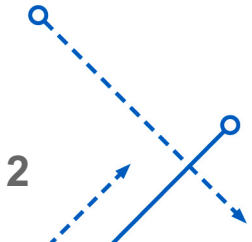
C Pointers

Karthik Dantu
Ethan Blanton
Computer Science and Engineering
University at Buffalo
kdantu@buffalo.edu

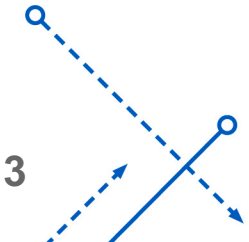
Administrivia

- Lab Exam 1 is next week
  - Missing lab is missing 5% of your grade
  - Lab Exam means exam, don't talk about it
  - NO external resources are allowed
  - No textbook, no notes, no friends, no google
  - man pages are allowed
  - If you understood PA0, you'll do well
- If you had >10 submissions for PA0, you are abusing the autograder – test your code on your own !
- PA1 will be released tonight



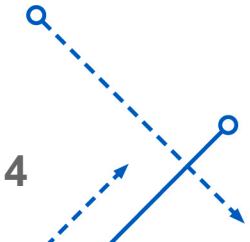
Memory

- Memory on POSIX systems is data storage identified by address
- All of the data accessible to your C program has an address
- On a POSIX system, every process appears to have its own memory
- This memory ranges from address zero to the maximum allowable address
- It may be the case that not all of it is available, however!
- On Unix systems, the usage of that memory is somewhat predictable



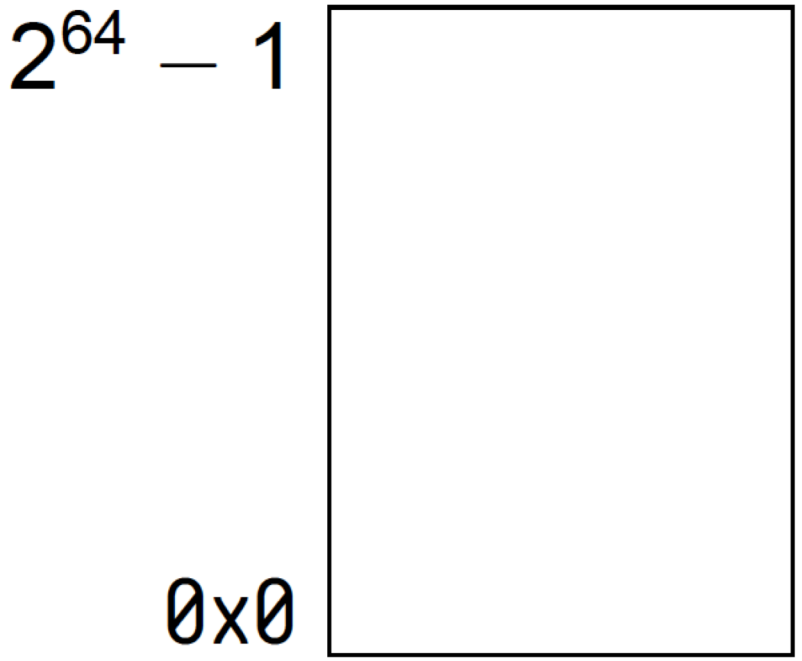
Pointers

- C pointers are variables that hold memory addresses
- Pointers lets your program interact with memory explicitly
- Pointers are very powerful, but potentially unsafe tools
- The C compiler doesn't know which pointers are valid!
- Most non-trivial data structures in C use pointers



Memory Addresses

- On our platform, you can consider memory as a large array
- A pointer is an index into that array
- If memory starts at address 0, a pointer with value p is the p'th byte of that array.
- Note that any given byte may not exist!



Pointer Concepts

- A pointer:
  - Contains an address
  - Allows the memory at that address to be manipulated
  - Associates a type with the manipulated memory
- Remember, to the computer, memory is just bits
- Programmers supply the meaning
- The special pointer value NULL represents an invalid address

Pointer Syntax

- A pointer variable is marked with *

```
char *str;
```

- This is a pointer to `char`

(`char *` is the idiomatic string type in C.)

- A pointer may be marked `const`, in which case the memory it points to is const

```
const char *str;
```

- It is a good idea to mark pointers `const` if you don't intend to modify their contents

Pointer Types

- What is a pointer to char anyway?
- An address of a character-size integer.

```
char *str = "Hello";
```

- This says:

  `str` contains an address

  The data at the object stored in `str` is of type char

Addresses

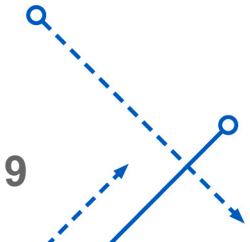
- Pointers must store a valid address
- There are limited opportunities to create valid addresses:

  Acquire the address of a variable

  Request new memory from the system

  Create a string or array constant

  Calculation from other addresses
- Pointers created in other manners probably are not valid



Pointer Syntax – Taking Addresses

- A pointer may be created from a variable using `&`
- This is sometimes called the address-of operator

```
int x = 42;
int *px = &x;
```

- `px` is now a pointer to `x`

(More on the implications of this later.)

Dereferencing a Pointer

- Dereferencing a pointer is accessing the data it points to
- It can be dereferenced to read or modify that data
- Dereferencing an invalid pointer is undefined behavior
- This will often result in a segmentation fault, but may silently corrupt memory!

Pointer Syntax — Dereferencing

- A pointer is dereferenced with `*`, `->`, or `[ ]`

(More on `->` when we get to structures)

- The `*` notation reads the value at the pointer address

```
int *px = &x;
int y = *px;
```

- The variable `px` is created as a pointer to `x`, an integer
- The variable `y` is created as an integer
- `y` is assigned the value of `x` by dereferencing `px` with `*`

Pointer Syntax - Dereferencing

- A pointer can also be dereferenced like an array, with `[]`

```
y = px[0];
```

- This is exactly the same as `y = *px;`

```
y = px[1];
```

- This treats `px` like an array, and retrieves the second element
- We will explore the mechanism by which this works more later.

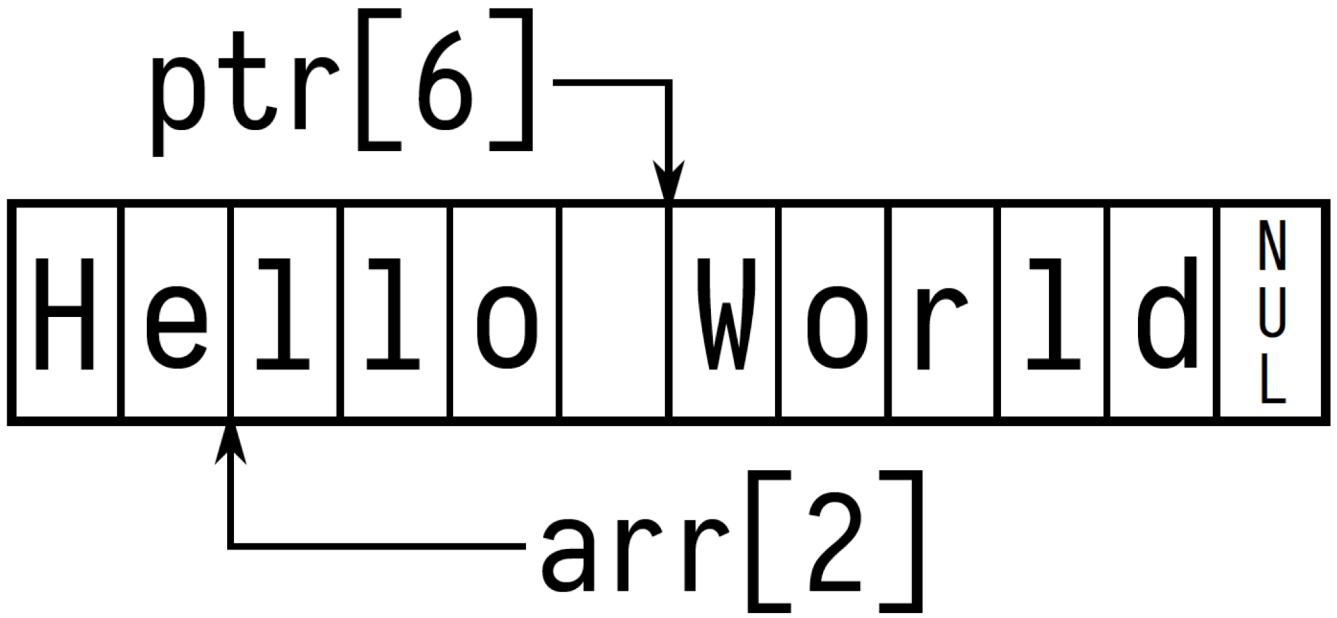
Pointers and Arrays

- Arrays and pointers are closely related in C
- You can often think of an array variable as a pointer to the first array element, and a pointer variable as an array
- However, they are not the same.
- In both cases, dereferencing with `[i]` says

  …add `i` times the size of the type of this variable to the base address (first element of the array or pointer value), then treat the memory at that location as if it is of the type of this variable.

Pointers and Arrays

```
char arr [] = "Hello World";
char *ptr = arr;
```



Arrays != Pointers

```
char arr [] = "string";
char arr2 [] = arr;
```

- “error: invalid initializer”

```
char arr [] = "Hello World";
char *ptr = arr;
```

- `ptr` points to `arr[0]`

Exploring Pointers

We will explore pointers in a program