

CPT109: C Programming & Software Engineering I

Lecture 5: Arrays and Pointers 1

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Outline of Today's Lecture (5)

- One-dimensional arrays (review)
- Multi-dimensional arrays
- Arrays and loops
- Introduction to pointers
- Pointer Arithmetic

- But first a couple of things...

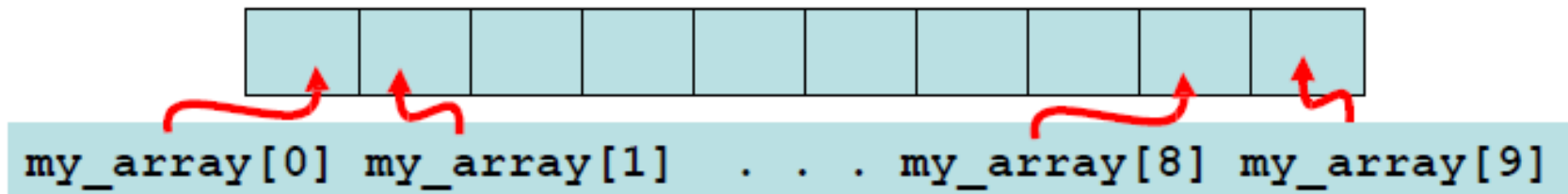
Arrays – An Introduction (1/2)

- In C, an array is essentially a group of elements all belonging to the **same type**, having the **same name**.
- Array elements are arranged **sequentially in the memory** space, but you can access them in any order.
- Each element of an array is accessed using an **index [an integer]**. The **index range** is from **zero** to **N-1**, where N is the array length.
- Arrays are commonly linked to pointers

Arrays – An Introduction (2/2)

Consider a 10 element array of integers called `my_array`:

```
int my_array[10];
```



`my_array[0]` – is the name of the first array element

`my_array[9]` – is the name of the 10th array element

`my_array[10]` – is outside of the array bounds

depending on the program accessing `my_array[10]` may cause a runtime error.

Declaring and Initialising Arrays (1/2)

- Arrays occupy space in the computer's memory
- Specifying the **array type** and the **number of elements** determines the amount of memory

```
int my_array[10];  
char x[100], y[20];
```

- Arrays can be initialised with a loop or at declaration:

```
for(i=0; i<10; i++){  
    my_array[i]=0;  
}
```

```
int array[10]={0};
```

Declaring and Initialising Arrays (2/2)

- Arrays can be declared and initialised at the same time with the help of initialisers.

```
int my_array[10]={1,2,3,4,5,6,7,8,9,10};  
float a[5]={3.0,2.0,3.0};
```

Any remaining elements are initialised to 0

```
int n[]={1,2,3,4,5};
```

**array size is omitted,
determined by initialised element number**

- The following causes a syntax error, Why?**

```
double x[5]={3.0,5.0,7.0,5.0,9.0,8.0};
```

- Initialisation of elements must begin at element 0.

Iterating through Array Elements

- A natural way to iterate through all of the elements of an array is to use a **for** loop:

```
int my_array[10]={1,2,3,4,5,6,7,8,9,10};  
printf("List all of the array elements");  
for(m=0;m<10;m++){  
    printf("%d \t",my_array[m]);  
}
```

It is wrong to try to access array elements outside of the declared array length, however depending on your compiler there may be no error... **be careful!**

Arrays and Strings

- Character arrays can be initialised by individual characters:

```
char text[]={'f','o','c','u','s','!'};
```

- They can also be initialised with a string:

```
char text[]={“focus!”};
```

Remember a string is a special character array ending in the **NULL** character **'\0'**.

Equivalent to:

```
char text[]={'f','o','c','u','s','!','\0'};
```


gets

Reading Strings

`char text[5];` Maximum string length 4 + NULL `'\0'`.

Functions to read strings:

- `scanf("%s", text);` Cannot read the space
- `gets(text);` No array bound checking

Reading Strings

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Options:

- `scanf("%Ns", text);` Enter a number of characters N
- `fgets(text, N, stdin);` Can read spaces

`fgets` must specify where to read from:

`stdin` refers to the computer standard input i.e. the keyboard.

Quick Quiz 1 – About Arrays

Which of the following statements is NOT true?

- a) An array is a list of data elements stored consecutively in memory.
- b) All the elements of an array are initially zero.
- c) Array elements are accessed using an integer subscript.
- d) Array elements can be modified using assignment statements.
- e) Array elements must all be of the same data type.

Quick Quiz 1 – About Arrays

Which of the following statements is NOT true?

- a) An array is a list of data elements stored consecutively in memory. **T**
- b) All the elements of an array are initially zero. **F**
- c) Array elements are accessed using an integer subscript. **T**
- d) Array elements can be modified using assignment statements. **T**
- e) Array elements must all be of the same data type. **T**

Two Dimensional Arrays

- In C, **two-dimensional arrays have two subscripts**, normally considered as: **[rowIndex][columnIndex]**

	ABZ	INV	GLA	EDI	
0	ABZ	0	106	147	125
1	INV	106	0	173	157
2	GLA	147	173	0	48
3	EDI	125	157	48	0
	0	1	2	3	

```
int miles[4][4] =  
{ { 0, 106, 147, 125 },  
  { 106, 0, 173, 157 },  
  { 147, 173, 0, 48 },  
  { 125, 157, 48, 0 } }; Or  
int miles[][4] = {0,106,147,125,106,0,173,  
157,147,173,0,48,125,157,48,0};
```

Example distances between pairs of cities

- The first row is highlighted to show the element order [0][[0...3]]
- The rowIndex can be left empty as long as initialisation is performed. The compiler can determine the number of rows.

Nested Loops and Arrays

- **Remember**, we looked at nested **for** loops:

```
char array[4][4];  
for(c=0;c<4;c++){  
    for(r=0;r<3;r++){  
        array[r][c]=' '  
    }  
}  
array[1][2] = '?';
```

	0	1	2	3
0				
1			?	
2		?		

More Dimensions

You can define arrays with as many dimensions as you like

A two dimensional array looks like a table

A three dimensional array looks like a stack of tables

```
float table[3][5][2];
```

3 nested loops would be required to process through all of the elements in this array.

Quick Quiz 2 - Counting

What will be printed out?

- a) 31
- b) 59
- c) 90
- d) 120
- e) 151

```
int days[]={31,28,31,30,31,30,  
            31,31,30,31,30,31};  
int i=0, sum=0;  
while(i<4)  
    sum = sum + days[i++];  
printf("sum=%d\n", sum);
```


Quick Quiz 2 - Counting

What will be printed out?

- a) 31
- b) 59
- c) 90
- d) 120
- e) 151

```
int days[]={31,28,31,30,31,30,
             31,31,30,31,30,31};
int i=0, sum=0;
while(i<4)
    sum = sum + days[i++];
printf("sum=%d\n", sum);
```

Pointers – An Introduction

Take a deep breath and prepare yourself...

Every **variable** is stored in the computer's **memory** at a specific **address**. Just like you living in your home at your street address.

A **pointer** is a variable used to **store the address** of another variable.

Pointers – An Introduction

- Pointers are declared to **point at** a specified **type of variable** i.e. a **float** pointer must point at a **float** variable, an **int** pointer must point at an **int** variable
- Internally a pointer is stored as an **unsigned int**
- However you **cannot** use a pointer like an **int**
e.g. you cannot multiply pointers

Pointer Declaration

Specify what type of variable the pointer points at

```
int *pAge;           /*pAge can point at an int*/
```

```
double *pHeight; /*pHeight can point at a double*/
```

pAge and pHeight are pointers, they store addresses

int and **double** variables use different numbers of bytes (4 and 8).

Do pAge and pHeight need a different number of bytes?

Pointer Declaration

Specify what type of variable the pointer points at

```
int *pAge;           /*pAge can point at an int*/
```

```
double *pHeight; /*pHeight can point at a double*/
```

pAge and pHeight are pointers, they store addresses

int and **double** variables use different numbers of bytes (4 and 8).

Do you think pAge and pHeight need a different number of bytes? **NO – they store the same thing!**

The Dereference Operator '*'

The * operator is used to operate with a specific address

pAge is a **pointer** variable used to **store** an **address**

*pAge is the **value** stored **at** that **address**

**If pAge points to
an integer**

- ***pAge is the integer
pointed at**

The Address of Operator '&'

Placing the '&' operator in front of a variable finds the **address of** that **variable**.

If Age is a variable, &Age is the address of that variable.

scanf() makes use of the & operator to determine where to store the value entered in memory

```
int Age;  
scanf("%d", &Age);
```

Using pointers and their op's

Things you can do with a pointer:

- De-referencing (Value finding)

- Assignment (Value storage)

- Taking the address of a pointer

- Incrementing a pointer

- Decrementing a pointer

- Differencing two pointers

Pointer Assignments

Assigning an address to a pointer:

```
int x, y[3]={10,20,30}, *p1, *p2;
```

```
p1=&x;    /* assign address of x to p1 */
```

```
p2=y;     /* assign address of y[0] to p2 */
```

```
p2=&y[2]; /* assign address of y[2] to p2 */
```

- **Note** the array name 'y' is equivalent to &y[0]
- Also, notice the pointers are type **int** and point at **int** values

Pointer Address

A pointer is a variable...therefore it has it's own address

```
printf("%p",&pArray);  
/* print the address of a pointer */
```

- pArray is a pointer variable stored in the computer memory.
- The '&' operator tells us where it is stored
- Format specifier %p %u or %lu can be used to print an address (it is an unsigned int or unsigned long)

De-referencing (Variables)

- Finding the value stored at another address **'***
- If the address of another variable is stored in a pointer, the pointer can access that variables value

```
int x=4, *p;  
p=&x;           /* assign the address of x to p */  
printf("%d", *p);  
/* print value stored at the address pointed at by  
p, which is 4) */  
*p=10;          /* place value 10 at memory address */  
printf("%d",x);
```

De-referencing (Variables)

- Finding the value stored at another address ‘*’
- If the address of another variable is stored in a pointer, the pointer can access that variables value

int x=4, *p;

p = &x;

Address	Value	Name
60ff10 - 60ff13	4	x
60ff14 - 60ff17	60ff10	p



*p = 10

Address	Value	Name
60ff10 - 60ff13	10	x
60ff14 - 60ff17	60ff10	p



De-referencing (Arrays)

- What if the pointer is used to point to an array?

```
int x[5]={4,2,3,8,9}, *p;  
p=x;  
printf("%d", *p);  
p=&x[2];  
printf("%d", *p);
```

What values are printed here?

4 and 3 (x[0] and x[2])

Moving Pointers

- **Incrementing** (++) and **Decrementing** (--) is possible with pointers.
- The value contained in the pointer is an address. Incrementing and Decrementing **moves** the **number of bytes for** the **variable type**.

```
int x[5]={4,2,3,8,9}, *p;  
p=x;  
printf("%d %p\n", *p, p);  
p++;  
printf("%d %p", *p, p);
```

Q. If the address &x[0] = 0022FF1C and there are 4 bytes per integer value. What is printed on the screen?

Moving Pointers

Q. If the address $\&x[0] = 0022FF1C$ and there are 4 bytes per integer value. What is printed on the screen?

```
int x[5]={4,2,3,8,9}, *p;  
p=x;          \* assigns &x[0] to p *\br/>printf("%d %p\n", *p, p);  
p++;  
printf("%d %p", *p, p);
```

4 0022FF1C

2 0022FF20

Moving Pointers

Q. If the address $\&x[0] = 0022FF1C$ and there are 4 bytes per integer value. What is printed on the screen?

```
int x[5]={4,2,3,8,9}, *p;  
p=x;          \* assigns &x[0] to p *\br/>printf("%d %p\n", *p, p);  
p++;  
printf("%d %p %p ", *p, p, &p);
```

If I include the value $\&p$ what else is printed?

The address of variable p (unknown here)

Moving Pointers

Be careful with precedence when working with pointers:

***p++ and (*p)++ are not the same**

* and ++ are both unary operators the precedence is from right to left

***p++** will get the value from the current address and then increment the pointer.

(*p)++ will get the value from the current address and add 1 to that value

Pointer Subtraction

Differencing (or subtracting) two pointers can be used to determine how many elements apart two elements are in an array.

```
int x[5]={4,2,3,8,9}, *p1, *p2;  
p1=&x[0];  
p2=&x[2];  
printf("%d %d", *p1-*p2, p2-p1);
```

Only useful if
pointers are
pointing to
elements in the
same array

What is printed in this case?

The first value is $4-3=1$

The second value is 2 because the addresses are 8 bytes apart which is equivalent to 2 integers sizes

!!!!!!WARNING!!!!!!

NEVER dereference an uninitialized pointer:

```
int *ptr    /* this is an uninitialized pointer  
            ptr contains a random value */  
  
*ptr = 5;   /* this is a very bad error */
```

This is trying to store a value in an **unknown location**
It could **overwrite** important **data**!

Pointers and Arrays (1/3)

Consider the following code extract:

```
float b[5] = {1.0, 2.0, 3.0, 4.0, 5.0};  
float *bPtr;  
bPtr=&b[0];
```

- Array element **b[3]** can be referenced by the pointer as:
 - ***(bPtr+3)**
 - ***(b+3)**
- The address of **&b[3]** is equivalent to **bPtr+3**

Pointers and Arrays (2/3)

- **char** s[] and **char** *s are equivalent (for any type)
- The following are **valid** pointer operations:
 - Assignment of pointers to same type variables
 - Adding or subtracting an integer and a pointer
 - Subtracting or comparing two pointers to elements of the same array
 - Assigning or comparing to zero
- **ALL other** operations are **illegal!**
- Behaviour is undefined for operations on pointers to elements of different arrays

Pointers and Arrays (3/3)

- **Pointers** are strongly related to arrays in C
- **Pointers** provide a symbolic way to use **addresses**
- **Pointers** are the most efficient way to deal with **arrays**

```
float a[5];  
printf("a=%p\n &a[0]=%p\n", a, &a[0]);
```

The name of the array **a** and the address of the first element **&a[0]** mean the same thing

Why is it useful to use a pointer for an array?

Operational use a++ illegal, processing efficiency

Pointers: Do's and Don'ts

Consider:

```
int one[3];  
int *ptr1, *ptr2;
```

Valid

`ptr1++;`

`ptr2 = ptr2 + 2;`

`ptr2 = one + 1;`

Illegal

`one++;`

`ptr2 = ptr2 + ptr1;`

`ptr2 = one + ptr1;`

Note: it is not legal to add, divide, multiply etc. two pointers or add a float or double, or assign a pointer of one type to a variable of another without a cast.

Quick Quiz 3

Which value does ptr point at after the code finishes?

```
int a = 7;  
int *ptr;  
ptr = &a;  
a += 5;  
printf("Value pointed to is %d", *ptr);
```

- a) 7
- b) 5
- c) 12
- d) 0
- e) undefined

Quick Quiz 3

Which value does ptr point at after the code finishes?

```
int a = 7;  
int *ptr;  
ptr = &a;  
a += 5;  
printf("Value pointed to is %d", *ptr);
```

- a) 7
- b) 5
- c) 12
- d) 0
- e) undefined

Quick Quiz 4

Which value does ptr point at after the code finishes?

```
int a = 7;  
int *ptr;  
ptr = &a;  
*ptr += a++;  
printf("Value pointed to is %d", *ptr);
```

- a) 7
- b) 8
- c) 14
- d) 15
- e) undefined

Quick Quiz 4

Which value does ptr point at after the code finishes?

```
int a = 7;  
int *ptr;  
ptr = &a;  
*ptr += a++;  
printf("Value pointed to is %d", *ptr);
```

- a) 7
- b) 8
- c) 14
- d) 15
- e) undefined



Questions?

Keep attending the labs 😊
We're here to help