COS 217: Introduction to Programming Systems

Pointers, Arrays, and Strings
POINTERS
Pointers in C

So... what’s a pointer?
• A pointer is a variable
• Its value is the *location* of another variable
• “Dereference” or “follow” the pointer to read/write the value at that location

Why is *that* a good idea?
• Copying large data structures is inefficient; copying pointers is fast
• \( x = y \) is a one-time copy: if \( y \) changes, \( x \) doesn’t “update”
• Parameters to functions are *copied*; but handy to be able to modify value
• Often need a handle to access dynamically allocated memory
Pointer types are target dependent

- Example: “int *pi;” – declares pi to be a pointer to an int
- We’ll see “generic” pointers later

Values are memory addresses

- ... so size is architecture-dependent – 8 bytes on ARMv8
- NULL macro in stddef.h for special pointer guaranteed not to point to any variable

Pointer-specific operators

- Address-of operator (&) – creates a pointer
- Dereference operator (*) – follows a pointer

Other pointer operators

- Assignment operator: =
- Relational operators: ==, !=, >, <=, etc.
- Arithmetic operators: +, -, ++, --, =, !, etc.

```
int iCyclic = 142857;
double dLookSay = 1.303577;
int *pi = NULL;
double *pd = &dLookSay;
pi = &iCyclic;
*pi = (int) *pd;
```
To Illustrate the Point...

```c
int iLife = 42;
int iJackie = 42;
int *piAdams = &iLife;
int *piBkn = &iJackie;
int **ppiMeta = &piAdams;

printf("%d %d\n",
    piAdams == piBkn, 0 1
    *piAdams == *piBkn);

printf("%d %d %d %d %d\n",
    ppiMeta == &piAdams,
    ppiMeta == &piBkn,
    *ppiMeta == piAdams,
    *ppiMeta == piBkn,
    **ppiMeta == *piBkn); <- same as *piAdams == *piBkn
```
piAdams = piBkn;

printf("%d %d\n", 
    piAdams == piBkn, 
    *piAdams == *piBkn);
Pointer Declaration Gotcha

Pointer declarations can be written as follows:

\[ \text{int* } \text{pi; } \]

This is equivalent to:

\[ \text{int *pi; } \]

but the former seemingly emphasizes that the type of pi is ("int pointer")

Even though the first syntax may seem more natural, and you are welcome to use it, it isn’t how the designers of C thought about pointer declarations.

\textbf{Beware!!!!!} This declaration:

\[ \text{int* p1, p2; } \]

really means:

\[ \text{int *p1; int p2; } \]

To declare both p1 and p2 as pointers, i.e.:

\[ \text{int* p1; int* p2; } \]

in one statement, you must "star" both vars:

\[ \text{int *p1, *p2; } \]
ARRAYS
Refresher: Java Arrays

- Always dynamically allocated
  - Even when the values are known at compile time (e.g., initializer lists)
- Access via a reference variable

```java
public static void arrays() {
    int[] arr1 = {1, 2, 3};
    int[] arr2 = new int[3];
    for(int c = 0; c < arr2.length; c++)
        arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}
```
C Arrays

- Can be *statically allocated* as local variables
  - Length must be known at compile time
- Can also be dynamically allocated
  - We will see this in Lecture 8

```c
void arrays() {
    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len = sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
        arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}
```
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    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len =
        sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
        arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}
```

<table>
<thead>
<tr>
<th>arr1[0]</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>arr1[1]</td>
<td>2</td>
</tr>
<tr>
<td>arr1[2]</td>
<td>3</td>
</tr>
<tr>
<td>arr2[0]</td>
<td>3</td>
</tr>
<tr>
<td>arr2[1]</td>
<td>6</td>
</tr>
<tr>
<td>arr2[2]</td>
<td>9</td>
</tr>
</tbody>
</table>
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void arrays() {
    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len = sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
        arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}
```
Pointer/Array Interplay

• Array name alone can be used as a pointer: arr vs. &arr[0]

```c
void arrays() {
    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len = sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
        arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}
```

```c
int *arr3 = arr1;
OR
int *arr3 = &arr1[0];
```
Pointer/Array Interplay

- Array name alone can be used as a pointer: `arr` vs. `&arr[0]`
- Subscript notation can be used with pointers

```c
void arrays() {
    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len = sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
        arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}

int *arr3 = arr1;
int i = arr3[1];
```
Array indexing is actually a pointer operation!

\[ \text{arr}[k] \text{ is syntactic sugar for } *(\text{arr} + k) \]

It follows that pointer addition is on elements, not bytes:

\[
\begin{align*}
\text{ptr} \pm k \text{ is implicitly} \\
\text{ptr} \pm (k \times \text{sizeof}(\ast \text{ptr})) \text{ bytes}
\end{align*}
\]

Pointer subtraction also works on elements, not bytes:

\[ (\text{ptr} + k) - \text{ptr} == k \]
Arrays with Functions

Passing an array to a function

- Arrays “decay” to pointers (the function parameter gets the address of the array)
- Array length in signature is ignored
- sizeof “doesn’t work”

Returning an array from a function

- C doesn’t permit functions to have arrays for return types
- Can return a pointer instead
- Be careful not to return an address of a local variable (since it will be deallocated!)

```c
/* equivalent function signatures */
size_t count(int numbers[]);
size_t count(int *numbers);
size_t count(int numbers[5]);
{
    /* always returns 8 */
    return sizeof(numbers);
}

int[] getArr();
int *getArr();
```
Dewch ymlaen, Cymru!

STRINGS
Strings and String Literals in C

A string in C is a sequence of contiguous chars

- Terminated with null char (\0) – not to be confused with the NULL pointer
- Double-quote syntax (e.g., "hello") to represent a string literal
- String literals can be used as special-case initializer lists
- No other language features for handling strings
  - Delegate string handling to standard library functions

Examples

- "abcd" is a string literal
- "a" is a string literal

Contrast

- 'a' is a character literal, not a string literal
  (really an int, as we've discussed)
Pointers for making a Lemon Gelatin Dessert

char string[10] = {'H','e','l','l','o','\0'};
(or, equivalently)
char string[10] = "Hello";

char *pc = string+1;

printf("Y%s\n", &string[1]));
printf("J%s!\n", pc);
#include <stdio.h>
#include <string.h>
#include <assert.h>
#include <stdlib.h>

enum { LENGTH = 14);

int main() {
    char h[] = "Hello, ";
    char w[] = "world!";
    char msg[LENGTH];
    char *found;

    if(sizeof(msg) <= strlen(h) + strlen(w))
        return EXIT_FAILURE;
    strcpy(msg, h);
    strcat(msg, w);
    if(strcmp(msg, "Hello, world!"))
        return EXIT_FAILURE;
    found = strstr(msg, ", ");
    if(found - msg != 5)
        return EXIT_FAILURE;
    return EXIT_SUCCESS;
}
Assignment 2: A String Module and Client

Purpose

The purpose of this assignment is to help you learn (1) arrays and pointers in the C programming language,