CS 261-020
Data Structures

Lecture 2

C Basics

1/11/24, Thursday

Oregon State University

Odds and Ends

- Due 1/14 Sunday 11:59pm: Quiz 1
- Assignment 1 is posted

Lecture Topics:

- C Basics

C Basics – printf()

- How to print the content of a variable?
  - Passing a **format string** and accompanying arguments to `printf()`
    - *Format string*: a template for the text to be printed. Contains format specifiers into which specific value will later be inserted
    - *Format specifier*: start with a %, followed by a character describing the data

  - E.g.:

```
int x = 8;
printf("This is the value of x: %d\n", x);
```

C Basics – scanf()

- How to accept input from standard input (keyboard)?
  - In C++, we use `cin`
    - i.e., `cin >> var;`
  - In C, we use `scanf()`
    - i.e., `scanf(“%d”, &var);`

  - To read in more than one value, use multiple format specifiers
    - i.e.,

```
printf(“Enter two integers: \n”);
scanf(“%d %d”, &var1, &var2);
```

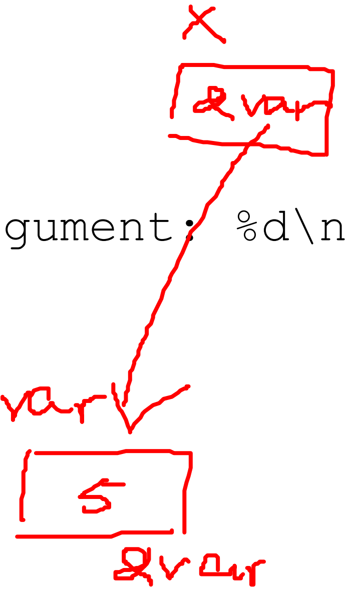
C Basics – Functions (cont.)

- Unlike C++, C has no reference types!
- Can only pass by value (or by pointers)

```
#include <stdio.h>

void foo(int *x) {
       printf("foo was passed this argument: %d\n", *x);
}

int main(int argc, char** argv) {
      int val = 5;
      foo(&val);
}
```



C Basics – Structures

- Unlike C++, C has no classes or class functions!
  - C++ is object oriented
  - C is procedural
- Use struct type to represent structured data in C
  - E.g., in C++, we might do:

```
Student s = new Student (“Harry Potter”);
s.print();
```

  - In C, we’d do:

```
struct Student s = {.name = “Harry Potter”};
print_student (s);
```

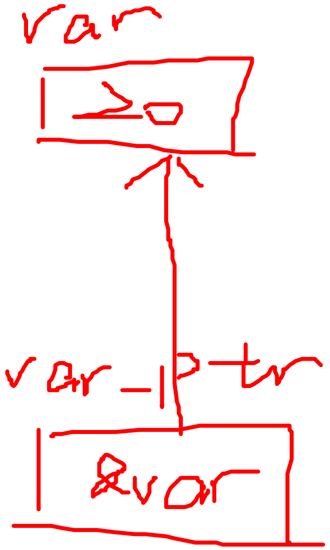
```
struct Student {
   char* name;
   int id;
   float gpa;
};
```

C Basics – Pointers

- A pointer is a variable whose value is a memory address
- Every pointer points data of a specific data type
  - E.g.,

```
int var = 20;
int *var_ptr = &var;
```

- Demo…

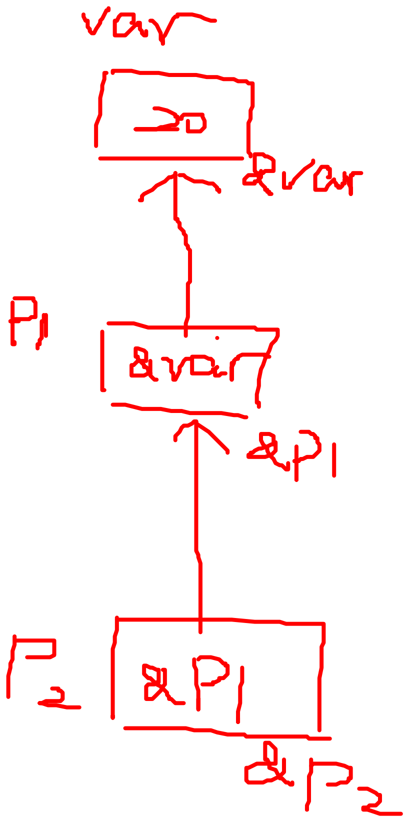


Ex. C Basics – Pointers

- A pointer is a variable whose value is a memory address
- Every pointer points data of a specific data type
  - Ex.,

```
int var = 20; //address of var: 0xfff0
int *p1 = &var; //address of p1: 0xffec
int **p2 = &p1; //address of p2: 0xffe4
```

`What prints 20?`	var	*p1	**p2
`What prints 0xfff0?`	&var	p1	*p2
`What prints 0xffec?`		&p1	p2
`What prints 0xffe4?`			&p2



C Basics – Void Pointers (void*)

- A void pointer is a pointer represented by the type `void*`.
- A void pointer is a generic pointer, it can point to data of any data type.
  - E.g., a void pointer points to an integer

```
int var = 20;
void *v_ptr = &var;
```

  - Can we use a `float*` instead of `void*`?
    - It gives us a warning…
  - Can use `void*` to point to any other type:

```
float pi = 3.1415;
struct Student s = {.name = "Harry Potter"};
v_ptr = &pi;
v_ptr = &s;
```

C Basics – Void Pointers (void*) (cont.)

- Void pointers cannot be dereferenced *directly* since there is no type information
  - E.g.

```
struct student s = { .name = “Harry Potter" };
void* v_ptr = &s;
printf("%s\n", v_ptr->name);  /* Compile-time error: can’t
                                 dereference void pointer */
```

- To dereference it, we need to move it back to a pointer variable of the correct type
  - E.g.

```
struct student* s_ptr = v_ptr;
printf("%s\n", s_ptr->name);
```

OR Cast it back

```
printf("%s\n", ((struct student*)v_ptr)->name);
```

C Basics – Void Pointers (void*) (cont.)

- Why `void*`?
  - It allows the data structures to contain data of any type while remaining type agnostic
- Demo...

C Basics – Program Memory (stack vs. heap)

- Stack: a small, limited-size chunk of memory from the larger blob of system memory
  - Stores local variables declared in functions,
  - Allocated at compile time, known as **statically allocated memory**
  - At most 8kb
- Heap: comprises essentially all the rest of system memory
  - A program must make requests to allocate memory from the heap
  - Allocated at runtime, known as **dynamically allocated memory**

C Basics – malloc()

- Allocating memory on the heap
  - In C++: use `new` operator
  - In C: use `malloc()` ← requires `#include <stdlib.h>`

- `malloc()`:
  - Allocates a contiguous block of memory
  - Arguments: number of bytes
  - Return: `void*`

```
void * allocated_memory = malloc(NUMBER_OF_BYTES);
```

C Basics – malloc() (cont.)

- How to figure out how many bytes to allocate?
  - Use `sizeof()`!
  - `sizeof()` – returns the size in bytes of a given variable or data type
  - E.g., `sizeof(int)` returns 4

- Q: How to allocate an array of 1000 integers on the heap?
  - `int* array = malloc(1000 * sizeof(int));`

C Basics – malloc() and struct

- Use malloc() with struct:
  - `struct Student *s = malloc(sizeof(struct Student));`

- To access the struct’s fields using the pointer:

```
(*s).name = “Harry Potter";
(*s).gpa = 4.0;
```

OR

```
s->name = “Harry Potter";
s->gpa = 4.0;
```

→ : (*__).

- To allocate an array of structs:
  - `struct Student* students = malloc(1000 * sizeof(struct Student));`

C Basics – Free dynamic memory

- We have to manually free memory allocated on the heap
  - otherwise → memory leak!
- How?
  - In C++, we use `delete`
  - In C, we use `free()`
  - E.g.,

```
int* array = malloc(1000 * sizeof(int));
...
free(array);
array = NULL;
```

- Rule of thumb: For every call to malloc() you should have a corresponding call to free()

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C Basics – valgrind

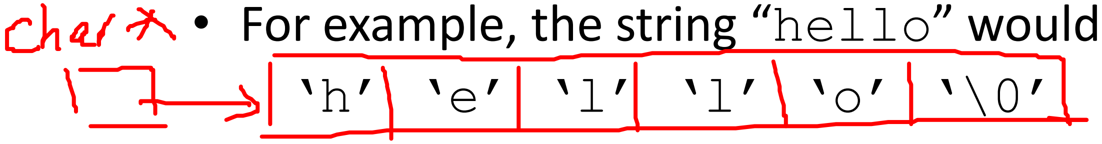
- Use `valgrind` to check if your program has memory issues:
  - `valgrind ./prog [cmd_line args]`
- To dig deeper into where memory was lost, pass the `--leak-check=full`:
  - `valgrind  --leak-check=full ./prog [args]`

- Demo …

C Basics – strings in C

- Unlike C++, there is no string objects in C
  - Thus, no `std::string` class
- Strings are represented in C as arrays of char values, i.e., `char*` type

- How do C strings indicate the end of the string?
  - Use a special character – null character (‘`\0`’)
  - Thus, C strings also called **null terminated strings**
  - For example, the string “`hello`” would look like this in memory in C:



`'h'` `'e'` `'l'` `'l'` `'o'` `'\0'`

← array of 6 characters

C Basics – strings in C (cont.)

- The null character is important → indicates the end of the string
- Functions rely on ‘`\0`’:
  - `printf()` – know when to stop processing the string
  - `strlen()` – returns the number of characters in a string
    - Count until it finds a null character

- Allocating memory to store a string: num of char + null char
  - Q: How many char can we store in the `str`?

```
char* str = malloc(64 * sizeof(char));
```

63 + null char

C Basics – strings in C (cont.)

- Constant strings in C:

```
char* name = "Harry Potter";
```

- Constant strings are read-only, thus cannot be modified.

```
name[0] = 'l'; //illegal but no error message
```

- Best to mark it be constant

```
const char* name = "Harry Potter";
name[0] = 'l'; //illegal with compiling error
```

C Basics – strings in C (cont.)

- Useful functions for C strings: → `#include <string.h>`
  - `strlen()` – returns the number of characters in the string
  - `strncpy()` – copy a specified number of characters from one string to another
  - `snprintf()` – “printing” content into a string, up to a specified number of characters
    - From `<stdio.h>`
  - `strcmp()` – compare two strings, returns 0 if they are equal

  - And many more… check string.h