C Built-in Arrays

This set of slides covers very important materials that were NOT covered in ENGG 233

Readings from textbook, C In Nutshell.

Pages: 111 – 116, 120

Arrays - Introduction

- **The definition given in your textbook:**
  - An array contains objects (instances) of a given type, stored consecutively in a continuous memory block.
- An array definition has the following syntax:

type_name identifier [number_of_elements];

- Examples of declaration of arrays with fixed length:

```
int a[3] = {44, 66, 85};          // declares an array of three integers
char c[3] = {'A', 'M', 'D'};      // declares an array of three characters
double z[3] = {2.3, 5.5, 7.8};    // declares an array of three doubles
```

a[0]	44
a[1]	66
a[2]	85

c[0]	'A'
c[1]	'M'
c[2]	'D'

z[0]	2.3
z[1]	5.5
z[2]	7.8

Arrays – Declaration

- Arrays can have any storage classes:
  - Can be declared outside all function.
  - Can be declared as local variable.
  - Can be declared within a block.
  - Can be declared as other storage classes such as local or global ***static*** (we will discuss about the keyword ***static*** later in the course).
  - The only restriction is that no function parameter can be an array. We will see later that an array argument passed to a function is always converted into a pointer to the first array element.
- C99 also allows declaration of arrays with variable-length at the **runtime**.
  - Examples:

```
double x [5 * 2];
duble y [200 + 2];
int x = 20;
double z [ x * 5 ];
```

Arrays – Access to Elements of the Array

- Accessing array elements:
  - Puts 99 into the third element of z:

```
z[2] = 99;
```

- Displaying the element's value:
  - Displays the third element of array z

```
printf("%d", z[2]);
```

  - How to display all element of z?
    - By using a for loop
- Reading and storing value into the array element:
  - Reads three integer numbers and stores into the the first three elements of the array z:

```
for(int I = 0; I < 3; i++) {
    printf( "\nEnter a number: ");
    scanf("%d", &z[i]) ;
}
```

Arrays - Initialization

- Initializing Arrays:
  - To initialize an array explicitly when you define it, you must use an initialization list:

    ```
    int a[5] = { 10, 23, 33, 44, 66};
    ```

  - If you do not explicitly initialize an array variable, the usual rules apply:
    - If array has automatic storage, its elements have undefined values.
    - For other storage classes, all elements are initialized to the value 0.
  - You cannot include an initialization in the definition of a variable-length array.
  - You may omit the length of the array, if you supply an initialization list:

    ```
    int a[ ] = { 10, 23, 33, 44, 66};
    ```

  - If array declaration contains both length and initialization list, then the length is indicated by the length between square brackets.
    - Any element with no initializer is initialized to zero.
    - If the list has more initializers than the array length, the superfluous initializers are ignored.

Arrays – Copying Issues

- Unlike data structures in some other language, arrays in C can not be copies.

```
int  a [ 2];
int b [2];
a[0] =  55;
a[1] = 60;
b = a;   // ERROR -- NOT allowed
```

- Unlike arrays in Processing, C arrays don't do index range checking.
  - Let's see an example:

Array of Characters
and
C-Strings

What is Character and What is a Character Constant

- Character in C is one byte memory space (or in fact a one byte integer).
- You can either assign an integer or a character constant in a character data type:

```
char c;
c = 65;
c = 'A';
```

- A character constant is confined between **single quotation** marks. A character constant can be a letter, a digit, or a non-printing character such as '\n'.

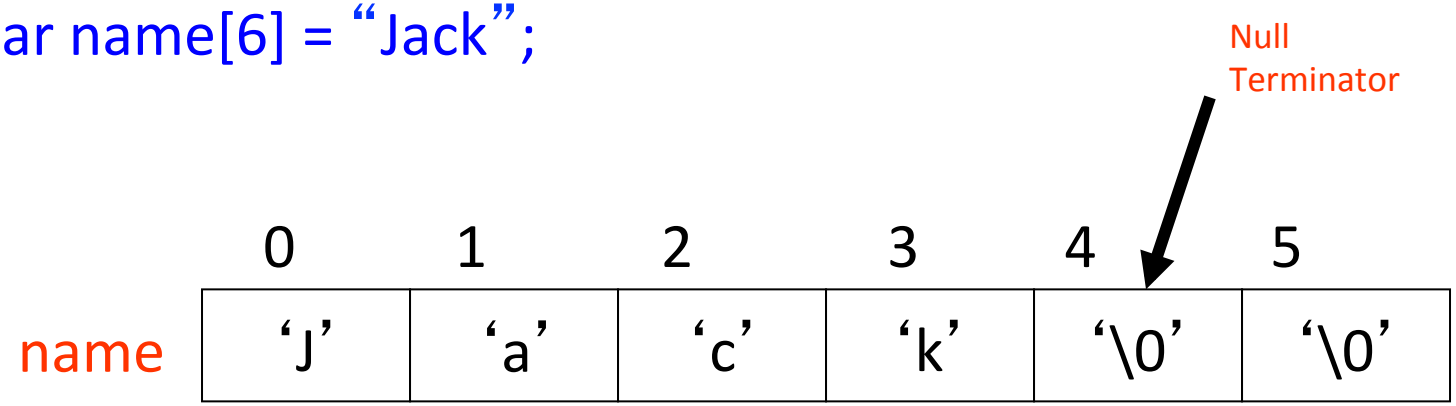
```
c = '3'
c = '\n'   // non-printing – end of line
```

- String constants are confined between double quotation marks:
  - "ABACDD"
  - "Judy"
  - "ENCM 339"
  - "34890'

C-Strings

- Basically, a string is represented by an array of characters which is terminated by a NULL ('\0') character.
- Null termination is only used for strings.
- Example:

```
char name[6] = "Jack";
```



Printing Strings and Characters

- Initializing array of characters and strings in C :

```
char str1[5] = "Apple"; // OK, as an array of chars, but not C-string
char str2[]   = "XYZ" ; // OK, as array of characters and C-string
char str3[3] = "AB";    // OK, as array of characters and C-string
char charArray [3] = {'X','Y','Z'};// OK as array of characters - not a C-string
```

- Access to the data in an element of a string:

```
printf("%c", str1[3]);                    //displays 'l' (ell)
printf("%c", str2[2]);                    //displays 'Z'
```

- Displaying strings:

```
printf("%s", str2);   //displays: XYZ
```

  – printf displays all characters starting from element zero, that up to the last element before the element that contains '\0'.

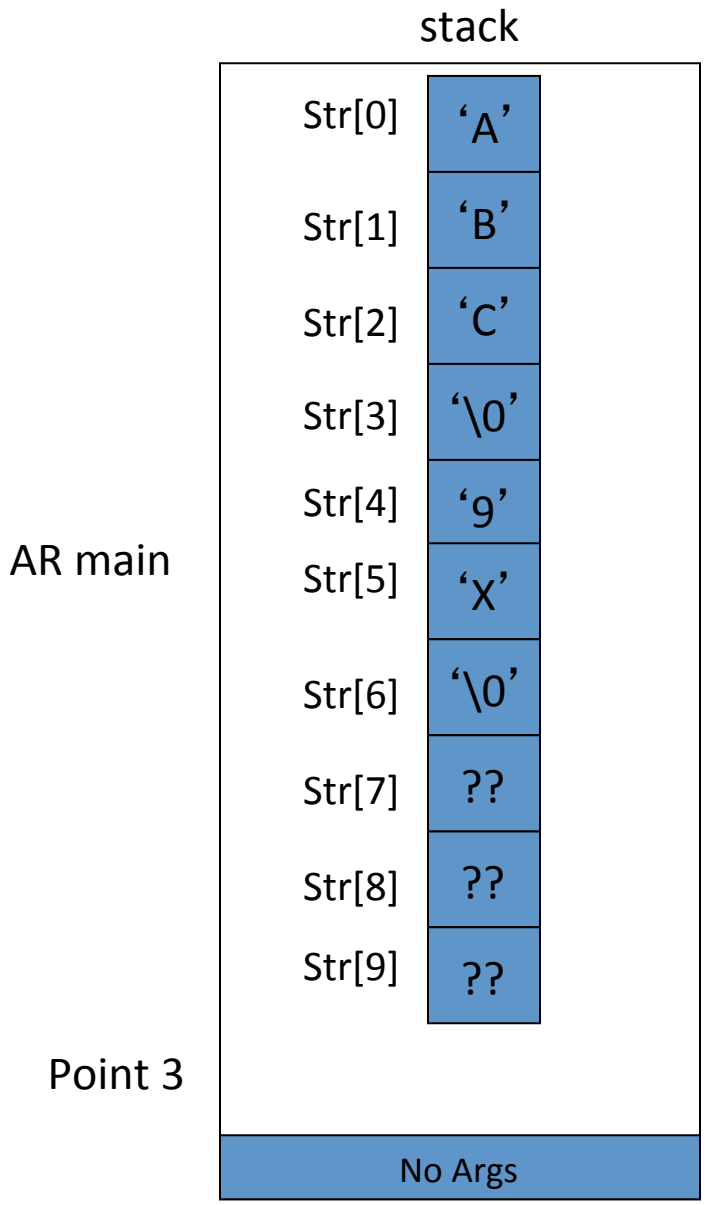
Question: Draw AR diagrams at point 1, 2, and 3? What is the program output?

```
int main(){
    char str[10];
    str[0] = 'A';
    str[1] = 'B';
    str[2] = 'C';
    // point 1

    str[3] = '\0'
    str[4] = '9';
    // point 2

    printf ("%s", str);
    str[5] = 'X';
    str[6] = '\0';
    // point 3

    printf ("%s", str);
    return 0;
}
```



Arrays and Pointers

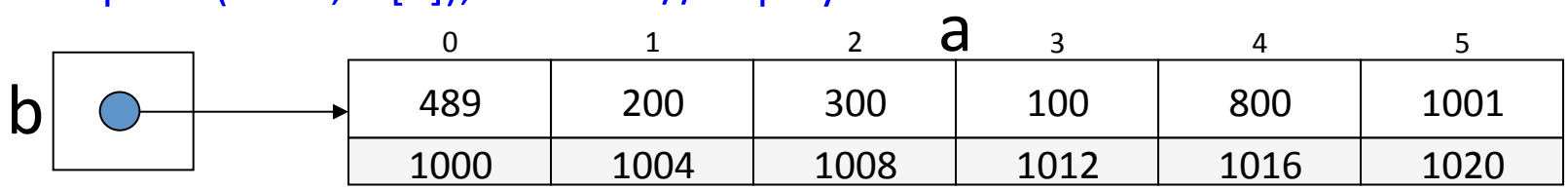
Arrays and Pointers

- The name of built-in arrays in C and C++ is treaded as a pointer
  - The name of an array holds the address of the first byte of the first element.
  - In other words the name of an array can be treated like a fixed-pointer that points always to the first element of the array (it can not hold another address).

```
int a [6] = {4, 2, 3, 1, 8, 11};
printf("%d",  *a);          // Using Pointer Notation – prints 4
printf("%d",  a[0]);        // Using Array Notation– prints 4
printf("%d",  a[5]);        // prints 11
```

- Another Examples:

```
int a[6] = {489, 200, 300, 100, 800, 1001};
int *b;
b = a;
printf("%d",  *b);          //displays 489
printf("%d",  *a);          //displays 489
printf("%d",  b[4]);        //displays 800
printf("%d",  a[4]);        //displays 800
```



Strings and Pointers

- A string name is also a pointer to the first element of an array of characters.

```
char name[6] = "Jack";
```

Null Terminator

0	1	2	3	4	5
'J'	'a'	'c'	'k'	'\0'	'\0'
1000	1001	1002	1003	1004	1005

- The following statement is true:

```
name == &name[0]
```

Address of name [0]

- Displaying strings:

```
printf("%s", name);        //displays jack
```

  – printf displays all characters from name[0] to name[3].

Arrays and Functions

Passing Arrays to Functions

- You can pass an array to a function by passing the name of the array as an argument.
- You may also need to pass the number of elements of the array to the function.
- Since the name of the array is the address of the first element of the array, a function argument must be a pointer to hold this value.
- Example:

```
#include <stdio.h>

int largest (const int *arr, int n);

int main()
{
   int x[5] = {90, 3, 4, 5, 1};
   int result;
   result = largest (x, 5); //only the name of the array is passed
   printf("The largest value is %d.", result);
   return 0;
}
```

Arrays as Function Arguments

As a function argument you can either use a pointer notation (int*), or array notation ([]).

- Argument arr in both cases in the following examples is a pointer, pointing to the first element of the array x in main.
- Within function largest, the value of any element of array x in main can be accessed via pointer arr.

```
int largest(const int *arr, int n)
 {

    int j;
    int max = arr[0];

    for (j = 1; j< n; j++)
         if (arr[j] > max)
           max = arr[j];

    return max;
}
```

```
int largest(const int arr[], int n)
 {

    int j;
    int max = arr[0];

    for (j = 1; j< n; j++)
         if (arr[ j ] > max)
           max = arr[j];

    return max;
}
```

Using `scanf` to Read Strings and Characters

Reading Strings and Characters using scanf

- scanf uses %s as a type identifier to read a string (up to a whitespace) from keyboard .

```
char lastName[25];
printf ("Enter your last name: ");
scanf ("%s", lastName);
```

  - Three character: spacebar, tab and return are considered as whitespace characters.
- scanf doesn't need an address operator to read a string. Why?
- scanf uses %c as a type identifier to read a character.

```
scanf ("%c", &lastName[0]);
```

  - Needs address operator to read a character.
- scanf is not the only library function to read strings and characters. There are other library functions such as:

gets, fgets, getc, fgetc.

Using const keyword as a Function Argument

- When pointers are supposed to be used as read-only pointer you should use the const keyword.
- This style programming protects you data from malicious and unwanted changes.

```
void doSothing( const double *p)
{
   *p = 100.5;       // illegal

   // more code..
}
```

Pointers to Constant Characters

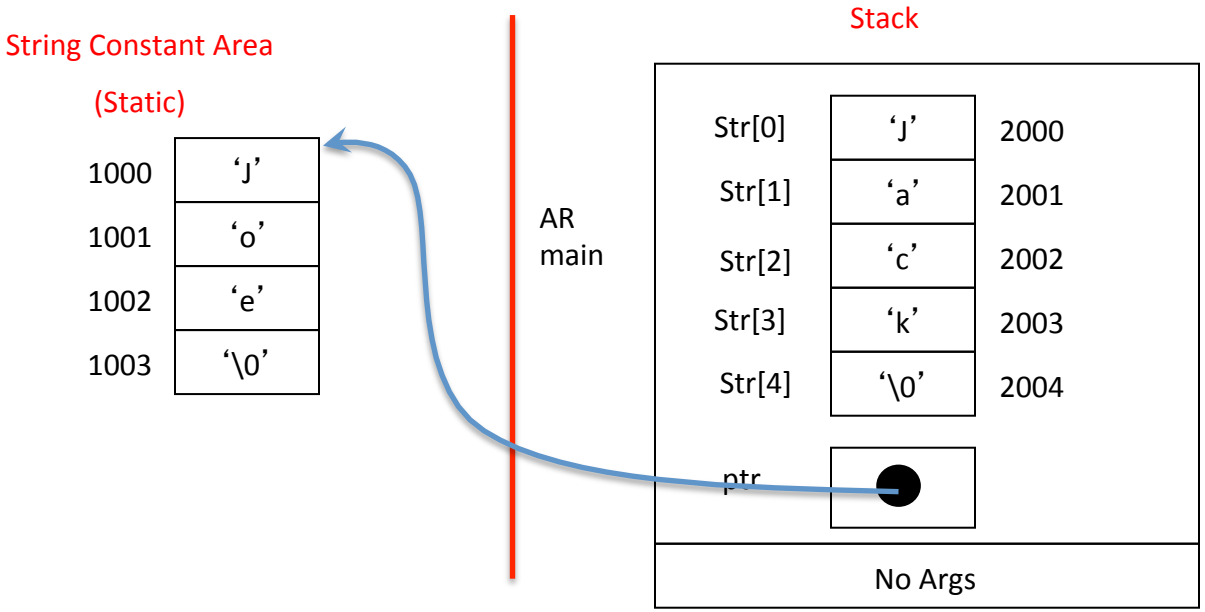
Using const char* to Declare a C-string

- Another way to define a c-string in C/C++ is to use a char*, pointing to a string constant on the static memory segment.

```
char * p   = "KLH" ;              // bad style. Why?
const char * ptc   = "CBC";       //  better style – ptc is a pointer to a const
```

- How do we show this type of declaration in an AR diagram:
  - Assume the following declarations are in a main function;

```
char str[ ] = "Jack";
const char *ptr = "Joe";
```



What is the size of an array
and
what is the size of a pointer

Size of Memory Spaces Allocated to Different Data Types

- If you are not sure about the size of a data type in C/C++ you can use the **sizeof** operator to indicate its size. Here are some examples of using **sizeof** opertor:

```
sizeof(double);   // returns 8
sizeof(int);      // in our ICT lab returns 4
int z = 9876;
sizeof(z);        // in our ICT lab returns 4
```

- You may also use **sizeof** operator to indicate the size of an array:

```
int a[9] = {100, 200, 300, 555, 666};
sizeof(a);        // in our ICT lab returns 36
```

- Size of different types of pointers are the same in a C/C++ program. p1, p2 and p3 in the following example are all the same size (8 bytes in our ICT lab):

```
int* p1;
double* p2;
char* p3;
```

Class Exercise
sizeof Operator

What is the program output if we are running this program in our ICT lab:

```
int main(void)
{
  int arr[] = {34, 55, 24, 89};

   int a = 45;

   foo(&a, arr, &arr[2] );

   return 0;
}

 /* Note: instead of unsigned
  * long in function foo, you can
  * use type called size_t and
  * instead of %lu in the printf
  * you can use %zu.
*/
```

```
void foo (int *a,  int b[], int c[9])
{
   int d[8];
   int e[10];
   int* f = e;
   unsigned long x, y, z, w, u, v;
   x =  sizeof(a);
   y =  sizeof(b);
   z =  sizeof(c);
   w = sizeof(d);
   u = sizeof(e);
   v = sizeof(f);

   printf("x = %lu  y = %lu z = %lu \n", x, y, z);
   printf("w = %lu  u = %lu v = %lu\n",  w, u, v);

   printf("a[0] = %d  b[0] = %d c[0] = %d\n",   a[0],  b[0],  c[0]);
   printf("c[-1] = %d c[-2] = %d\n", c[-1],  c[-2]);
}
```

Program output is:

```
x = 8  y = 8 z = 8
w = 32  u = 40  v = 8
a[0] = 45  b[0] = 34 c[0] = 24
c[-1] = 55 c[-2] = 34
```

Common Mistakes When Designing Function with Array or String Argument

Comparing Numeric Arrays and C-string Passed to the Functions

- Sometimes students make mistakes in designing function that uses numeric arrays or C-string. Common mistakes include:
  - Checking for '\0' in a numeric array to terminate the loop
  - Using sizeof in numeric arrays to get the number of elements of an array
  - Using size of to get the length of string
- Lets take look at the following example:

```
int countNegative(const int *x, int n);
int countSpaces(const char *);
 int main(void) {
      int a[] = {6, -4, -10, 11};
      char s[] = "ENCM 339 Programming in C";
      Int x = coutnNegatives(a, 4);
      Int y = countSpaces (s);
      …
      return 0;
 }
```

Comparing function that receive numeric array and c-string

```
int countNegative(const int *x, int n)
{
    int counter = 0;
    int i  = 0;
    while (i < n) {
        if(x[i] < 0)
            counter++;
        i++;
    } // end of while
    return counter;
} // end of function
```

- **Functions using pointer to a numeric array as their argument need to know the number of elements of array, as one of their arguments.**
- **Do not check for the '\0' when function uses numeric array.**
- **The sizeof operator doesn't give you the number of elements of the array.**

```
int countSpaces(const char *)
{
    int counter = 0;
    int i  = 0;
    while (s[i] != '\0') {
        if(s[i] == ' ')
            counter++;
        i++;
    } // end of while
    return counter;
} // end of function
```

Or:
while(s[i])

- **Functions using pointer to a c-string as their argument don't need to know the length of string, as one of their arguments. Normally have one less argument than a similar function that receives an numeric array as its argument.**
- **Check for '\0' to terminate the loop when function receives a c-string.**
- **The sizeof operator doesn't return the length of string.**