

Arrays

Fundamentals of Computer and Programming
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What We Will Learn

- Introduction
- Arrays in functions
- Multidimensional arrays
- String
- String functions
- Array of Strings



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Introduction

- Algorithms usually work on large data sets
 - Sort a set of numbers
 - Search a specific number in a set of numbers
- How to read and store a set of data?
- To read
 - Repeat the scanf statement
 - Use the loop statements
- To store the data
 - Save each data in a single variable??
 - 3000 int variables! ! ! !



Array

- A collection of **same type** variables
- A $n \times 1$ vector of
 - Integers, chars, floats, ...

- Example

- An array of 8 integer

0	1	2	3	4	5	6	7
3	1	5	11	10	19	0	12

- An array of 5 chars

0	1	2	3	4
'a'	'z'	'F'	'z'	'k'



Arrays in C

➤ Array declaration in C

<Elements' Type> <identifier>[<size>]

➤ <Elements' Type>: int, char, float, ...

➤ <size>

➤ Old compilers (standard): it should be constant

➤ New compilers (standard): it can be variable

➤ Elements in array

➤ From 0 to (size – 1)



Example

```
int num[20];
```

- **num** is array of 20 **integers**
- **num[0]** is the first integer variable
- **num[19]** is the last integer

```
float farr[100];
```

- **farr** is array of 100 **floats**
- **farr[0]** is the first float
- **farr[49]** is the 50th **float**
- **farr[99]** is the last float



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Arrays in Functions

```
int number[20];
```

- `number[i]` is an **integer** variable
- Array element can be used for call by value input
- Array element can be use for output

```
int f(int x);
```

```
void h(void) {
```

```
    int arr[50];
```

```
    //Array element in call by value
```

```
    arr[30] = f(arr[5]);
```

```
}
```



Arrays in Functions (cont'd)

- Array cannot be used as output type of function

```
int [] f(int x, int y); //compile error
```

- Arrays can be used in input list of functions
- Arrays are not passed by Call By Value
- Arrays are passed by Call By Reference
 - If we change array elements in a function
 - The element is changed in the caller function



Arrays in Functions (version 1)

- Function `arr_func` takes an array of integers

```
int arr_func(int num[90]) {  
    }
```

or

```
int arr_func(int num[]) {  
    }
```

- Array `a` is passed to function `arr_func`

```
int a[90];  
i = arr_func(a);
```



```
#include <stdio.h>
```

```
void init_array(int arr[10]) {  
    int i;  
    for(i = 0; i < 10; i++)  
        arr[i] = i;  
}
```

```
void main(void) {  
    int a[10];  
    init_array(a);  
  
    int j;  
    for(j = 0; j < 10; j++)  
        printf("a[%d] = %d\n", j, a[j]);  
}
```

تابعی که یک آرایه به طول ۱۰ را
می‌گیرد و اعضای آن را با اعداد
۰ تا ۹ مقداردهی می‌کند.

Array Size in Functions

- If array is an **input parameter** of a function
 - It **cannot** find out the size of the array
- Array size should be passed from caller function to called function
 - Using definitions

```
#define SIZE 20
```

```
void func(int a[]){ for(int i = 0; i < SIZE; i++)
```

```
...
```

- Using input variable

```
void read(int a[], int size){ for(int i = 0; i < size; i++)
```

```
or
```

```
void read(int size, int a[size]){
```

```
    for(int i = 0; i < size; i++)
```



Array Size in Functions (cont'd)

- If array is declared in a function
 - It knows the size of the array
 - It **can** find out the size of the array using **sizeof**

```
void func(void) {  
    int i, a[200];  
    for(i = 0; i < 200; i++)  
        a[i] = 0;  
  
    or  
  
    for(i = 0; i < sizeof(a)/sizeof(a[0]); i++)  
        a[i] = 0;  
  
}
```



Out-of-range access

- C compiler does not check the range you access
 - `int x[10]; x[20] = 30; y = x[100];`
 - No compiler error!
- What happen
 - Read: Logical error
 - `y = x[100];`
 - Write: May or may not logical or runtime error
 - `x[20] = 30;`



```
#include <stdio.h>
```

Out-of-range Example

```
void init_array(int size, int arr[]){
```

```
    int i;
```

```
    for(i = 0; i < size; i++)
```

```
        arr[i] = i;
```

```
}
```

```
void print_array(int size, int arr[]){
```

```
    int i;
```

```
    for(i = 0; i < size; i++)
```

```
        printf("arr[%d] = %d\n", i, arr[i]);
```

```
}
```



```
void main(void) {  
    int x = 1;  
    int y = 2;  
    int a[10] = {0};  
  
    init_array(10, a);           //OK  
    print_array(10, a);         //OK  
  
    print_array(30, a);         //Wrong output  
  
    init_array(1000, a);        //May be Run-time error!!!  
  
    init_array(20, a);          //May changes X, Y!!!  
                                //Logical error  
    printf("x = %d, y = %d\n" , x, y);  
}
```

```
#include <stdio.h>
```

تابعی که یک آرایه را بگیرد و محل
بزرگترین عضو آنرا برگرداند.

```
int max_index(int a[], int size){
```

```
    int i;
```

```
    int index = 0;
```

```
    for(i = 1; i < size; i++)
```

```
        if(a[i] > a[index])
```

```
            index = i;
```

```
    return index;
```

```
}
```

```
void main(void) {
```

```
    int arr[] = {1, 4, 12, 93, 23};
```

```
    printf("max index = %d\n", max_index(arr, 5));
```

```
}
```

تابعی که یک آرایه و دو محل آنرا بگیرد و آنها را باهم جابجا کند.

```
#include <stdio.h>
```

```
void array_swap(int a[], int i, int j){
```

```
    int tmp;
```

```
    tmp = a[i];
```

```
    a[i] = a[j];
```

```
    a[j] = tmp;
```

```
}
```

```
void main(void){
```

```
    int num[10] = {1, 2, 5, 6};
```

```
    int x = 2, y = 6;
```

```
    printf("num[%d] = %d, num[%d] = %d\n", x, num[x], y,  
    num[y]);
```

```
    array_swap(num, x, y);
```

```
    printf("num[%d] = %d, num[%d] = %d\n", x, num[x], y,  
    num[y]);
```

```
}
```

```
#include <stdio.h>
```

تابع مرتب‌سازی مجموعه اعداد صحیح

```
void array_swap(int a[], int i, int j){  
    int tmp;  
    tmp = a[i];  
    a[i] = a[j];  
    a[j] = tmp;  
}
```

```
void bubble_sort(int a[], int size){  
    int i, j;  
    for(i = 0; i < size - 1; i++)  
        for(j = i + 1; j < size; j++)  
            if(a[i] < a[j])  
                array_swap(a, i, j);  
}
```

```
void print(int a[], int size){
    int i;
    for(i = 0; i < size; i++)
        printf("%d ", a[i]);
    printf("\n");
}

int main(void){
    int arr[] = {1, 7, 3, 7, 11, 0};
    int size = sizeof(arr) / sizeof(arr[0]);
    printf("Before sort: ");
    print(arr, size);
    bubble_sort(arr, size);
    printf("After sort: ");
    print(arr, size);
    return 0;
}
```

Call print in bubble_sort
to show progress

Binary Search

```
int bsearch(int start, int end, int a[], int
value){
    int mid = (start + end) / 2;
    if(a[mid] == value)
        return mid;
    else if(start >= end)
        return -1;
    else if(value > a[mid])
        return bsearch(mid + 1, end, a, value);
    else
        return bsearch(start, mid - 1, a, value);
}
```



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Multidimensional Arrays

- If element of an array is array itself, it will be Multidimensional array
- nxn matrix, mxnxxnm matrix

```
int t[10][20];
```

- 10x20 matrix of integers

```
t[1][1]; //t[1,1] → compile error
```

- Integer variable in location (1,1)



Initializing Multidimensional Arrays

```
int num[2][3] = {1, 2, 0, 3, 4, 7};
```

```
int num[2][3] = {{1, 2, 0}, {3, 4, 7}};
```

➤ num[0][2] is 0, num[1][0] is 3

```
int num[5][3] = {{1, 2, 0}, {3, 4, 7}};
```

➤ num[2][2] is 0, num[1][2] is 7

```
int num[2][3][2] = {{{1, 2}, {3, 4}, {5, 6}},  
                     {{1}, {2}, {3}}};
```

➤ num[0][2][1] is 6, num[1][0][1] is 0

```
int num[][2] = {{1, 1}, {2, 2}, {3, 3}};
```

➤ num[1][1] is 2, num[2][0] is 3



Multidimensional Arrays in Functions

- Can be used as input of functions

All dimensions except the first one must be given

```
void func(int a[10][20][5]);
```

- Input is a 10x20x5 integer matrix

```
void func(int a[][20][30], int size);
```

```
void func(int size1, int size2, int  
a[size1][size2]);
```

- Input is a matrix of integers that both rows and columns are variable



```
#define SIZE 5
```

محاسبه ترانزپوز ماتریس

```
void swap(int a[SIZE][SIZE], int i, int j){  
    int tmp;  
    tmp = a[i][j];  
    a[i][j] = a[j][i];  
    a[j][i] = tmp;  
}
```

```
void transpose(int a[][SIZE]){  
    int i, j;  
    for(i = 0; i < SIZE; i++)  
        for(j = i; j < SIZE; j++)  
            swap(a, i, j);  
}
```

```
#include <stdio.h>

void displayMatrix (int nRows, int nCols, int
    matrix[nRows][nCols]) {
    int row, column;
    for ( row = 0; row < nRows; ++row) {
        for ( column = 0; column < nCols; ++column )
            printf ("%5i", matrix[row][column]);
        printf ("\n");
    }
}
```

تابعی برای چاپ یک ماتریس
که ابعاد آن مشخص نیست.

```
int main (void){
    int sampleMatrix[3][5] =
    {{ 7, 16, 55, 13, 12 }, { 12, 10, 52, 0, 7 }, { -2, 1,
        2, 4, 9 }};

    printf ("Original matrix:\n");
    displayMatrix (3, 5, sampleMatrix);
}
```

$$A * B$$



Array In Memory

```
#define ROWS 3
#define COLS 6

int table[ROWS][COLS];
```

		columns					
		0	1	2	3	4	5
rows	0						
	1						
	2						

		rows																	
		0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2
table																			
		0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
		columns																	

```
&table[i][j] = &table[0][0] + sizeof(int)(i * COLS + j)
```



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Introduction

➤ Until now

- We have seen strings in printf
- Our old definition: string is a set of char between “”

```
printf("This is a string\n");
```

```
printf("This is %s\n", "a string\n");
```

➤ Strings:

- An array of chars
- Terminated by the **null char** ' \0 '



Strings in C

- Since strings are array

```
char str3[] = {'p', 'r', 'o', 'g', 'r', 'a',  
'm', '\0'};
```

```
char str1[8] = "program";
```

```
char str2[] = "program";
```

```
char *str3 = "program"; //we will see later
```

'p'	'r'	'o'	'g'	'r'	'a'	'm'	'\0'
-----	-----	-----	-----	-----	-----	-----	------



Reading & Writing Strings

- `printf` can be used to print strings

```
printf("program");
```

```
printf("%s", "program");
```

- `scanf` can be used to read strings

```
char str[200];
```

```
scanf("%s", str);
```

- Initial white spaces are ignored
- Read until **space** or `'\n'` (which is replaced by `\0`)
- We must allocate **sufficient size**



Reading & Writing Strings (cont'd)

- **puts (str)** is very simple version of **printf**
 - Can only be used to print strings
 - Adds '\n' to end of string
- **gets (char str[])** can be used to read strings
- **gets** does **not** ignore the white spaces
 - Read until \n
- String should be large enough



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String Library

- Access to string library by

#include <string.h>

- Many functions to work with strings
 - Find the length of string
 - Compare strings
 - Copy strings
 - Search in strings
 - ...



Length of String

- `strlen(str)`: Length of string
- From start to first occurrence of the **null char**

```
char str[] = "This is test";
```

```
char str1[10]={'a', 'b', '\0', 'c', '\0'};
```

```
strlen(str) → 12
```

```
strlen(str1) → 2
```



Compare Strings

- `str1` and `str2` are compared as follows
 - Compare **char by char** from **left to right** until `str1` and `str2` has same chars.
 - In the first different char
 - If(char of `str1` < char of `str2`) → `str1` < `str2`
 - If (both string finish) → `str1` = `str2`
- **`strcmp(str1, str2)`** : compare `str1` and `str2`
 - If(`str1` == `str2`) → return 0
 - If(`str1` < `str2`) → return -1
 - If(`str1` > `str2`) → return 1



Compare Strings: Examples

```
char s1[] = "abc";  
char s2[] = "abc";  
i = strcmp(s1, s2); //i = 0
```

```
char s3[] = "abc";  
char s4[] = "abx";  
i = strcmp(s3, s4); //i = -1
```

```
char s5[] = "axc";  
char s6[] = "abc";  
i = strcmp(s5, s6); //i = 1
```

```
char s7[] = "ab";  
char s8[] = "abc";  
i = strcmp(s7, s8); //i = -1
```

```
char s9[] = "abc";  
char s10[] = "aBc";  
i = strcmp(s9, s10); //i = 1
```



Compare Strings

- `strcmpi(str1, str2)`
- Compares `str1` and `str2` similar to `strcmp`
- But ignores uppercase/lowercase difference

```
char str1[]="ABC", str2[]="abC";
```

```
strcmpi(str1, str2) → 0
```



Copy Strings

- Strings should be copied char by char
- `strcpy(dst_str, src_str)`: copy the `src_str` to the `dst_str`
- `src_str` is a constant string
- `dst_str` should have **sufficient size**



Copy Strings: Example

```
char str1[] = "Test String";
```

```
char str2[20];
```

```
strcpy(str2, str1);
```

```
printf("%s\n", str2);
```

Test String

```
printf("%s\n", str1);
```

Test String



Concatenate Strings

- `strcat(dst, src)`: Append the `src` string to the end of `dst`
- `src` is constant string
- `dst` should have **sufficient space**



Concatenate Strings: Example

```
char str1[] = "String";
```

```
char str2[20] = "Test ";
```

```
strcat(str2, str1);
```

```
printf("%s\n", str2);
```

 Test String

Sized Version of the Functions

➤ **strncpy(dst, src, n):**

➤ copys **n** chars from **src** to **dst**

➤ **If (strlen(src) > n)**

➤ Copies **n** chars to **dst**

➤ Does **not** add '\0' to end of **dst**

➤ **If (strlen(src) < n)**

➤ Copy **src** to **dst**

➤ Add $n - \text{strlen}(\text{src}) - 1$ '\0' to end of **dst**

➤ **dst** must be large enough

➤ $n < \text{size of dst}$



Sized Version of Functions

- **strncmp(str1, str2, n):**
 - compares the first **x** chars
 - **x** = $\min\{n, \text{strlen}(\text{str1})+1, \text{strlen}(\text{str2})+1\}$

- **strncat(dst, src, n):**
 - Appends the **x** chars from **src** to **dst**
 - **x** = $\min\{n, \text{strlen}(\text{src})\}$
 - Adds '\0' to end of dst
 - dst must be large enough



Numbers and Strings: number → string

- To convert a number to string

```
char str1[100];
```

```
int i = 100;
```

```
sprintf(str1, "%d", i);
```

str1 = "100"

```
float f = 10.11;
```

```
sprintf(str1, "%0.2f", f);
```

str1 = "10.11"

- String `str1` should have **sufficient size**



Numbers and Strings: string → number

➤ To convert from strings to numbers

```
#include <stdlib.h>
```

```
char str1[] = "10";
```

```
int i;
```

```
i = atoi(str1);      // i = 10
```

```
sscanf(str1, "%d", &i); // i = 10
```

```
char str2[] = "20.44";
```

```
double f;
```

```
f = atof(str2);      // f = 20.44
```

```
sscanf(str2, "%lf", &f); // f = 20.44
```



String as Array

- Strings are array of chars
- We work on arrays element by element
- We can work on strings char by char

```
char str1[] = "100000";
```

```
str1[2] = '2';
```

- We can pass strings to functions



```
#include <stdio.h>
#include <string.h>
```

```
void str_n_m_cat(char s1[], char s2[], int n, int m, char
    res[]){
    strncpy(res, s1, n);
    res[n] = '\0';
    strncat(res, s2, m);
    res[n+m] = '\0';
}
```

تابعی که دو رشته s1 و s2 و دو عدد n و m را بگیرد و یک رشته تولید کند که شامل n عضو اول s1 و m عضو s2 است.

```
void main(void){
    char s1[] = "abcdefgh", s2[] = "abcdefgh";
    char result[50];

    str_n_m_cat(s1, s2, 6, 6, result);
    str_n_m_cat(s1, s2, 600, 6, result); //Runtime error
}
```

Array of Strings

- 2 dimensional array, each row is a string

```
char numeri[][8] = {"zero", "uno", "due", "tre", "quattro"};
```

numeri

'z'	'e'	'r'	'o'	'\0'	'\0'	'\0'	'\0'
'u'	'n'	'o'	'\0'	'\0'	'\0'	'\0'	'\0'
'd'	'u'	'e'	'\0'	'\0'	'\0'	'\0'	'\0'
't'	'r'	'e'	'\0'	'\0'	'\0'	'\0'	'\0'
'q'	'u'	'a'	't'	't'	'r'	'o'	'\0'



```
#include <stdio.h>
#include <string.h>
```

```
#define MAX_NAME_SIZE 100
```

```
void read_data(char names[][MAX_NAME_SIZE], double grades[], int size){
    int i;
    for(i = 0; i < size; i++){
        printf("Enter name: ");
        scanf("%s", names[i]);
        printf("Enter grade: ");
        scanf("%lf", &(grades[i]));
    }
}
```

```
double get_average(double grades[], int size){
    int i;
    double res = 0;
    for(i = 0; i < size; i++)
        res += grades[i];

    return (res / size);
}
```

برنامه‌ای که تعداد دانشجویان را بگیرد، سپس اسم هر دانشجو و نمره را بگیرد. اسم دانشجویانی که نمره آنها بیشتر از میانگین است را چاپ کند.

```
void print_names(char names[][MAX_NAME_SIZE], double grades[], int size, double
average){
    int i;
    printf("Average = %lf \n", average);
    printf("List of students whose grade is above the average: \n");
    for(i = 0; i < size; i++)
        if(grades[i] > average)
            printf("%s\n", names[i]);
}
```

```
int main(void){
    int num;
    printf("Enter number of students: ");
    scanf("%d", &num);
    double grades[num];
    char names[num][MAX_NAME_SIZE];
    read_data(names, grades, num);
    double average = get_average(grades, num);
    print_names(names, grades, num, average);

    return 0;
}
```

cctype.h

- Many function to work on chars
 - Check digit
 - Check alphabetic
 - Check lower or upper case
 - Convert from/to upper/lower case



ctype.h

- **int isdigit(ch)**
 - Check ch is digital char or not
- **int isalpha(ch)**
 - Check ch is alphabetic or not
- **int islower(ch)**
 - Check ch is lowercase alphabetic or not
- **int isupper(ch)**
 - Check ch is uppercase alphabetic or not
- **char tolower(ch)**
 - Convert ch to lowercase and return it
- **char toupper(ch)**
 - Convert ch to upper case and return it



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Common Bugs & Avoiding them

- Strings which are used as destination
 - scanf, sprintf, strcpy,
 - **Must be large enough**

Take care about the '\0'

- You should never destroy it, some library functions do!
- Out of range array index!!!! (read/write, wrong size in function, multidimensional array memory)
- You cannot assign a value to array

```
int a[4], b[4];  a = b;  // Error
```

- To debug
 - Print the array index and corresponding value



Reference

- **Reading Assignment:** Chapters 6 and 8 of “C How to Program”



Homework 6

