C++ For C Coders 3

Data Structures
C++ for C Coders

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Default function arguments
Reference operator
const, const reference
function overloading
Template
new and delete operator
command line processing

Default Function Arguments

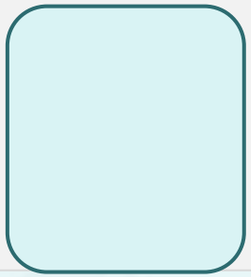
- In calling of the function, if the arguments are not given, default values are used.

```
int exp(int n, int k = 2) {
  if (k == 2) return (n * n);
  return (exp(n, k - 1) * n);
}
```

Default Function Arguments

- In calling a function argument must be given from left to right without skipping any parameter

```
void foo(int i, int j=7);                 // right
void goo(int i=3, int j);                 //
void hoo(int i, int j=3, int k=7);        //
void moo(int i=1, int j=2, int k=3);      //
void noo(int i=2, int j, int k=3);        //
```



Default Function Arguments

- In calling a function argument must be given from left to right without skipping any parameter

```
void foo(int i, int j=7);                 // right
void goo(int i=3, int j);                 // wrong
void hoo(int i, int j=3, int k=7);        // right
void moo(int i=1, int j=2, int k=3);      // right
void noo(int i=2, int j, int k=3);        // wrong
```

Reference Operator &

- A reference allows to declare an alias to another variable.
- If the **aliased** variable lives, you can use indifferently the variable or the alias.

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

int main() {
  int x;
  int& foo = x;
  foo = 49;
  cout << x << endl;
  retrn 0
}
```

Reference Operator &

- Use references to **avoid copying of large structures** when passing arguments. If we pass it without reference, a new copy of it is created which causes wastage of CPU time and memory.

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

struct Student {
    string name;
    string major;
    int SN;
};
```

Reference Operator &

- Use references to **avoid copying of large structures** when passing arguments. If we pass it without reference, a new copy of it is created which causes wastage of CPU time and memory.

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

struct Student {
    string name;
    string major;
    int SN;
};
```

```
void print(const Student& s) {
    cout << s.name << " " << s.major << endl;
}

int main() {
    Student one{"Handong", "CSEE", 1230456};
    print(one);
    return 0;
}
```

Using Reference

Reference Operator &

- Use references to **avoid copying of large structures** when passing arguments. If we pass it without reference, a new copy of it is created which causes wastage of CPU time and memory.

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

struct Student {
    string name;
    string major;
    int SN;
};
```

```
void print(const Student& s) {
    cout << s.name << " " << s.major << endl;
}

int main() {
    Student one{"Handong", "CSEE", 1230456};
    print(one);
    return 0;
}
```

Using Reference

```
void print(const Student* s) {
    cout << s->name << " " << s->major << endl;
}

int main() {
    Student one{"Handong", "CSEE", 1230456};
    print(&one);
    return 0;
}
```

Using Pointer

Reference Operator &

- Use references to **avoid copying of large structures** when passing arguments. If we pass it without reference, a new copy of it is created which causes wastage of CPU time and memory.

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

struct Student {
    string name;
    string major;
    int SN;
};
```

```
void print(const Student& s) {
    cout << s.name << " " << s.major << endl;
}

int main() {
    Student one{"Handong", "CSEE", 1230456};
    print(one);
    return 0;
}
```

Using Reference

```
void print(const Student s) {
    cout << s.name << " " << s.major << endl;
}

int main() {
    Student one{"Handong", "CSEE", 1230456};
    print(one);
    return 0;
}
```

w/o using reference & pointer

```
void print(const Student* s) {
    cout << s->name << " " << s->major << endl;
}

int main() {
    Student one{"Handong", "CSEE", 1230456};
    print(&one);
    return 0;
}
```

Using Pointer

Reference Operator &

- Fix the code to have an expected output. Use a reference variable in C++.

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

int main() {
    vector<int> vec{ 10, 20, 30, 40 };

    for (auto x: vec)
        x = x * x;

    for (auto x: vec)
        cout << x << " ";
    cout << '\n';
    return 0;
}
```

Expeced Output: 100 400 900 1600

Reference Operator &

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

int main() {
    vector<int> vec{ 10, 20, 30, 40 };

    for (auto& x: vec)
        x = x * x;

    for (auto x: vec)
        cout << x << " ";
    cout << '\n';
    return 0;
}
```

Expeced Output: 100 400 900 1600

Example swap(): Reference Operator &

- Complete swap() using pointers in C.

Solution in C/C++

```
void swap(int  a, int  b) {
  int temp =  a;
  a = b;
  b = temp;
}

int main() {
  int i = 3, j = 5;
  swap( i,  j);
  printf("%d, %d\n", i, j);
}
```

& is an address operator.

```
5  3
```

Example swap(): Reference Operator &

- Complete swap() using pointers in C.

```
void swap(int  a, int  b) {
  int temp =  a;
  a = b;
  b = temp;
}

int main() {
  int i = 3, j = 5;
  swap( i,  j);
  printf("%d, %d\n", i, j);
}
```

& is an address operator.

Solution in C/C++

```
void swap(int *a, int *b) {
  int temp = *a;
  *a = *b;
  *b = temp;
}

int main() {
  int i = 3, j = 5;
  swap(&i, &j);
  printf("%d, %d\n", i, j);
}
```

5 3

Example swap(): Reference Operator &

- Complete swap() in C++

Solution in C++

```
void swap(int a, int b) {
  int temp = a;
  a = b;
  b = temp;
}

int main() {
  int i = 3, j = 5;
  swap(i, j);
  cout << i << " " << j << endl;
}
```

& is a reference operator.

Example swap(): Reference Operator &

- Complete swap() in C++

```
void swap(int a, int b) {
  int temp = a;
  a = b;
  b = temp;
}

int main() {
  int i = 3, j = 5;
  swap(i, j);
  cout << i << " " << j << endl;
}
```

& is a reference operator.

Solution in C++

```
void swap(int& a, int& b) {
  int temp = a;
  a = b;
  b = temp;
}

int main() {
  int i = 3, j = 5;
  swap(i, j);
  cout << i << " " << j << endl;
}
```

& is a reference operator.

Example swap(): Comparison using pointer and reference

C/C++

```
void swap(int *a, int *b) {
  int temp = *a;
  *a = *b;
  *b = temp;
}

int main() {
  int i = 3, j = 5;
  swap(&i, &j);
  printf("%d, %d\n", i, j);
}
```

& is an address operator.

C++

```
void swap(int& a, int& b) {
  int temp = a;
  a = b;
  b = temp;
}

int main() {
  int i = 3, j = 5;
  swap(i, j);
  cout << i << " " << j << endl;
}
```

& is a reference operator.

No Function Overloading in C

- Function overloading is a feature of object-oriented programming where two or more functions can have the same name but different parameters.

This code would **not** work since no overloading supported in C

```
int main() {
  int i = 3, j = 5;
  swap(&i, &j);
  printf("%d, %d\n", i, j);

  double x = 3, y = 5;
  swap(&x, &y);
  printf("%f, %f\n", x, y);
}
```

```
void swap(int *a, int *b) {
  int temp = *a;
  *a = *b;
  *b = temp;
}

void swap(double *a, double *b) {
  double temp = *a;
  *a = *b;
  *b = temp;
}
```

Function Overloading in C++

- Function overloading is a feature of object-oriented programming where two or more functions can have the same name but different parameters.

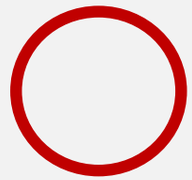
C++ Function overloading

```
int main() {
  int i = 3, j = 5;
  swap(i, j);
  cout << i << " " << j << endl;

  double x = 3, y = 5;
  swap(x, y);
  cout << x << " " << y << endl;
}
```

```
void swap(int& a, int& b) {
  int temp = a;
  a = b;
  b = temp;
}

void swap(double& a, double& b) {
  double temp = a;
  a = b;
  b = temp;
}
```



Using C++ Template

- You still need two exact same functions but types in C++ unless using Template.

```
void swap(int& a, int& b) {
  int z = a;
  a = b;
  b = z;
}
void swap(double& a, double& b) {
  double z = a;
  a = b;
  b = z;
}
int main() {
  int i = 1, j = 2;
  double x = 10, y = 20;
  swap(i, j);
  swap(x, y);
  cout << i << " " << j << endl;
  cout << x << " " << y << endl;
}
```

Using C++ Template

- You still need two exact same functions but types in C++ unless using Template.

```
void swap(int& a, int& b) {
  int z = a;
  a = b;
  b = z;
}
void swap(double& a, double& b) {
  double z = a;
  a = b;
  b = z;
}
int main() {
  int i = 1, j = 2;
  double x = 10, y = 20;
  swap(i, j);
  swap(x, y);
  cout << i << " " << j << endl;
  cout << x << " " << y << endl;
}
```

```
template <typename T>
void swap(T &a, T &b) {
  T z = a;
  a = b;
  b = z;
}

int main() {
  int i = 1, j = 2;
  double x = 10, y = 20;
  swap(i, j);
  swap(x, y);
  cout << i << " " << j << endl;
  cout << x << " " << y << endl;
}
```

const Reference

- To prevent the function from changing the parameter accidentally, we pass the argument as **constant reference** to the function.

```
struct Person {
  char name[40];
  int age;
};
void print(Person k){
  cout << "Name: " << k.name << endl;
  cout << "Age: " << k.age << endl;
}

int main(){
  Person man{"Adam", 316};
  print(man);
  return 0;
}
```

C style coding in C++

const Reference

- To prevent the function from changing the parameter accidentally, we pass the argument as **constant reference** to the function.

```
struct Person {
  char name[40];
  int age;
};
void print(const Person& k) {
  cout << "Name: " << k.name << endl;
  cout << "Age: " << k.age << endl;
}

int main(){
  Person man{"Adam", 316};
  print(man);
  return 0;
}
```

C style coding in C++

k is constant reference parameter

What is good about passing by const reference?

- Instead of 44 bytes, only 4 bytes (address) are sent to the function.
- Calling function knows that Person k would not be changed.

Return by reference

- By default in C++, when a function returns a value, it is copied into stack. The calling function reads this value from stack and copies it into its variables.
- An alternative to "return by value" is "return by reference", in which the value returned is not copied into stack.
- One result of using "return by reference" is that the function which returns a parameter by reference **can be used on the left side of an assignment** statement.

```
funcReturnByRef(a_parm) = a_value;
```

the left side of an assignment

Return by reference

- Modify the following programs such that it sets the maximum element to zero.

```
int max(int a[], int n) {
  int x = 0;
  for (int i = 0 ; i < n; i++)
    if (a[i] > a[x]) x = i;
  return a[x];
}

int main() {
  int a[] = {12, 42, 33, 99, 63};
  int n = 5;

  for (int i = 0; i < n; i++)
    cout << a[i] << " ";
}
```

12 42 33 0 63

Return by reference

- Modify the following programs such that it sets the maximum element to zero.

```
// returns an integer
// reference of the
// max element
```

```
int& max(int a[], int n) {
  int x = 0;
  for (int i = 0; i < n; i++)
    if (a[i] > a[x]) x = i;
  return a[x];
}

int main() {
  int a[] = {12, 42 , 33 , 99, 63};
  int n = 5;
  max(a, n) = 0;          // overwrite the max
                          // element with 0
  for (int i = 0; i < n; i++)
    cout << a[i] << " ";
}
```

The left side returns by the reference such that it can placed at the left side of an assignment

12 42 33 0 63

Never return a local variable by reference

- Since a function that uses "return by reference" returns an actual memory address, it is important that the variable in this memory location remain in existence after the function returns.

```
int& foo() {
  int x;
  ...
  return x;       // Compiler warning: reference to local variable 'x' returned
                  // Run Time ERROR since x does not exist anymore after returned
```

- Local variables can be return by their values

```
int foo() {
  int i;                    // Local variable, created in stack
  ...
  return i;                 // OK! does not exist anymore
```

Quiz 1

- Predict the output of the following programs when compiled or executed.
- Select all that apply.

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

int& foo() {
    int x = 10;
    return x;
}

int main() {
    cout << foo();
    return 0;
}
```

```
(A) Syntax error
(B) Compile warning
(C) Compile error
(D) Run time error
(E) Logic error
(F) 10
(G) 20
```

References vs Pointers

- References are **less powerful** than pointers, but still **extremely useful**.
  - Once a reference is created, it cannot be later made to reference another object; it cannot be reset. References cannot be NULL.
  - A reference must be initialized when declared. References in C++ cannot be used for implementing data structures like Linked List, Tree, etc.
- References are **safer** and **easier** to use:
  - **Safer:** References are less likely to become invalid since they must be initialized.
  - **Easier:** References don't need a dereferencing operator to access the value. They can be used like normal variables.
    '&' operator is needed only at the time of declaration. Also, members of an object reference can be accessed with dot operator ('.'), unlike pointers where arrow operator (->) is needed to access members.

malloc & free vs. new & delete

- In C, dynamic memory allocation is done with malloc() and free().
- The C++ new and delete operators performs dynamic memory allocation.

```
int *p = (int *)malloc(sizeof(int) * N);

for (int i = 0; i < N; i++)
  p[i] = i;

free(p);
```

```
int *p = new int[N];

for (int i = 0; i < N; i++)
  p[i] = i;

delete[] p;
```

Using new & delete

- The **new** operator allocates memory and **delete** frees it.

```
int *pi = new int;                        // pi points to uninitialized int
int *pi = new int(7);                     // which pi points has value 7
string *ps = new string("hello");         // ps points "hello", cout << *ps << endl;
string st = "hello";                      // string st("hello"), cout << st << endl;

int *pia = new int[7];                    // block of seven uninitialized ints
int *pia = new int[7]();                  // block of seven ints values initialized to 0

string *psa = new string[5];                 // block of 5 empty strings
string *psa = new string[5]();               // block of 5 empty strings
int    *pia = new int[5]{0, 1, 2, 3, 4};     // block of 5 ints initialized
string *psa = new string[2]{"a", "the"};     // block of 2 strings initialized

delete   pi;
delete[] pia;
```

Command line processing

- Open Atom editor
  - Filename: **args.cpp**
  - Add the source code.
  - Save the file.
- Compile and Execute

```
$ g++ args.cpp –o args
$ ./args Why not change the world?
```

- Read more about this in github: **/nowic/ArgcArgv.md**
- Write a function **args_to_strs()** that returns an array of strings to replace both argc and argv;
  - **Use vector<string>**
- Once you complete it, move the function into a new file called **args_to.cpp**.
- Test **args.cpp** and **args_to.cpp**.

```
// args.cpp
#include <iostream>
using namespace std;

int main(const int argc, char** argv) {
  cout << "You entered: "
       << argc << " arguments:" << endl;

  for (int i = 0; i < argc; ++i)
    cout << argv[i] << endl;
  return 0;
}
```

Multiple Source Files

- If you have multiple files to compile and link, for example,
  - Filename: **`args.cpp`**
  - Filename: **`args_to.cpp`**

- Compile and execute

```
$ g++ args.cpp args_to.cpp –o args
$ ./args
```

(3)

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