Week 5

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Outline

- Multi-dimensional arrays
- C-string

Multi-dimensional Array

- An array of arrays
- int xy[3][4] = { {1,2,3,4} , {5,6,7,8}, {4,3,2,1} };

1	2	3	4
5	6	7	8
4	3	2	1

  - Two-dimension represents a matrix (2-d tensor)
  - Three-dimension represents a cube (3-d tensor)
  - Higher-dimension … hyper-cube (k-d tensor)
- All elements in a multi-dimensional array has to be the same type

How to declare a 2-d array

- Without initialization
  - int xy[3][4];
  - means 3 rows of 4-int arrays,
  - Or a 3 rows * 4 cols of int matrix
- Type name[#rows][#cols]
  - Both #rows and #cols need to be specified in declaration (**if without initialization**)
  - In the same way of #elements for a 1-d array

How to initialize a 2-d array;

- Regard it as an array of arrays
  - int xy[3][4] = { {1,2,3,4} , {5,6,7,8}, {4,3,2,1} };
- Regard it as a series of int folds to a matrix
  - int xy[3][4] = {1,2,3,4 , 5,6,7,8, 4,3,2,1};
- #rows can be omitted if with initialization
  - int xy[ ][4] = {1,2,3,4 , 5,6,7,8, 4,3,2,1};
- We'll get the same 3*4 int array

1	2	3	4
5	6	7	8
4	3	2	1

Initialize a 2-d array with less elements

- Less elements in some rows
  - int xy[3][4] = { {1,2,3,4} , {5,6}, {4,3,2,1} };
  - Missing elements in such rows will be all-zero

1	2	3	4
5	6	**0**	**0**
4	3	2	1

- Less total elements
  - int xy[3][4] = { 1, 2, 3, 6, 7, 8, 4, 3, 2 };
  - Elements in the end will be all-zero

1	2	3	6
7	8	4	3
2	**0**	**0**	**0**

Unacceptable ways of initializing a 2-d array

- int xy[3][4] = { {1,2,3} , {5,6,7,8, 9}, {4,3,2,1} };
  - Row out-of-bound **X**
- int xy[3][4] = {1,2,3,4,5,6,7,8,9,10,11,12,13};
  - More elements than #cols * #rows **X**
- int xy[3][ ] = {1,2,3,4,5,6,7,8,9,10,11,12};
  - #cols not specified **X**
- int xy[3][4] = {1,2,3,4,**"a"**,6,7,8,9,10,11,12}; **X**
  - Inconsistent and inconvertible types of elements

Accessing elements in a 2-d array

1	2	3	4
5	6	**7**	8
4	3	2	1

- Access an element
  - xy[1][2]; //2nd row, 3rd col

7

- Access a row
  - xy[1]; //2nd row

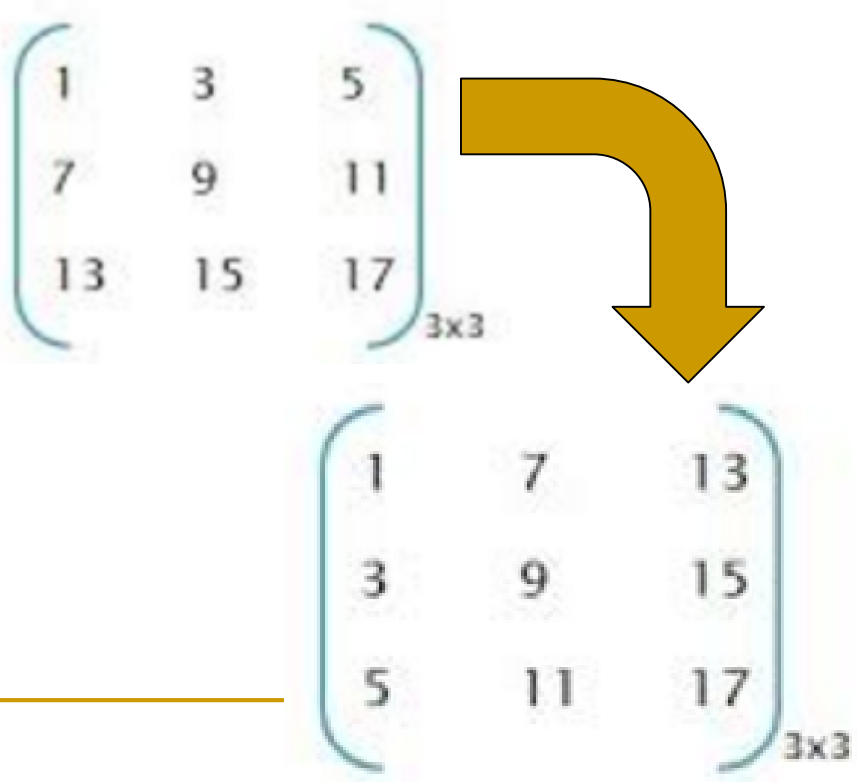
5	6	7	8

- However, there's no direct way to access a column

Example: Transpose a square matrix

- Swap each element in position (x,y) with that in position (y,x)
- To simplify, make the matrix as a square

```
void transpose(int m[][], int n) {
    int tmp;
    for (int i=0; i<n; ++i)
        for (int j=i + 1; j < n; ++j) {
            tmp = m[i][j];
            m[i][j] = m[j][i];
            m[j][i] = tmp;
        }
}
```



Note: 2-d Array will not check the bound

- For a 1-d array, we know this will be regarded as out-of-bound
  - int a[3] = {0}; cout << a[3];
- For a 2-d array, the compiler won't know when it's out-of-bound

```
int main()
{
    int s[3][4] = {1};
    cout << s[4][5];
    //cout << strcmp(t, s) << endl;
    system("pause");
    return 0;
}
```

Note: 2-d Array will not check the bound

- s[4][5] is just to access the ((4 + 1) * #cols + 5)-th byte after s.

1	0	0	0
0	0	0	0
0	0	0	0
unknown	unknown	unknown	unknown
unknown	unknown	unknown	unknown
unknown	unknown	unknown	unknown

The s[3][4] we defined

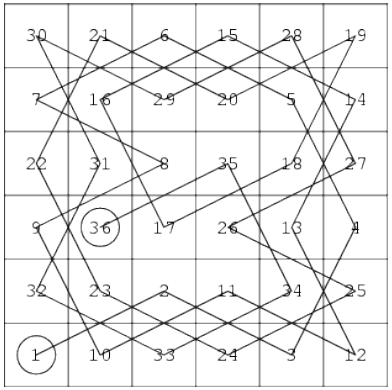
The s[4][5] we accessed

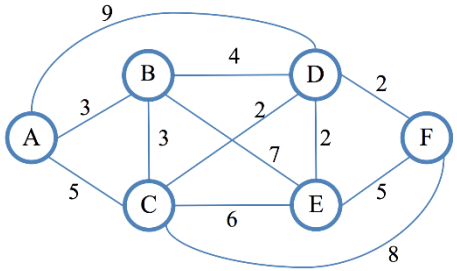
Note: 2-d Array will not check the bound

- We need to remember the boundaries of 2-d arrays ourselves. Otherwise it's possible for a 2-d array to access any unexpected block of the memory.

Applications of 2-d Arrays

- Image processing
  - Images are usually represented as k-d arrays
- Chessboard problems
  - 8-queen problem
  - Knight's tour problem
  - Etc
- Graph
  - (adjacency matrix)
- 2-d tensors for neural networks these days





C-strings in detail

C-String review

- What is a c-string
  - A char array which terminates by ‘\0’ (or 0, or NULL).
- How to initialize a c-string
  - Use either a string value or a set of char ended with a ‘\0’.
  - char c[] = {‘g’, ‘o’, ‘o’, ‘g’, ‘l’, ‘e’, ‘\0’}
  - char c[] = “google”
- How to input/output a c-string
  - char c[100]; cin >> c; cout << c;
- How to copy a c-string (deep copy)
  - char c[]=“google”; char d[100];
  - for (i=0; c[i] != ‘\0’; i++) d[i] = c[i];
  - d[i] = ‘\0’;

C-string

- What if multiple ‘\0’ coexist in a C-string initialization
  - The first ‘\0’ always represents the end
  - char c[100]=“abc\0def\0hg”;
  - cout << c;
  - abc
  - cout << c[4];
  - d

Library functions for C-string

- include <cstring> (or include <string.h>)
  - Library functions for C-strings
- Member functions of C++ Strings, such as size() and substr(), no longer work for C-strings.

strlen(s)

- Returns the length of s.
- char s[] = “aaaaaa”;
- cout << strlen(s);

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Implement strlen(s)

- What if we're not allowed to use strlen

```
int strlen(s) {
    int len;
    for (len=0; s[len] != '\0'; ++len);
    return len;
}
```

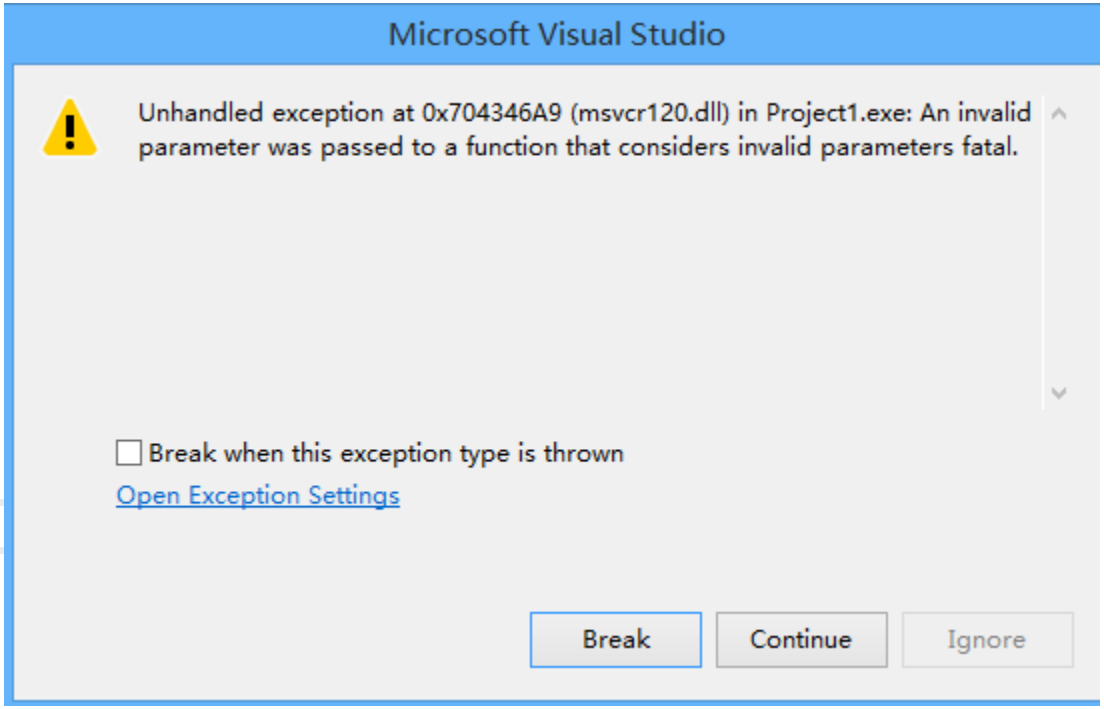
strcpy(t, s)

- Copy the C-string *s* to C-string *t*.
- This works as a **deep copy**.
- We have to make sure there's enough space in *t*.
  - If length of *s* is larger than the size of *t*, program will cause a runtime error.
- The return value is *t.*

strcpy(t, s) error: insufficient space in t

```
#include "stdafx.h"
#include <iostream>
#include <cstring>
using namespace std;

int main()
{
    char c[100] = "abc";
    char s[2];
    strcpy(s, c);
    cout << s;
    system("pause");
    return 0;
}
```



strncpy(t, s, n)

- Copy at most n characters from *s* to *t*.

```
char* strncpy(char *t, char *s, int n) {
    for (int i=0; i < n; ++i) {
        t[i] = s[i]; if(s[i]) == '\0') break;
    }
    return t;
}
```

- A safe way of strcpy(t, s):
  - strncpy(t, s, sizeof(t) / sizeof(char));
- Note: if n < strlen(s), no '\0' will be copied to *t*!
  - Thus we cannot assume *t* as a completed C-string by strncpy.
  - We have to manually assign t[n]='\0';

strncpy

```
int main ()
{
  char str1[]= "To be or not to be";
  char str2[60];
  char str3[60] = “David the Someberg who buys lots of watermelons”;

  /* copy to sized buffer (overflow safe): */
  strncpy ( str2, str1, sizeof(str2) );
  cout<< str2 << endl;

  /* partial copy (only 5 chars): */
  strncpy ( str3, str2, 5 );
  cout<< str3 << endl;
  str3[5] = '\0';   /* set the null character manually */
  cout<< str3 << endl;
  return 0;
}
```

```
To be or not to be
To be the Someberg who buys lots of watermelons
To be
```

strcat(t, s)

- Append C-string *s* to the end of *t*.
  - t += s won't do the job. Use strcat(t, s) instead.

```
char * strcat(char *t, char *s) {
    int shift = strlen(t)
    for (int i=0; i <= strlen(s); ++i)t[shift + i]=s[i];
    return t;
}
```

- Note: there's also no size check for t, we have to make sure t has enough space for strlen(t) + strlen(s);

strcat(s, t) example

```
/* strcat example */
#include <stdio.h>
#include <string.h>

int main ()
{
  char str[80] = “”;
  strcpy (str,"these ");
  strcat (str,"strings ");
  strcat (str,"are ");
  strcat (str,"concatenated.");
  cout << str;
  return 0;
}
```

```
these strings are concatenated.
```

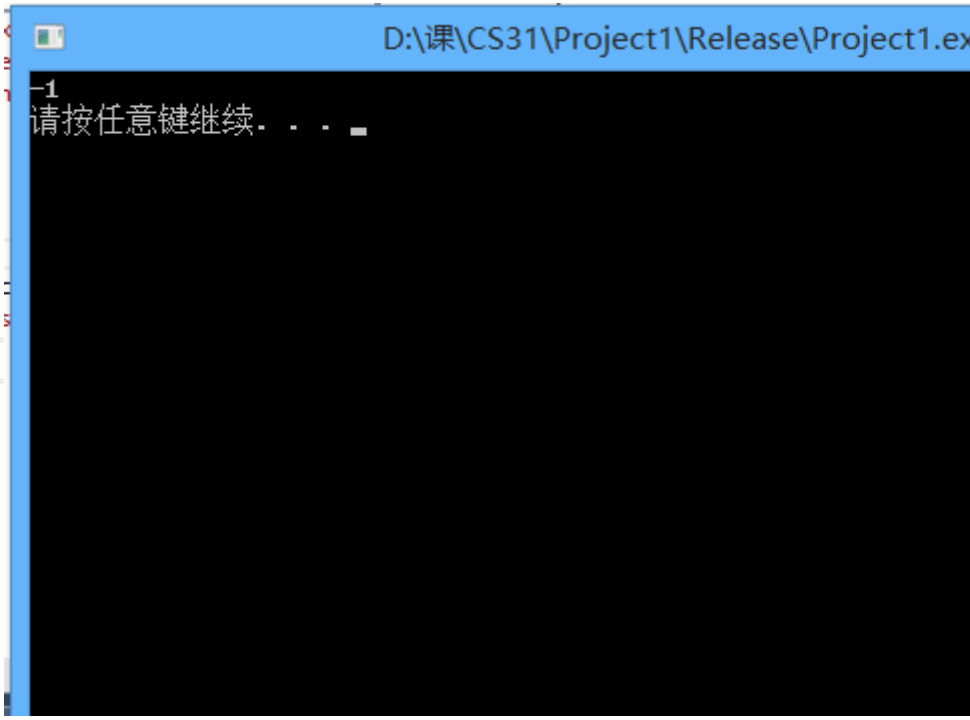
int strcmp(char *t, char *s)

- Compare two C-strings
  - s == t; s < t; s > t; won't do the work.
- Return value of strcmp is int, not bool!
  - t equals to s: return 0
  - t less than s: return something <0
  - t greater than s: return something >0
- How to tell if *t* is greater than *s*?
  - if (strcmp(t, s) > 0) …

strcmp(t, s)

```
#include <iostream>
#include <cstring>
using namespace std;

int main()
{
    char s[100] = "999999", t[10] = "11123";
    cout << strcmp(t, s) << endl;
    system("pause");
    return 0;
}
```



strcmp(t, s)

```
int main ()
{
  char key[] = "apple";
  char buffer[80];
  do {
     printf ("Guess my favorite fruit? ");
     fflush (stdout);
     cin >> buffer;
  } while (strcmp (key,buffer) != 0);
  cout << “Correct answer!";
  return 0;
}
```

```
Guess my favourite fruit? orange
Guess my favourite fruit? apple
Correct answer!
```

Summary of C-string functions

Functions	Usage
strlen(s)	Return the length of s
strcpy(t, s)	Copy s to t.
strncpy(t, s, n)	Copy at most n characters from s to t.
strcat(t, s)	Append s to t.
strcmp(t, s)	Compare s and t.

- http://www.cplusplus.com/reference/cstring/

Convert a C-string to a C++ String

- char cs[10] = “hello”;
- We can use either of the two below:
  - string cpps = cs;
  - string cpps(cs);

Convert a C++-string to a C-string

- string cpps = “abc”; char c[100];
- Don’t use c = cpps; //error
- Use strcpy(c, cpps.c_str()); instead
  - c_str() Get the “C-string body” of a C++ string

Create an Array of C-strings

- A C string is an array of characters. This means an array of C strings is simply a 2D array:
  - char s[10][20];
  - In s, we can store up to 10 C strings, and each C string can be at most 19 characters long.
- s[2] : the third C-string
- s[2][4] : the fifth character of the third C-string

Assign Values to Already-defined C-String Array

- Always use strcpy to store a string to a row.
- char s[10][20];
- strcpy(s[0], “First string”);

- s[0] = “First string”; won’t do the work

Example of creating and using a C-string array

```
char s[3][6]; // Can store three 5-letter words.
strcpy(s[0], “hello”);
strcpy(s[1], “apple”);
strcpy(s[2], “world”);
cout << s[0] << endl; // prints “hello”
cout << s[2][2] << endl; // prints “r”
```

Thank you.