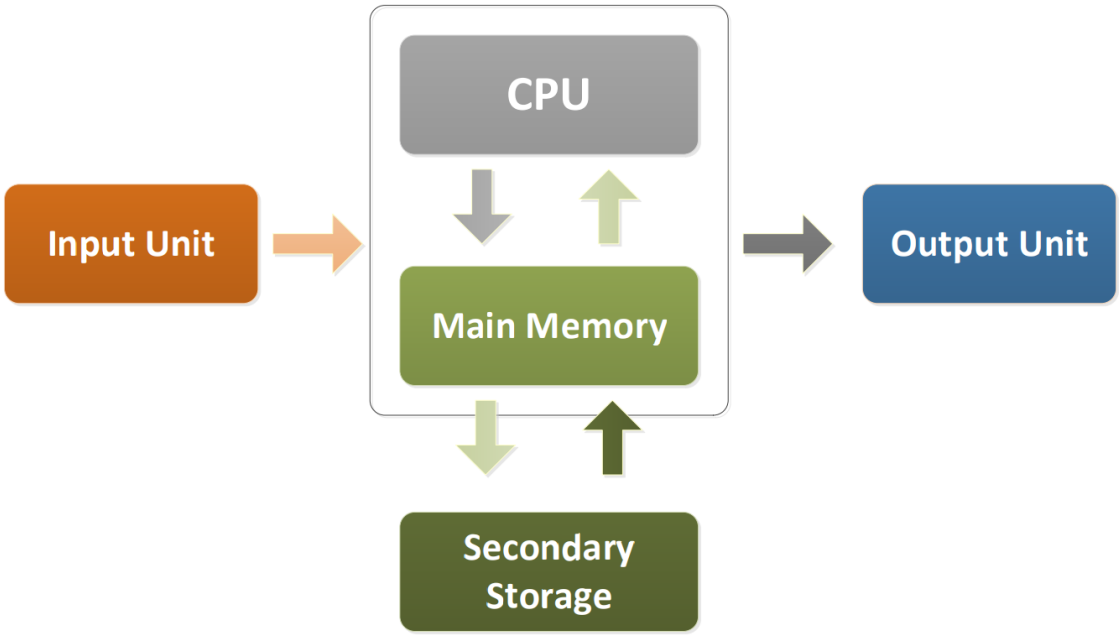
Computer Programming

Lecture 1

Stored Program Computer (Von Neumann Machines)



- CPU: read and execute **instructions** from main memory
- Main Memory: *fast* **storage** of active program and data
- Secondary Storage: *slow* **storage** of program and data, maintain them after shutting down

Programming Languages

- Machine Language, *directly* understood by the computer, **binary code**
- Symbolic Language, English-like *abbreviations*, **assembly language**
- High-level Language

Basic Concepts of Programming

- (External View) Input->Process->Output
- (Internal View) Computer Program = Instructions (with Logic Flow) (with Data Access)
    - Instructions = **predefined actions**
    - Logic Flow = *arrangement* of instructions
    - Data = Variable + Constant

Building C++ Program

- Writing source code
- Preprocessing
- Complication
    - Check *syntax*

    - Source code -> **Object code (.obj)**
    - Every source code has corresponding object code
- Linking
    - Object code + Library -> **Executable (.exe)**
    - Library/SDK/Package
    - Every project has only one executable

C++ Program Framework

```
/* The traditional first program in honor of
  Dennis Ritchie who invented C at Bell Labs
  in 1972 */

#include <iostream>
using namespace std;

void main()
{
  cout << "Hello, world!\n";
}
```

- `#include <iostream>`: library `iostream` contains the definition of `cout`
- `using namespace std;`: can use `cout` as `std::cout`
- `void main()`: the **starting point** of the program, first function to be called
- `cout`: console output
- `<<`: output (insertion) operator
- `"Hello, world!\n"`: **literal** (character string)

Object - cout

- `\` + character = **escape sequence**
- `\n`: newline
- `\\`: character `\`
- `\"`: character `"`
- `endl`: `\n`

Tokens

- **keywords**: data type, flow control, syntax keywords
- **identifiers**: variables, objects, functions
- string constants
- numeric constants
- operators
- punctuators

Identifiers

- unique
- cannot use keywords
- can only be composed by **letters, digits, underscores (_)**, no hyphen (-)
- **cannot begin with digits**

Variables and Constants

- stored in **memory**, expires after the program execution
- attributes: **type, name, scope**
- scope: where the variable can be accessed, also identifier conflict domain

Lecture 2

Variable Types

Integers

- `int` (4 bytes = 32 bits), range $[-2^{31}, 2^{31}-1]$
- `short` (2 bytes)
- `long` (8 bytes)
- `unsigned(=unsigned int)`, range $[0, 2^{32}-1]$

two's complement

Character and String

- `char` (1 byte = 8 bits) : single character, enclosed by single quotation mark `''`
- `char*`, double quotation mark `""`

```
char lecture[] = "CS2310 Lecture02";
char * lecture = "CS2310 Lecture02";
```

Floating Numbers

- `float` (4 bytes)
- `double` (8 bytes)

`sizeof` operator

- `sizeof(variable)` or `sizeof(type)`
- result is **bytes** in unsigned integer

Data type conversion

Implicit type conversion

- binary (as opposed to unary) expressions (e.g. `x + y`) **promote to high rank**
- assignment (e.g. `x = y`) **convert to the type on the left**

Explicit type conversion

may change or invalidate value

Variable Scope

Local Variables

Declared in a block {} and can only be accessed in the block

Global Variables

Declared in the global sections, outside any blocks

Local variable has higher priority than the global variable of the same name

Namespace

- scope operator `::`
- only using `::` = global scope

Operators

Terminology

- **operands** are values that used to calculate
- **expression** is a combination of constants, variables and function calls that **evaluate to a result**

Assignment Operator `=`

- `variable = expression`
- **assignment statement has a value** equal to `expression`

Increment & decrement Operators `++` `--`

```
int x, y;

x = 10;
y = (x++) + (x++);
cout << y << endl; // 20

x = 10;
y = (x++) + (++x);
cout << y << endl; // 22

x = 10;
y = (++x) + (x++);
cout << y << endl; // 22

x = 10;
y = (++x) + (++x);
cout << y << endl; // 24
```

Division & modulus operators `/` `%`

quotient + division remainder (integer division only)

Precedence & Associativity

Precedence	Operator	Associativity
2 unary variable left	`a++` `a--` (**postfix** incdec) `a()` (function call) `a[]` (subscript) `.` `->` (member access)	`->`
3 unary variable right	`++a` `--a` (**prefix** incdec) `+a` `-a` (unary plus / minus) `!` `~` (logical NOT; bitwise NOT) `(int)` (**type cast**) `*a` (dereference) `&a` (address-of) `sizeof`	**Right**
5	`a*b` `a/b` `a%b`	`->`
6	`a+b` `a-b`	`->`
7	`<<` `>>`	`->`
9	`<` `<=` `>` `>=`	`->`
10	`==` `!=`	`->`
11	`a&b` (bitwise AND)	`->`
12	`a^b` (bitwise XOR)	`->`
13	`a|b` (bitwise OR)	`->`
14	`a&&b` (logical AND)	`->`
15	`a|b` (logical OR)	`->`
16 binary variable left expression right	`a?b:c` (ternary conditional) `=` (**assignment**) `+=` `-=` `*=` `/=` `%=` `<<=` `>>=` `&=` `^=` `|=`	**Right**

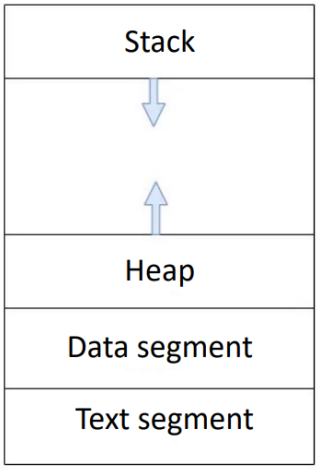
Lecture 5

Array definition

DO NOT USE VARIABLE AS ARRAY SIZE

Memory Layout

- **Data segment**
  - global variables and static variables
  - string constant
  - global constant
- **Stack**
  - local variables
  - function parameters, etc.
- **Heap**
  - dynamic memory allocation



Lecture 9

Pointer

```
#include <cstdio>
int x, y;
int main () {
    int *p1, *p2;
    x = 10;
    y = 12;
    p1 = &x;
    p2 = &y;
    *p1 = 5; // x = 5
    *p2 = *p1 + 10; // y = x + 10 = 15
}
```

- `int *p1`: declare a pointer
- `*p1`: **dereference**, the value of pointed variable; **can modify pointed variable**
- `&x`: **reference**, the address of variable

Constant Pointer and Pointer to Constant

- **Constant Pointer**: Address is constant, cannot change to point other variables
- **Pointer to Constant**: Can change pointed address, cannot change pointed variable from pointer but can change from variable itself

```
int main () {
    // constant pointer
    int x = 10;
    int y = 12;
    int *const p1 = &x;
    *p1 = 5; // OK
    // p1 = &y; // Error
    printf("%d %d\n", x, *p1);
    // constant pointer can only point to one specific variable
    // i.e., its address is constant

    // pointer to constant
    const int *p2 = &x;
    // *p2 = 5; // Error
    p2 = &y; // OK
    y = 15;
    printf("%d\n", *p2); // 15
    // pointer to constant can point to different variables
    // the pointed variable cannot be changed from the pointer
    // but can be changed from the variable itself
}
```

Call By Pointer and Reference

```
void swap(int *a, int *b) { // *a and *b store the address of x and y
    int tmp = *a; // here * is dereference operator
    *a = *b; // to get x and y values
    *b = tmp;
}

void swapByRef(int &a, int &b) { // a and b are aliases of x and y
    int tmp = a; // they store the values of x and y
    a = b;
    b = tmp;
}

int main () {
    int x = 10, y = 12;
    swap(&x, &y); // address of x and y are passed
    printf("%d %d\n", x, y);
    swapByRef(x, y); // x and y are passed
    printf("%d %d\n", x, y);
}
```

Reference

- reference is **alias** of a variable
- reference is **constant pointer**
- must be **initialized** in the declaration and cannot be pointed to another variable

```
    int n = 10;
    int &ref = n; // equiv. int* const ref = &n;
    ref = 5; // n = 5

    // int &ref0; // Error: must be initialized
    // int &ref1 = 100; // Error: must be initialized with a variable
    const int &ref2 = 100; // OK
    int m = 15;
    const int &ref3 = m; // OK
    m = 20; // OK
    // ref3 = 20; // Error: ref3 is a constant reference
```

`main()` arguments

```
int main(const int argc, const char** argv) {
    for (int i = 0; i < argc; i++)
        printf("%s\n", *(++argv));
}
```

File I/O

```
#include <fstream>
ifstream fin; // variable fin
ofstream fout; // variable fout
fin.open("input.txt");
fin >> x;
fin.close();
fout.open("output.txt");
fout << x;
fout.close();
```

Open Mode

`open(filename, mode)`

- `mode=in`, `mode=out`, `mode=binary`

I/O Failures

- `fin.fail()`
- `fin.eof()`
    - EOF can also be detected by `while(fin >> x)`. In case of EOC return false

Lecture 10

Pointer Copy

Copy the Address

```
p = q;
```

By copying the address, changing the value of `*p` will also change `*q` as they point to the same variable.

Copying the content

```
*p = *q;
```

By copying the content, changing the value of `*p` will not change `*q` as they point to different variables though starting value is the same.

`NULL` pointer

```
int *ptr1 = NULL; // or
int *ptr2 = 0;
```

The pointer points to nothing. Used to **initialize** the pointer.

Pointer and Array

Array-like notation can be used to pointer.

```
int num[2] = {40, 50};
int *p = num;
p[0] = 400;
p[1] = 500;
num = p; // illegal
```

Do notice that **pointer operation cannot be applied to array**.

This is because:

- `num` is **a constant pointer** pointed to `num[0]`
- `p` is **a pointer variable**

pointer `++` operator

Additionally, `++p` increments the content of `p` (which is an address) by `sizeof(int)` buyes

```
int *p = num;
*p = 400; // num[0] = 400;
++p; // p = num+1=&(num[1])
*p = 500; // num[1] = 500;
```

- `num+i` is the address of `num[i]`
- `num+i=&(num[i])`
- `*(num+i)=num[i]`

Pointer and 2D array

for a 2D array `int a[m][n]`:

- `a[i] (i=0, 1, ..., m-1)` is **the address of the first element** of `i`-th row
- use `int *p = a[i];` to manipulate `i`-th row as one 1D array

```
int a[4][3];
int *p = a[0]; // or int *p = a;
for (int i = 0; i < 12; i++) {
    cout << *p << endl;
    p++;
}
```

Char Pointer and Array

```
char s[] = "abc";
s = "abcd"; // illegal
```

This is because `s` is a **constant pointer** pointed to `s[0]`. `"abcd"` is at a different memory address, and `s` cannot change the pointed variable.

Also, `cin >> s` can cause array out-of-bound.

Use `cin.getline(s, 5);` instead (read at most 4 characters).

Passing arrays to functions

Since arrays are already pointers, passing arrays is always call-by-pointer.

```
double sum(int *a); // is the same as
double sum(int a[]);
```

Dynamic Memory Allocation

```
int *p = new int; // (*p) can access some int variable
int *p = new int(10); // this is only the starting value of (*p)
// and can be changed
char *p = new char('a');

delete p; // DELETE (*p), NOT DELETE p itself
// *p = 10; // illegal
p = NULL;
```

Dynamic Arrays

```
int *p = new int[20];
char *p = new char[20];

delete [] p;
p = NULL;
```

2D Dynamic Arrays

```
int **p = new int*[n];
for (int i = 0; i < n; i++) {
    p[i] = new int[3];
}

for (int i = 0; i < n; i++) {
    delete [] p[i];
}
delete [] p;
```

Copy Constructor

Besides **default and parameterized** constructor, can use another object of the **same class** to initialize the variable

If no user-defined copy constructor, default copy contsructor is provided (member-wise copy)

Shallow Copy

For pointer, only address is copied.

```
class Student {
    public:
    int *pID;
    int age;
    Student(int id, int a) {
        pID = new int(id);
        age = a;
    }
    ~Student() {
        delete[] pID;
        pID = NULL;
    }
    // default copy constructor
}

Student s1(123456, 20);
Student s2(s1);
```

`s1.pID` and `s2.pID` points to the same address. When `s1` is destructed, `s1.pID` is deleted, and then `s2` destructor tries to delete it again, which causes error.

Deep copy

Copy the value of pointer.

```
Student (const Student &s) {
    age = s.age;
    pID = new int(*s.pID);
}
```