Lecture 9: C Pointers

CSE 374: Intermediate Programming Concepts and Tools

Administrivia

HW2 due Thursday
HW3 getting posted later today – due Thursday Oct 28th
Reminder Midterm Friday Oct 29th
- last day of material for midterm Monday Oct 25th
- Bash + C programming

Where do computers store data?

- **CPU** – Central Processing Unit – computer circuitry that followed computer instructions in assembly
- **RAM** – Random Access Memory – a computer's short-term memory where data is stored during program operation
  - When a program ends the memory in use "goes away"
- **Hard disc storage** – a computer's long-term memory, this is where data is stored when you need to preserve it across re-starts.
  - Data is stored indefinitely
  - Can be modified by different processes

How do computers store data?

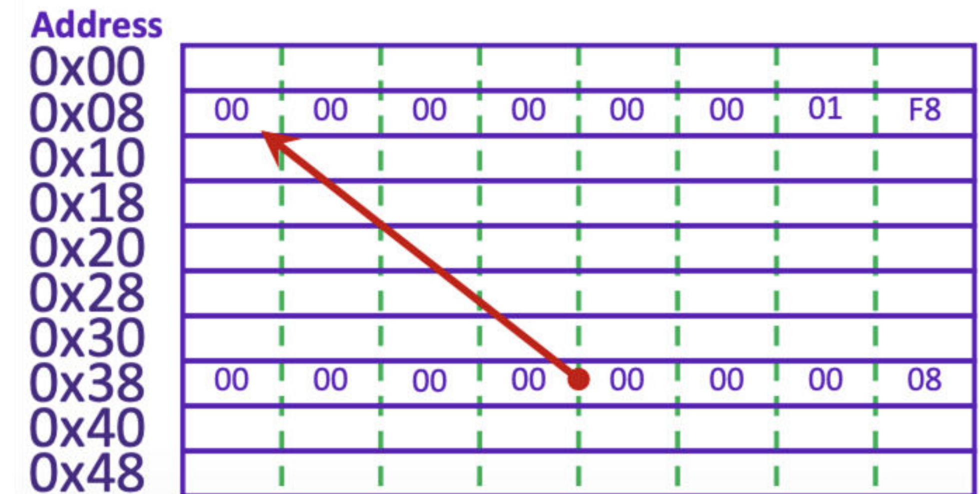
- Large sequences of numbers
  - Numbers are representations for electrical switches “transistors” that make up the brains of the CPU
- All data is binary – 1s and 0s
  - A single digit is called a “bit”
  - Bits come in groups of 8 called “bytes”
  - All instructions can be translated into sequences of binary
- Numbers represent other types of data
  - ASCII – each byte represents a letter of the English alphabet
  - Unicode – similar encoding structure to ASCII but covers a wider range of characters including non-English characters, emojis etc…
  - Images – represented by a 2D array of “pixels”
    - Each pixel is represented by 3 numbers: Red, Blue and Green values 0-255

english	h	e	l	l	o
ascii	104	101	108	108	111
binary	01101000	01100101	01101100	01101100	01101111

Binary Explained

Addresses in Memory

- Computer memory operates just like an array – addresses and the spaces they represent
  - Spaces are measured in ”bytes” of 8 bits
- Each space in memory is referred to by its address
  - Value 504 stored at address 0x08
  - Address of value 504 stored at 0x38
- A pointer is a data object that holds an address
  - Addresses can point to any type of data because they simply point to any space in memory
  - Like a “contact” object that stores someone’s phone number, doesn’t store the actual person
  - Pointers are also stored in memory
  - Pointers can point to other pointers! <follow down the rabbit hole>
  - Pointers can **either** point to a single variable or an array



Pointers

Storing in memory an address to another location in memory

```
int x = 4; // Variable called 'x' of type 'int' given value '4'
int *xPtr = &x; //Variable called 'xPtr' of type 'int pointer' given value 'location of x'
int xCopy = *xPtr; //variable called 'xCopy' of type 'int' given value 'value found at address xPtr'
int* noPtr = NULL; //variable called 'noPtr; of type 'int pointer' given value of 'null'
```

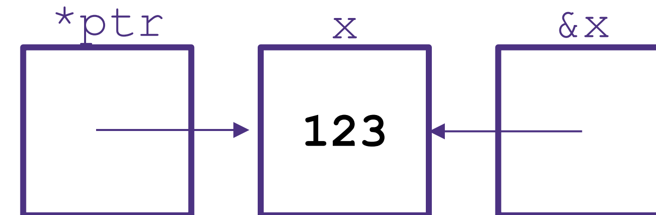

Pointer and Address Syntax in C

`int *ptr;` also works! Programmer preference

```
int* ptr; // a variable of type "pointer to int" without assignment

int x = 123; //an int variable called "x" that stores "123"

ptr = &x; // store the address of "x" in "ptr"
```



`*` Means "pointer to type"

- `*` placed after type indicates a pointer data type
  - Similar in java if you add [] after type you declare an array of that type
  - `int*` means "pointer to int"

`&` means "address variable"

- Placing an & before a variable name will give you the address in memory of that variable

Dereferencing Pointers

```
int x = 123;
int* ptr = &x;
*ptr = 456;
printf("new value of y:%d\n", *ptr);
```

- Placing a * before a pointer **dereferences** the pointer
  - Means "follow this pointer" to the actual data
  - `*ptr = <data>` will update the data stored at the address the pointer is referring to ie 'write to memory'
  - `*ptr` will read the data stored at the address indicated by the pointer
  - Accessing unused addresses causes a 'segmentation fault'
- A **dangling pointer** is one that points to a dead local variable
  - Data that is no longer in use
  - Dereferencing a dangling pointer is "undefined behavior" (UB)
  - UB means ANYTHING could happen
    - Program could crash(best case), silently fail(worst case)
    - GCC can catch this kind of error with a warning, but not always

Strings in C

```
char s1[] = {'c', 's', 'e', '\0'};
char s2[] = "cse";
char* s3 = "cse";
```

0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09
a	q	s	h	e	l	l	o	\0	r

All are equivalent ways to define a string in C

There are no "strings" in C, only arrays of characters

- "null terminated array of characters"

`char*` is another way to refer to strings in C

- Technically is a pointer to the first char in the series of chars for the string

Strings cannot be concatenated in C

```
printf("hello, " + myName + "\n"); // will not work
```

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Printf – print format function

- Produces string literals to stdout based on given string with format tags
  - Format tags are stand ins for where something should be inserted into the string literal
  - %s – string with null termination, %d – int, %f – float
  - Number of format tags should match number of arguments
    - Format tags will be replaced with arguments in given order
- Defined in `stdio.h`
- printf(“format string %s”, stringVariable);
  - Replaces %s with variable given
  - `printf(“hello, %s\n”, myName);`

https://en.wikipedia.org/wiki/Printf_format_string

Arrays

Contiguous blocks in memory

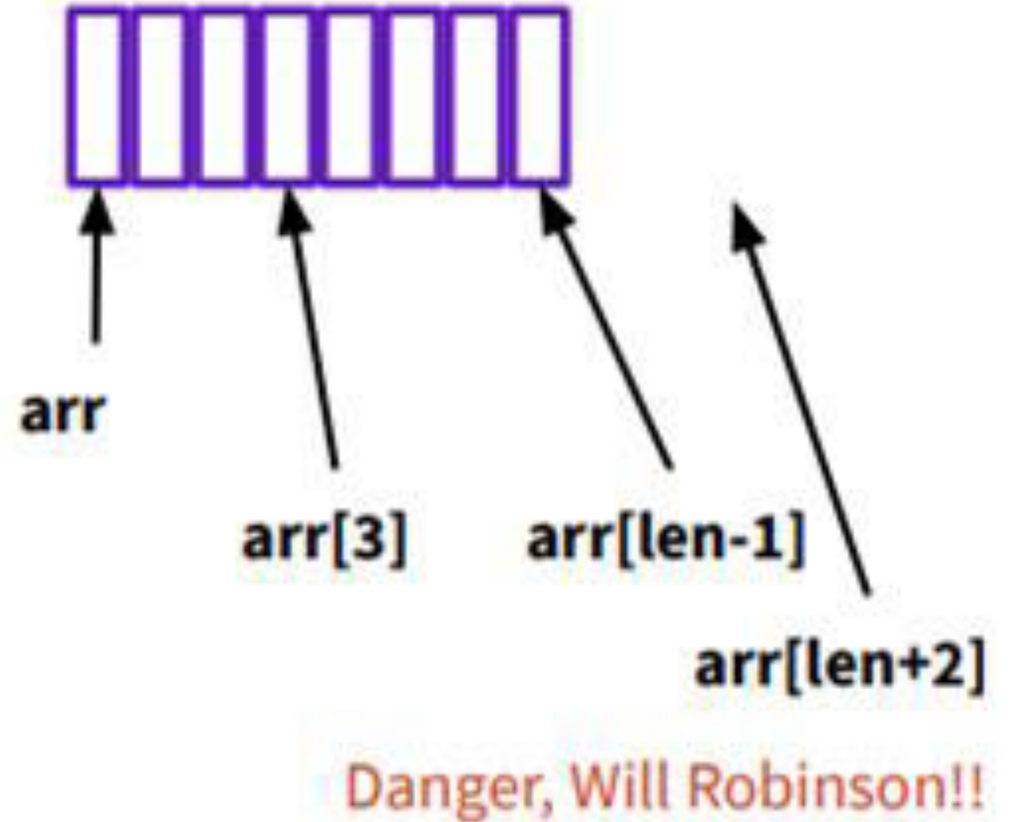
Declare as: `<datatype> arr[<len>]`

EX: `int* arrayOfInts = int arr[10];`

Stores location in memory of first value.

Does NOT store length, user must store and pass around separately.

Not automatically initialized to any value.



Demo: fopen, fgets

I/O : Printf, scanf

Printf and scanf are two I/O functions, prototyped in stdio.h

- Printf (print-format)
- int printf(const char *format, ...)
- 'Format' is a string that can contain format tags
- + additional arguments to match tags
- Number of arguments better match number of %
- Corresponding arguments better have the right types (%d, int; %f, float; %e, float (prints scientific); %s, \0- terminated char*; ... Compiler might check, but not guaranteed
    - best case scenario: you crash
- `printf("%s: %d %g\n", p, y+9, 3.0)`

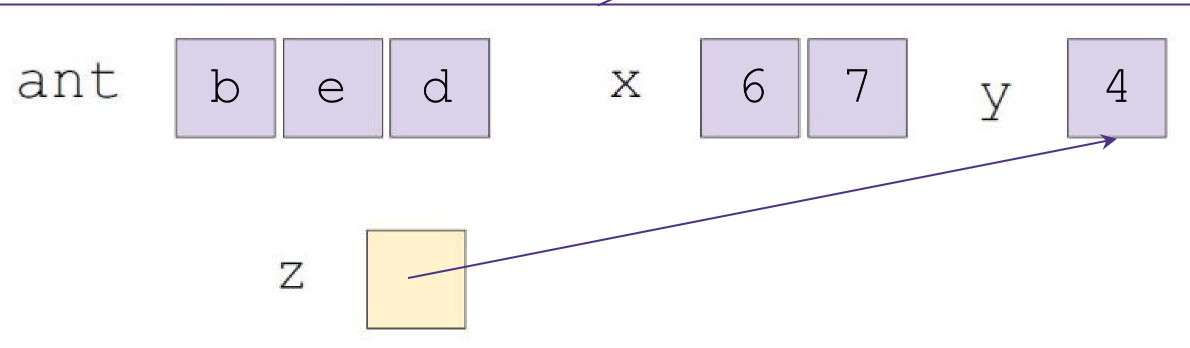
- scanf (gets input, formatted)
- int scanf(const char *format, ...)
- 'Format' is a string that can contain format tags
- + additional arguments to match tags - should be pointers to the right data type so input can be stored in them
- `scanf("%d %s", &n, str);`
- `scanf("%*s %d", &a);`
    - %*s ignores string until space, then reads in an integer

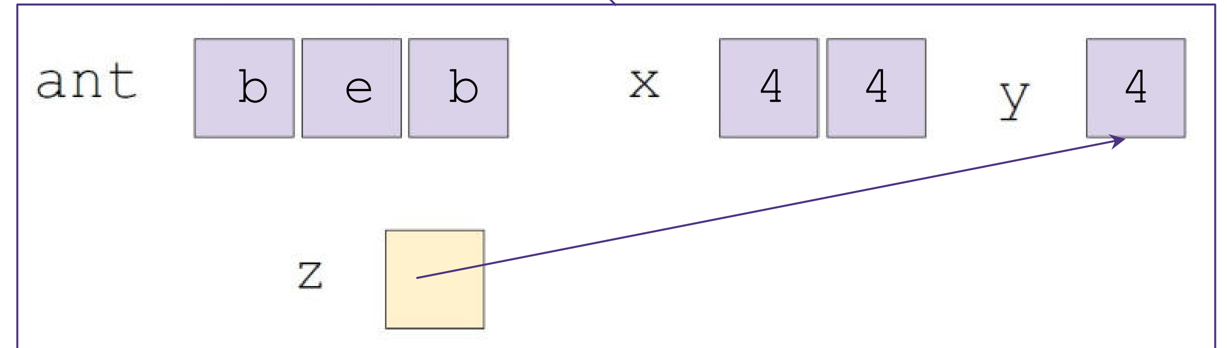
Puzzle: What Prints?

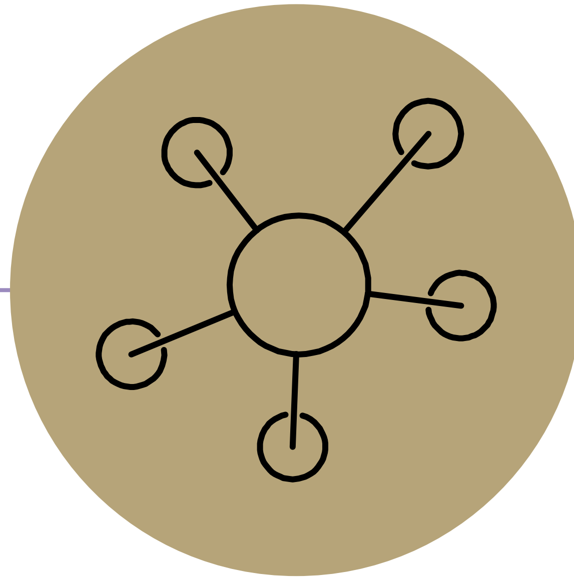
```
#include <stdio.h>
void mystery(char *a, int *b, int c)
{
    int *d = b-1;
    c = *b +c;

    *b = c - *d;
    *d = c - *d;
    a[2] = a[b - d];
}
```

```
int main (int argc, char **argv)
{
    char ant[4] = "bed";
    int x[3];
    *x = 6;
    x[1] = 7;
    int y = 4;
    int *z = &y;
    *z = *x;
    printf("%d %d %d %s \n", *x, x[1], y, ant);
    mystery(ant, x+1, y);
    printf("%d %d %d %s \n", *x, x[1], y, ant);
}
```







Questions

Example: echo.c

```
#include <studio.h>
#include <stdlib.h>
#define EXIT_SUCCESS = 0;
int main (int argc, char** argv)
{
   for (int i = 1; i < argc; i++)
   {
      printf("%s ", argv[i]);
   }
   printf("\n");
   return EXIT_SUCCESS;
}
```