CS 35L- Software Construction Laboratory

Winter 19

TA: Guangyu Zhou

Course Information

- Presentation
- Today:
  - Varun Raju & Kathir Ilango
  - Dong Han
- Next Monday:
  - Shizhe Chen
  - Zihan Liu & Siqi Liu
  - Pete Shen

- Upload your slides (pdf, ppt) to CCLE **before** presentation
- Check-in the Q&A Bonus if you asked questions

Important Announcement

- Common new final exam for **ALL** sections
- Time: Sunday, March 17 from 3:00-6:00pm.
- Location: We don‘t have a room assignment yet, but we’ll get one.
- If anybody has another final exam scheduled at the same time, please contact Professor directly.

Lab 4: Clarification

- Make sure you apply the patch to fix the “make file” bug first
  - Then run **configure, make, make install**
- When you generate the bug, make sure you run *“ls” from the directory you installed (XXX/bin/ls)*
- When using GDB, run from the directory where the compiled ls lives *(XXX/bin/ls)*
- You can run *ls* with **options** in the GDB terminal:
  - *(gdb) r -lt --full-time wwi-armistice now now1*
- Construct a new patch file:
  - *diff -u old_buggy_file new_fixed_file> patch.diff*

Lab 4: Clarification

Buggy version:

```
$ tmp=$(mktemp -d)
$ cd $tmp
$ touch -d '1918-11-11 11:00 GMT' wwi-armistice
$ touch now
$ sleep 1
$ touch now1
$ TZ=UTC0 ls -lt --full-time wwi-armistice now now1
-rw-r--r-- 1 eggert csfac 0 1918-11-11 11:00:00.000000000 +0000 wwi-armistice
-rw-r--r-- 1 eggert csfac 0 2018-10-29 16:43:16.805404419 +0000 now1
-rw-r--r-- 1 eggert csfac 0 2018-10-29 16:43:15.801376773 +0000 now
$ cd
$ rm -fr $tmp
```

Correct output should be:

```
-rw-r--r-- 1 eggert csfac 0 2018-10-29 16:43:16.805404419 +0000 now1
-rw-r--r-- 1 eggert csfac 0 2018-10-29 16:43:15.801376773 +0000 now
-rw-r--r-- 1 eggert csfac 0 1918-11-11 11:00:00.000000000 +0000 wwi-armistice
```

More hints on Lab 4

- Use “info functions” to look for relevant starting point
- Use “info locals” to check values of local variables
- Compiler optimizations: -O2 -> -O0
  - If you want to see more details for optimized variables
  - https://gcc.gnu.org/onlinedocs/gnat_ugn/Optimization-Levels.html
- ./configure … CFLAGS= "-g -O0"

Review: Pointers to Functions

- **qsort (values, 6, sizeof(int), compare);**
- User can pass in a function to the sort function
- Declaration
  - double (*func_ptr) (double, double);
  - func_ptr = &pow; // func_ptr points to pow()
- Usage
  - // Call the function referenced by func_ptr
    double result = (*func_ptr)(1.5, 2.0);
  - // The same function call
    result = func_ptr(1.5, 2.0);

Some facts about C function pointers

- Unlike normal pointers, a function pointer points to code, not data. Typically a function pointer stores the start of executable code.
- Unlike normal pointers, we do not allocate, de-allocate memory using function pointers
- Many object oriented features in C++ are implemented using function pointers in C. For example virtual functions. Class methods are another example implemented using function pointers
- A function's name can also be used to get functions' address

```c
#include <stdio.h>
// A normal function with an int parameter
// and void return type
void fun(int a)
{
    printf("Value of a is %d\n", a);
}

int main()
{
    void (*fun_ptr)(int) = fun;  // & removed

    fun_ptr(10);  // * removed

    return 0;
}
```

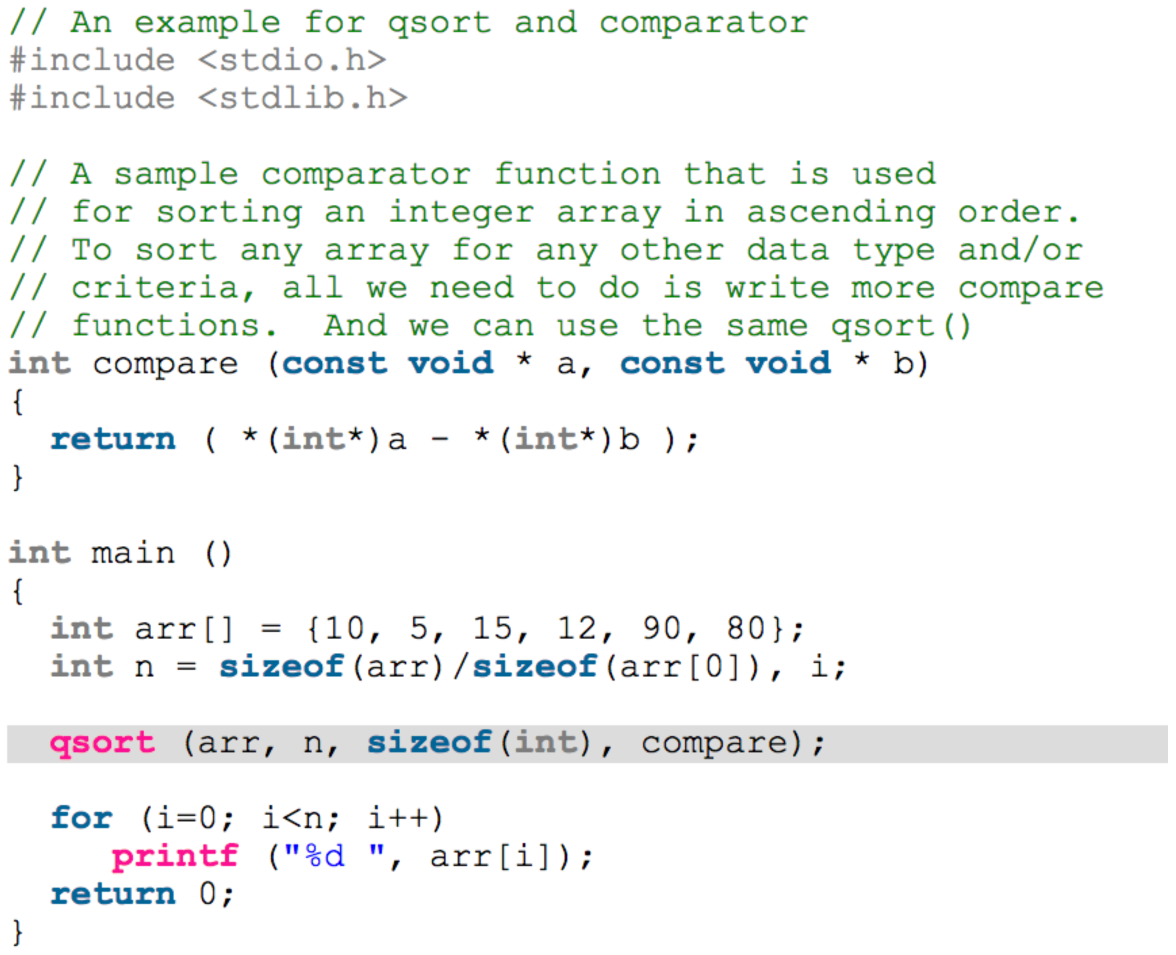
Some facts about C function pointers

- Like normal pointers, we can have an array of function pointers.

```c
#include <stdio.h>
void add(int a, int b)
{
    printf("Addition is %d\n", a+b);
}
void subtract(int a, int b)
{
    printf("Subtraction is %d\n", a-b);
}
void multiply(int a, int b)
{
    printf("Multiplication is %d\n", a*b);
}

int main()
{
    // fun_ptr_arr is an array of function pointers
    void (*fun_ptr_arr[])(int, int) = {add, subtract, multiply};
    unsigned int ch, a = 15, b = 10;

    printf("Enter Choice: 0 for add, 1 for subtract and 2 "
            "for multiply\n");
    scanf("%d", &ch);

    if (ch > 2) return 0;

    (*fun_ptr_arr[ch])(a, b);

    return 0;
}
```

Some facts about C function pointers

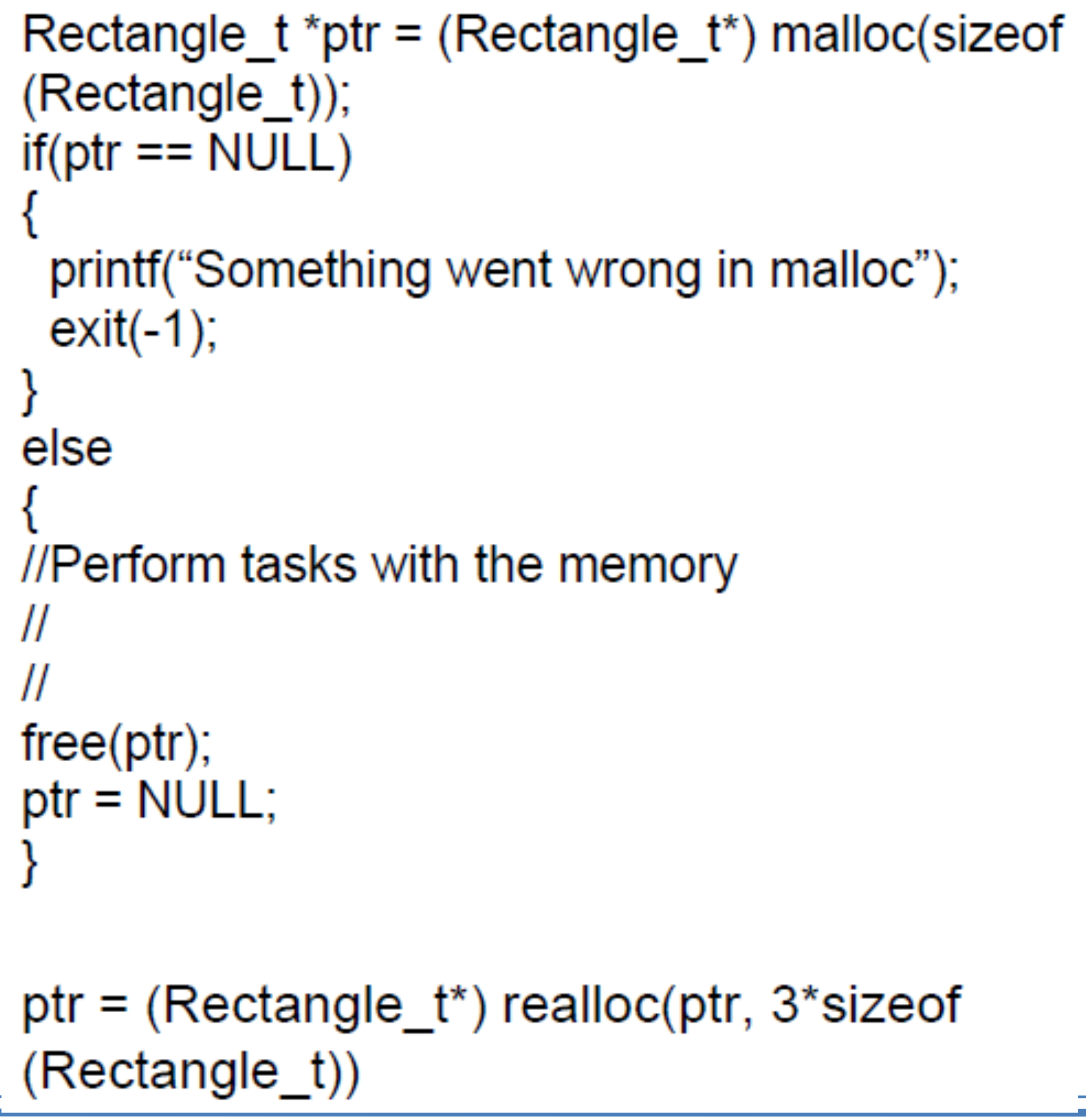
- Like normal data pointers, a function pointer can be passed as an argument and can also be returned from a function.



```c
// An example for qsort and comparator
#include <stdio.h>
#include <stdlib.h>

// A sample comparator function that is used
// for sorting an integer array in ascending order.
// To sort any array for any other data type and/or
// criteria, all we need to do is write more compare
// functions.  And we can use the same qsort()
int compare (const void * a, const void * b)
{
  return ( *(int*)a - *(int*)b );
}

int main ()
{
  int arr[] = {10, 5, 15, 12, 90, 80};
  int n = sizeof(arr)/sizeof(arr[0]), i;

  qsort (arr, n, sizeof(int), compare);

  for (i=0; i<n; i++)
     printf ("%d ", arr[i]);
  return 0;
}
```

Review: Dynamic Memory Allocation

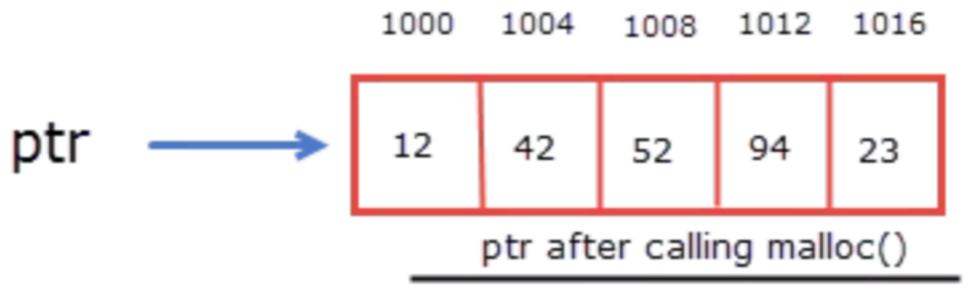
- malloc(size_t size): allocates a block of memory whose size is at least size
- free(void *ptr): frees the block of memory pointed to by ptr
- realloc(void *ptr, size_t newSize) : Resizes allocated memory
- Allocate memory **on heap**



```
Rectangle_t *ptr = (Rectangle_t*) malloc(sizeof
(Rectangle_t));
if(ptr == NULL)
{
  printf("Something went wrong in malloc");
  exit(-1);
}
else
{
//Perform tasks with the memory
//
//
free(ptr);
ptr = NULL;
}

ptr = (Rectangle_t*) realloc(ptr, 3*sizeof
(Rectangle_t))
```

Demo of realloc

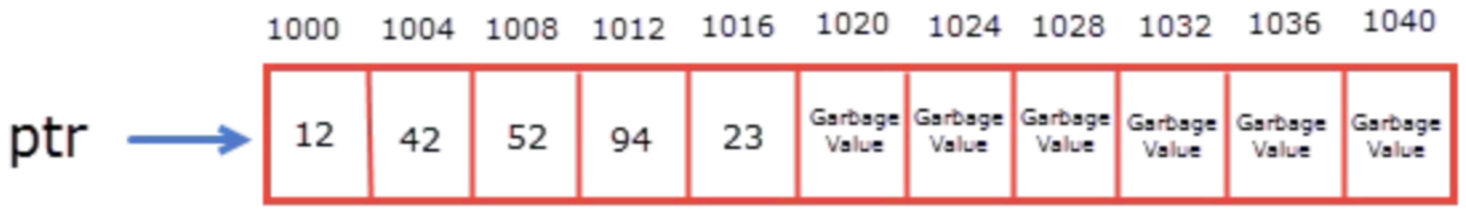
p = (int)malloc(5*sizeof(int));*



p = (int)realloc(p, 11*sizeof(int));*

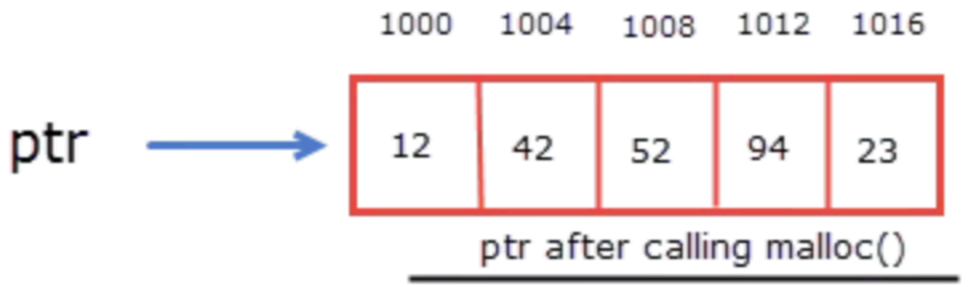
Now two conditions may arise:

1st case: If sufficient memory is available after address 1016, then the address of ptr doesn't change.

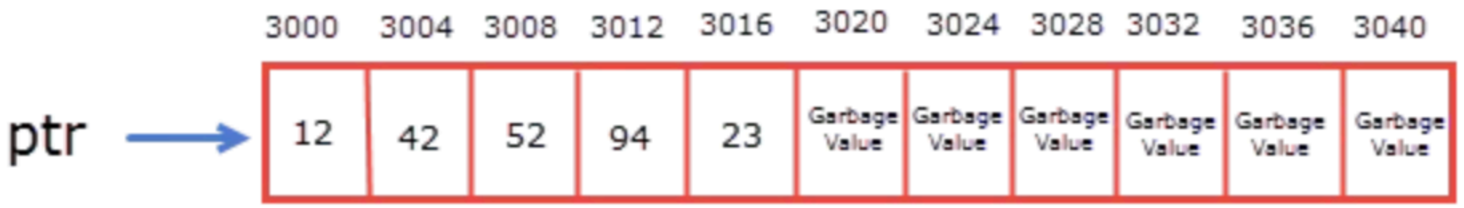


Demo of realloc

p = (int)malloc(5*sizeof(int));*



2nd case: If sufficient memory is not available after address 1016, then the realloc() function allocates memory somewhere else in the heap and copies the all content from old memory block to the new memory block. In this case the address of ptr changes.



Homework 4

- Implement a C function frobcmp as the template of qsort
  - takes two arguments a and b as input
  - returns an int result that is negative, zero, or positive depending on whether a is less than, equal to, or greater than b. Each argument is of type char const *.
  - a, b point to array of non-space bytes
- Returns an int result that is:
    - Negative if: **a** < **b**
    - Zero if: **a** == **b**
    - Positive if: **a** > **b**
    - Where each comparison is a lexicographic comparison of the unforbnicated bytes

Homework 4: hints

- Then, write a C program called *sfrob*
  - Reads stdin **byte-by-byte** (getchar)
  - Each byte is frobnicated
    - frobnicated - encoded with memfrob (XOR decimal 42)
    - Sort records without decoding (**qsort, frobcmp**)
    - Output result in frobnicated encoding to stdout (putchar)
  - Consider error checking (**fprintf**)
  - Dynamic memory allocation (**malloc, realloc, free**)
  - Program should work on empty and large files too

Note: if you don’t allocate memory from heap using malloc/realloc, there will be a memory issue that makes your program fail

Homework 4: example

- 1) Input: printf 'sybjre\nobl’
  - $ printf 'sybjre\nobl**\n**' | ./sfrob
- 2) $ cat 'sybjre\nobl’ > foo.txt
- Input: contents of foo.txt
  - $ ./sfrob < foo.txt
- Read the records: sybjre, obl
- Compare records using *frobcmp* function
- Use frobcmp as compare function in qsort
- Output:

```
obl
sybjre
```

Homework 4: instruction

- Use ***gdb*** for debugging
- Use *exit*, not *return* when exiting with error
- When performing malloc/realloc, do check for whether it is successful
- Array of pointers to char arrays to store strings (char ** arr)
- Use the right cast while passing frobcmp to qsort
  - cast from void * to char ** and then dereference because frobcmp takes a char *
- Use realloc to reallocate memory for every string and the array of strings itself, dynamically

- Assignment 5 **requires** having a solid handle on assignment 4, so this is important!
- Your code must do thorough error checking, and print an appropriate message on errors.
- Plug all memory leaks!

Valgrind

- Powerful dynamic analysis tool
- Useful to detect memory leaks
- Example:
  $ valgrind --leak-check-full
  ./sfrob < foo.txt

```
 88 (...) bytes in 1 blocks are definitely lost ...
   at 0x........: malloc (vg_replace_malloc.c:...)
   by 0x........: mk (leak-tree.c:11)
   by 0x........: main (leak-tree.c:25)
```

Valgrind Example

1st Problem: heap block overrun

```
1   #include <stdlib.h>
2
3   void f(void)
4   {
5       int* x = malloc(10 * sizeof(int));
6       x[10] = 0;
7   }
8
9   int main(void)
10  {
11      f();
12      return 0;
13  }
```

```
==19182== Invalid write of size 4
==19182==    at 0x804838F: f (example.c:6)
==19182==    by 0x80483AB: main (example.c:11)
==19182==  Address 0x1BA45050 is 0 bytes after a block of size 40 alloc'd
==19182==    at 0x1B8FF5CD: malloc (vg_replace_malloc.c:130)
==19182==    by 0x8048385: f (example.c:5)
==19182==    by 0x80483AB: main (example.c:11)
```

2nd Problem: memory leak

```
==19182== 40 bytes in 1 blocks are definitely lost in loss record 1 of 1
==19182==    at 0x1B8FF5CD: malloc (vg_replace_malloc.c:130)
==19182==    by 0x8048385: f (a.c:5)
==19182==    by 0x80483AB: main (a.c:11)
```

There are several kinds of leaks; the two most important categories are:
•"definitely lost": your program is leaking memory -- fix it!
•"probably lost": your program is leaking memory, unless you're doing funny things with pointers (such as moving them to point to the middle of a heap block).

Try to fix all of them to ensure full grade!

Segmentation fault

- A segmentation fault is caused when the code attempts to access memory that it **doesn't have permission to access**.
- Possible Reasons:
  - Accessing a NULL or uninitialized pointer
  - Accessing a dangling pointer
  - Stack overflow
  - Wild pointers
  - Attempting to read past the end of an array
  - Forgetting a NUL terminator on a C string
  - Attempting to modify a string literal
  - Mismatching Allocation and Deallocation methods

Segfault examples

```c
// C program to illustrate
// Core Dump/Segmentation fault
#include <stdio.h>
#include<alloc.h>
int main(void)
{
    // allocating memory to p
    int* p = malloc(8);
    *p = 100;

    // deallocated the space allocated to p
    free(p);

    // core dump/segmentation fault
    //  as now this statement is illegal
    *p = 110;

    return 0;
}
```

Some exercises

1. Write a C program using getchar() and putchar() which continuously takes user input and prints it on the screen. This should keep on happening till the user inputs a string containing ‘#’ and Enters. Hint: use while(getchar() != ‘#’)

```
#include <stdio.h>
/* --  Copy input to output -- */
int main(void)
{
        char c;
        c = getchar();
        while ( c != "#" ) {
           putchar(c);
           c = getchar();
        }
        return 0;
}
```

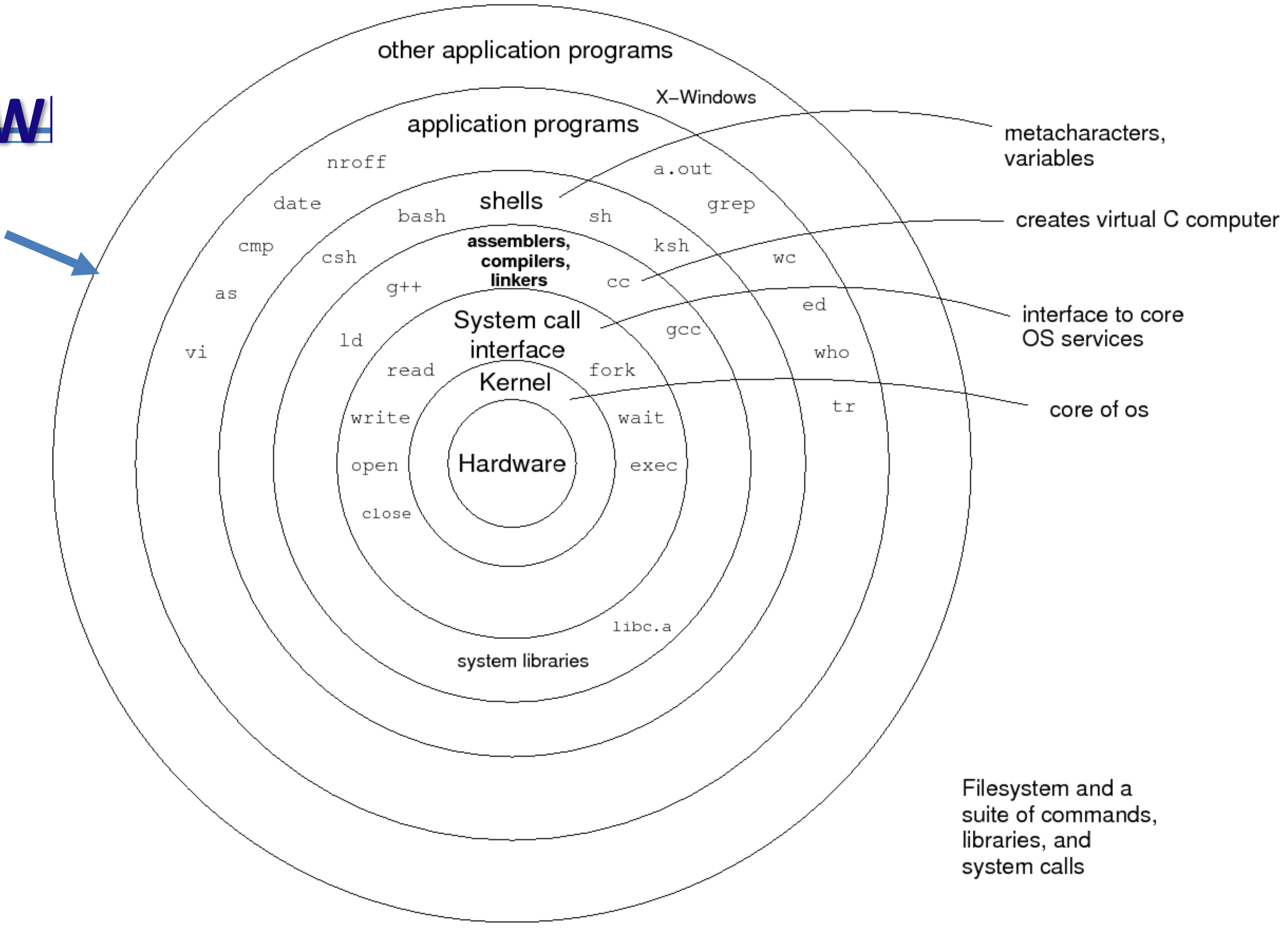
Some exercises

2. Write the following line in a file called file.txt. The value stored is 100. Use fscanf to read the value 100 from file.txt and store it in a variable <var>. Then write this value to another file file1.txt “Value read is <var>” using fprintf

Hint: fscanf(fp, "This is the value %d", &a); fprintf(fp1, "Value read is %d",a);

```
#include <stdio.h>
#include <stdlib.h>
int main() {
int a;
FILE * fp;
FILE * fp1;
fp = fopen("file.txt","r+");
fp1 = fopen("file1.txt", "w+");
fscanf(fp, "This is the value %d", &a);
fprintf(fp1, "Value read is %d",a);
fclose(fp);
return 0;}
```

W



other application programs
X–Windows
application programs
nroff
a.out
date
grep
cmp
wc
as
ed
vi
who
tr
shells
bash
sh
csh
ksh
assemblers, compilers, linkers
g++
cc
ld
gcc
System call interface
read
fork
write
wait
open
exec
close
Kernel
Hardware
libc.a
system libraries
metacharacters, variables
creates virtual C computer
interface to core OS services
core of os
Filesystem and a suite of commands, libraries, and system calls

Conceptual Architecture of UNIX SYSTEMS

From: The Design of the UNIX Operating System