor
awk	[op] files	awk 'NR==1'text (reads first line)	scan for patterns in file

clear			clears screen/prompt
expr	math	expr 1 + 2	Does integer math

Common switches (mainly cp, mv, rm)

. -i: interactive

prompt and wait for confirmation

. -r or -R: recursive

visits directory recursively, visits files and subdirs

. -f: force

don't prompt for confirmation, overrides -i

Killing   ^Z (ctrl-Z) forceful kill
^C (ctrl-C) gentle kill

3.2   Files & Directories

Hidden Files/Folders   : Start with ., i.e. .config
Can be seen with ls -a

Wild cards

| *	anything
?	any single char
[abc]	a or b or c

Directories   Directories are folders. Use same permission system as files. Root denoted by /
Common Unix system has following directories:

- /etc : config files, pws

- /bin : OS executables

- /usr : Application installations

- /opt : Another application installation dir

- /dev : Device files for hardware

- /var : Files that vary a lot, like logs

Typical Directory Structure
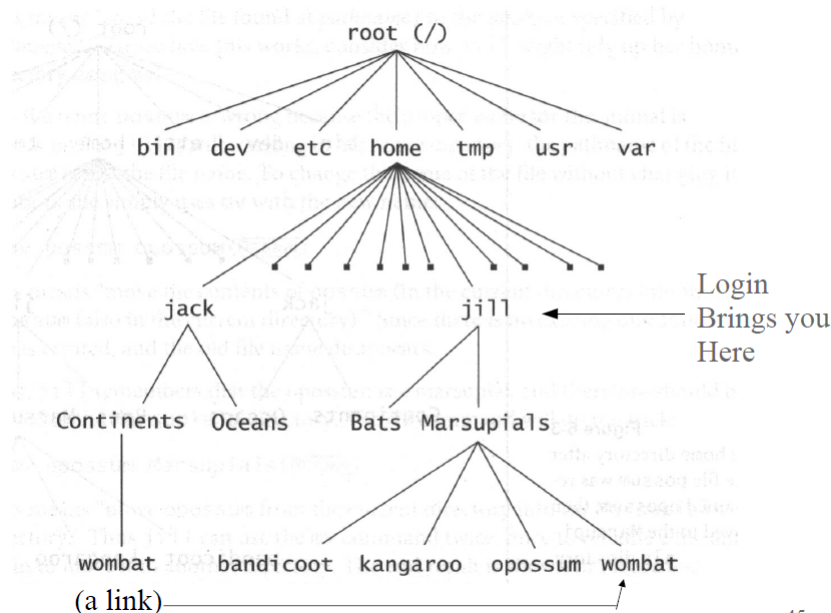
Absolute vs Relative Paths

. Relative paths: Path from your current directory

. Absolute paths: Path from root

- ./folder from current directory, same as folder
- ../folder parent directory one up

File Descriptors   Created by OS when file opened. Reference to that file. Unix has 3 special file descriptors that are always opened.

- STDIN 0 : keys typed by user gathered here

- STDOUT 1 : normal application output sent here

- STDERR 2 : where error output is sent

Permissions   Three levels, user, group and other. 3 types of rights, read, write and execute. Can give any combination of these rights to the 3 levels. Permissions usually shown by string of 10 characters, first is if directory or not, then next bunches of 3 are rwx for 3 levels.

Directory Listing (ls)   Long format:

```
$ ls -l /bin/ar
-r-xr-xr-x   1 bin       bin        21428 Sep 24  1983 /bin/ar
$
```

We are now looking at details about the file *ar* in the */bin* directory.

     Figure 3.3 below shows a typical display from an `ls -l` command and shows the interpretation of the fields in the listing.

```
-rw-r--r--   1   henry  widget  9121 Mar 3 18:11  preface.mexp
```

File Modes

Number of Links

Owner Name

Group Name

File Size

Date and Time of Last Modification

File Name

Overlapping   If all/other have rwx, but everyone else has nothing, owner and group cannot rwx, unless the Unix system interprets other as all.

Archives   TAR, GZIP & GUNZIP. Archive is a collection of files combined into one file, often compressed. tar combines, gzip compresses.

3.3   Redirection

Output   > redirects STDOUT to a text file
>> appends STDOUT to a text file.

Input   < takes all input from a file
To redirect something specific, can prefix by file descriptor, i.e. prog 2>errors, redirects errors from prog to errors file.

Piping/Chaining

. Piping commands: redirects STDOUT to another program. i.e. (ls | more) paginates ls output

. Doing multiple commands in SUCCESSION: (ls ; echo hi) does ls then echoes hi

. Doing multiple commands at ONCE: (ls & echo hi) does ls and echo at the same time

3.4   Quotes

- ` nested execute symbol ` , executes what's in between first $\rightarrow$ string

- 'as is '

- "pre-process "

Escape Characters

- \ $\leftarrow$ escape character

- \n new line

- \t tab

- \a bell (noise)

3.5   Editors

Command line text editors allow for creation/editing of files at CLI.

- vi, one of the original ones on Unix, hard to learn. Available on every Unix machine.

- pico, simple, based on pine mail client, available on most

- emacs, popular, powerful, heavyweight

There are also graphical text editors.

Vi   Different modes:

- Edit (i, a, o, O, etc.)
  - Edit text
  - Can press any char

– Some vis let you use arrows

- Escape Mode (ESC)

  – Stops edit

  – Can use arrow keys

  – Can use special one letter commands (i,a,h,j,k,l,etc.)

- Command Mode (:)

  – Can save, load, quit, etc

ESC:

- dd deletes a whole line

- x deletes current char

- r replaces current char by next char types

- / to search

Command:

- w writes

- q quites

- wq both

- q! quit without saving

- e filename to edit file

3.6 Regular Expressions

Some commands/editors allow you to search text patters, known as regex. See grep, sed and awk in 3.1 for info about those commands.

Examples

- grep -i '^[aeiouy]'text , want first letter to be a vowel

- '[aeiouy]$ ', want last letter to be vowel

- '[aeiouy]{2,} '{min,max}, want it at least 2 times, 2 vowels next to each other

- '^.e ', Start with anything then an e

- '^e|a ', start with e or a

- '^[a-e] ', start with anything from a to e on unicode table

4 Bash Scripts

Scripts are collections of commands grouped in a file to execute in a sequence. Not compiled, interpreted. Run from top to bottom, can alter flow with if statements and loops. Can also create functions (before called). # indicates a comment. Scripts sensitive to spaces. Good uses for scripts:

- Backups

- Startups

- Scheduled

- Maintenance

- Programmer

Boot & Login Scripts   Modify OS environment. Boot made by root for all users, login scripts created by users for themselves. At login, shell looks for default login script.

Login Scripts   Used for:

- Configure UI (prompt, color)

- TERM communication method, how server speaks to computer

- Routines

In Bash, to change your prompt:

PS1="Something here"

Aliasing commands

alias lsa='ls -a'

PATH   Set of directories a shell searches for executables, separated by (:)

Command-line Scripts   Created by users to automate command-line things. Everything is a text file, text files can be executed, just add x permission using chmod. Launch a script in current directory using ./myScript

4.1   Shell Scripting

Start off your script with the sha-bang #!, to show that script is directly executable and specify shell language/path. #!/bin/bash

Variables   3 kinds in a shell script

- Environment Variable, used to customize OS, used by shell

- User-created, created by script itself

- Positional Parameters, store what was used to start script

Positional Variables

- $# number of args on command line

- $- options supplied to shell

- $? exit val of last command executed

- $$ process number of current process

- $! process number of last command done in background

- $n argument on command line, n=1-9

- shift shifts all arguments by 1, lose $0, but get $10

  - $0 name of shell/program

  - $* all args on command line as 1 string

    – $@ all args, separately quoted with spaces

Declaring variables: Just write x=10

Some Default Variables

- $HOME

- $SHELL

- $TERM

- $USER

- $PWD

Reading   Use the *read* command to read a string from STDIN. i.e. read name $\implies$ $name now stores whatever string the user typed.

Capturing Complex Output
If you want to parse multiple args from a command: set ` date ` will store output in $n ($1,$2, ...). Will erase data already there.

Arithmetic   Use, either expr, bc or tell Bash it's math. To make Bash treat Strings as a number, do:
$((1+1)) or $[1+1]
For fractions, use bc. echo "scale=#ofdecimals;3/4 "| bc

Conditionals   Use the test command to evaluate an expression or case. Bash does not require the test command though. Can evaluate at file, string or integer level.

File Tests

- -r file : exists + readable

- -w file : exists + writable

- -x file : exists + executable

- -f file : exists + regular

- -d name : exists + directory

- -h or -L file : exists + link

- etc.

String Tests

- -z string : string length zero (Not null, but 0)

- -n string : length non-zero

- string1 = (or ==) string2 : strings identical

- string1 != string2 : not identical

- string : not null

Integer Tests

- n1 -eq n2 : integers equal

- n1 -ne n2 : not equal

- n1 -gt n2 : $n1 > n2$

- n1 -ge n2 : $n1 \geq n2$

- n1 -lt n2 : $n1 < n2$

- n1 -le n2 : $n1 \leq n2$

if Statement

```
if _condition_
then
        stuff
elif _condition_
then
        stuff
else
        stuff
fi
```

case Statement

```
case what_to_check in

condition1) action1;;
condition2) action2;;
*) else_action;;
esac
```

for Loop   Iterates.

```
for var in list
do
        stuff
done
```

while Statement   Continues until statement false.

```
while condition
do
        stuff
        continue (back to beginning)
        break (end loop)
done
```

```
function() {
stuff
}
```

Functions must be declared before called.

Etc.   Good practice to exit scripts with exit codes, 0 for no errors, 1-255 for errors.

5 C

5.1 About C

History Successor for B and BCPL. Creation parallel to development of early Unix OSes (1969-1973). Good because it's portable and can access hardware, lower level language. C++, successor to C. Java, C# and JavaScript based on C.

Comparison to Java Same as Java for:

- If

- For loop

- While/do-while loop

- Methods (called functions)

- Types : int, float, double, char

- Variable creation

- Mathematical and logical expressions

Mathematical operators ($+$,*, etc.) exact same as Java. Type casting sometimes implicit, like int $\rightarrow$ float, but can cast specifically like in Java.
Similar to Java for:

- Arrays

- References (pointers)

- Main method (main function)

- Scope

Different from Java for:

- Strings

- No objects (but there are modules)

- Libraries

- Pre-processor, compiling in different languages, Eng/Fr, etc.

5.2   C Program Structure

```c
#include <stdio.h> // C library, always need stdio.h
int main (int argc, char *argv[]){
//main function, *argv[] are command-line parameters
        printf("Hello_World_\n"); //prints
        return 0; //return if there's an error or not to calling program
}
```

int argc consists of number of arguments at command-line (including argv[0], prog name)

char *argv[], each cell has one command-line parameter.

5.3   Format of Types for Strings/printf,etc.

To input a char or String or int or something else indirectly into printf, have to declare the spacing of it with %.

<div align="center">

int, optional. How much space?

%   #   c

type, c=char, s=string, d=int, f=float

</div>

More control codes:

- %d or %i : signed integer

- %x : unsigned hexadecimal

- %u : unsigned decimal

- %E : double of form m.ddExx

Ex.

```c
printf("user_%s_hello_\n", name);
```

Prints user bob hello, if bob stored in name. %10s represents 10 white spaces, first x amount with variable. If you write less numbers than the length of the String, it won't truncate, will just use length, like %s.

For floats, %5.2f, 5 is total amount of numbers, .2 is number after decimal.

x++ increments after operation (x++-3=x-3+1), ++x increments before (++x-3=x+1-3)

5.4   Libraries & Functions

Functions   If you want to write the code for a function after calling it, have to use a function prototype, that is, declare the function at the beginning, but write the code later

(telling compiler to look for the function). Names of variables in prototype don't have to match, but return type has to match.

```c
void add (int, int);
.
.
.
void main(void){
int z = sum (5,10);
}
.
.
.
void add (int a, int b){
int x=a+b
}
```

You **CANNOT** overload functions in C, counts as conflicting signatures (function name, return type and parameters).

What are libraries?   Toolbox for common routines that are often optimized and speed up development time. They allow you to create reusable code to share with others, but can make code size large. Include at beginning of code. Can also include things like headers or c code.

Made up of .h, the header file with function prototypes & typedefs and .o, compiled from .c without a main

stdio.h

function	example(s)	use
printf("stuff")	printf("Hello World"); printf("%d ", 25);	Prints to screen
scanf(a)	scanf("%d %d ", &age1, &age2);	scans variables from user
int getchar(void)		gets on char from STDIN
int putchar(int)		displays one char to STD-OUT
gets(array)		reads string into array

fgets(char array, int size, *stream)		reads string of certain size from file into array
int getc(any stream)/getchar(STDIN only);		read one char
int puts(*string)		place char
remove (*file)		
rename(*file1, *file2)		
fopen (filename, mode [rt,wt,at])	fopen (text.txt, "wt ");	opens file ptr
fprintf(ptr, description, vars)		
fscanf(ptr, description, &vars)		
feof(ptr)		0, 1 if end of file
fclose(ptr)		
fflush(ptr)		empties buffer without writing

scanf anomaly: Does not process carriage returns properly, viewed as string or char. When you read numbers, carriage return is left in input buffer! You should scan numbers after all strings, unless you have intermediate garbage (char) scans to scan leftover carriage returns.

scanf limiting vs gets, need specific amount of args/words, get gives you the whole line.

sprintf & sscanf do same thing as printf & scanf, except they return how many they were able to read/print

stdlib.h

- NULL 0

- EXIT_FAILURE 1

- EXIT_SUCCESS 0

- rand(void), 0 to RAND_MAX

- system(string), sends command to system, command-line

- atof(string), ascii to float

- atoi(string), ascii to integer

- abs(int), abs val

- exit(int), 1 or 0

math.h

- sqrt(double);

- power(base,exponent);

- abs(int);

- fabs(double);

- floor(double);

- ceil(double);

- sin, cos, tan, asin, etc.

ctype.h
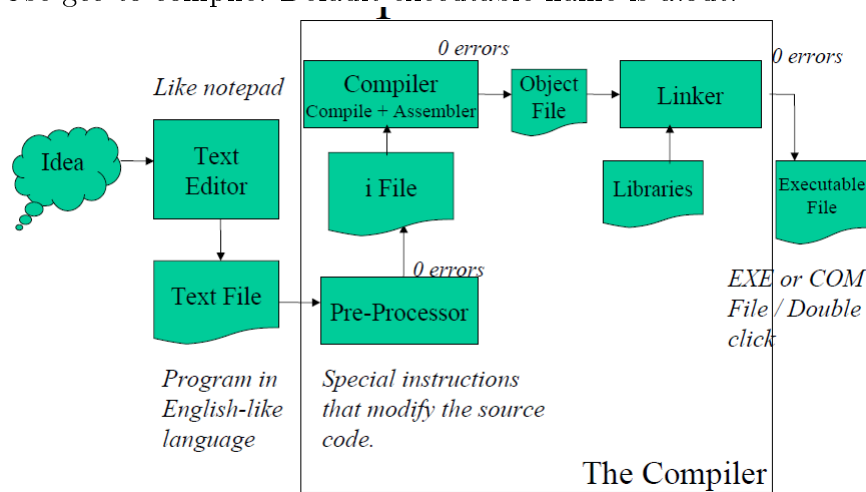
- toupper(int);

- tolower(int);

- isalpha(int);

- isalphanum(int);

- isdigit(int);

string.h

- strlen(string)

- char *strcpy(char *dest, char *src), copies string

- char *strcat(char *dest, char *src), concatenates string

- strcmp(char *s1, char *s2), compares contents of 2 strings (instead of addresses), 0 if same

5.5   Compiling

Use gcc to compile. Default executable name is a.out.

C Files

- Source files: file.c (program). file.h (header, shared)

- Pre-processed: file.i

- Object & assembler: file.o, file.s

- Executables: file, a.out

GCC Syntax   GCC is the GNU C Compiler.
gcc -o executablename sourcefilenames
Variations include:

- gcc -E main.c, also make main.i

- gcc -S main.c, also make assembler code

- gcc -c main.c, also make object code

- gcc main.c, make a.out

- Extra switches:

    - -o filename, specify name of output
    - -v verbose
    - -w suppress warnings

- -W extra warnings

- -Wall all warning messages

- -O1 optimize for size and speed

- -O2 optimize even more

C Types

DESCRIPTION	RESERVED WORD	BITS	RANGE
Integer	short	8	- 128 to + 127
	int	16	+/- 32,768
	long	32	+/- 2,147,483,648
Floating Point	float	32	+/- 3.4 x 10^{38} with 7 significant digits
	double	64	+/- 1.7 x 10^{308} with 15 significant digits
Boolean	short, int, long		0 is false, other true
Character	char	8	0 to 256
String	char *	32	address in memory (special case of pointer)
Pointers	TYPE*	32	address in memory

Notice that booleans don't really exist (they're just ints) and Strings are char pointers. Strings end with a null.

Booleans   0 = false, anything else is true. Greatly affects if statements, as your condition can solely be math and it'll check if it's 0 or not. So you won't have a compilation error for something like x=5, but very different from x==5.

Strings   Strings are just character arrays terminated by a null. Can declare some like: char *x = "Bob ";
Cannot scanf into a *, as * constant/fixed to what they were when declared. When scanning into a char array, don't use &.

Arrays   int x[10];
Can also declare literally and also leave extra commas to denote extra spaces.
int x[]={1,2,3,4,,,,,}
In C, you can go past the indexes of an array.
char x[10]; → [char][char]...[char]
char *y[10]; → [ptr][ptr]...[ptr]

Declaring a Variable

SCOPE MODIFIER TYPE VAR_NAME;

SCOPE is static, extern or not used. MODIFIED is unsigned(no signed bit), short($\frac{1}{2}$ bits), long($2\times$ bits) or not used. TYPE, a built in type.

Variables are **NOT** defaulted to 0.

Can also chain assignments, int a,b,c,d=4;

Can also declare constants

int const a = 1; or const int a = 2;

Variables declared at either top of file (global variable) or in a function (local variable). Global variables are positionally global, accessible to everything below it. Only one copy of a global variable exists. Global variables should be avoided if not needed, hard to debug and not considered clean.

Variable preference: block vars $\rightarrow$ local vars $\rightarrow$ global $\rightarrow$ extern $\rightarrow$ error/compiler error

typedef Declaration   Can make your own type, i.e.

typedef int boolean;

5.6   Pointers

Special unsigned integer storing an address. Can reference anything really. Mainly used to point to a variable or location in RAM. Note that a pointer is not the same thing as a reference, a reference is a Java concept.

Pointer Operations

- & unary/monadic operator, gives address of variable

- * indirection/dereference, gives contents of object pointed to, declare pointers using *

	content	address of
int a	a	&a
int *p	*p	p

```
int a,b,*p;
p=&a
```

p will now point at a's address.

```
int a, b;
int *p;


a = 5;
b = 10;
p = &a; // p is pointing to a
*p = 6; // Value of a is now 6
p = &b; // p is pointing to b
*p = 11 // Value of b is now 11;
```

Giving type to your pointer means it can only point to that type. void * can point to anything.

```
char* x,y,z; // all vars are char*
char x, *y, z; // only y is char*
```

Files/text, displayed in 2D but actually 1D structure, like an array. The Disk actually consists of the FAT (File Allocation Table), a bunch of name of files and pointers.
Pointers are not constant, can change (since they're variables), unless you declare explicitly, like a String (then it's static/literals).

```
char *string = "bob"; // Literal / static
char array[10]; // Variables / dynamic

```

void* Pointers   void pointers can point to anything, anywhere. They are the bit-size of addresses.

```
int x=5,y;
void *p;


p=&x;
y=*p; // Warning
y=*(int *)p; // Cast

```

Arrays   When you create an array in C, you're allocating a block of memory and creating a pointer to the first element of the block (like using malloc).

SCOPE MODIFIER **char**$*$ VARNAME $=$ "characters"

Going to different indices in a String/pointer, add the offset.

```
*(str+2); // 3rd char of the String
```

If we don't terminate a String by a null, it will keep going until it hits a null (when trying to read it).

5.7   Parameter Passing

- Primitive types are passed by value. You get a local copy of the variable for the function.

- Arrays are passed by reference, affects the whole program if you change them in a function (same for pointers).

- Passing a parameter with the unary (&) operator makes it pass as a pointer, which is how scanf works.