COMP2012 Object-Oriented Programming and Data Structures

Review: References

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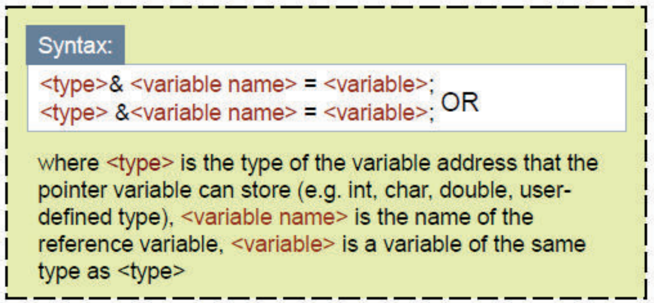
What are References?

- A reference is an alternative / another name (alias) for a variable or an object
- Reference variables are usually used in parameter passing to functions



Syntax:

<type>& <variable name> = <variable>;
<type> &<variable name> = <variable>; OR

where <type> is the type of the variable address that the pointer variable can store (e.g. int, char, double, user-defined type), <variable name> is the name of the reference variable, <variable> is a variable of the same type as <type>

<type>& p = q;
<type> &p = q;

Declaration of Reference Variables

- Recall, the syntax for declaring a reference variable:
  `<type>& <variable name> = <variable>;`

```
// Declare an int variable
int j = 1;  // the value of j is 1

// Declare a reference variable r, which is another name of j
int& r = j; // now r = j = 1

// Assign r to x
int x = r;  // now x = 1

// As r is just j, r changes to 2 means j changes to 2 as well
r = 2;      // now r = j = 2
j = 10;     // now r = j = 10
```

A reference allows indirect manipulation of a variable / object, somewhat like a pointer, without requiring the complicated pointer syntax ;)

Important Points about Reference

- A reference MUST always bound to a variable / an object (similar to constant pointer)
- It must therefore be initialized when it is created

```
int j = 1;
int& r1 = j; // ok
int& r2;     // error!
```

- A reference cannot bound to another object once it initially was initialized to. But what does the following mean?

```
int j = 10;
int& r = j;
int k = 50;
r = k;       // what does this mean?
```

Assignment from a variable, say k, to a reference variable, say r, means r get assigned with the value of k

The Different Uses of Operator &

- Do not confuse the use of operator & in declaring reference variable versus the use of & as the address of operator for pointer
- Example

```
int j;
// The following statement declares a reference variable
// "&" is a part of reference type
int& i = j;
// The following statement is used to get the address
// of j and assign it to p
int* p = &j;
```

Questions

- The following is wrong. Why?

```
int j;
int& i = &j;
```

- The following is correct. What does it mean?

```
int j;
int* p = &j;
int*& ref = p;
// a reference of "int pointer"
```

Example

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

int main() {
  int j = 1;
  // pi is an int pointer initialized to the address of j
  int* pi = &j;
  int*& ref = pi; // ref is a reference variable of type int*
  cout << "j = " << j << ", ";
  cout << "*pi = " << *pi << ", *ref = " << *ref << endl;

  int k = 2;
  pi = &k;
  cout << "j = " << j << ", ";
  cout << "*pi = " << *pi << ", *ref = " << *ref << endl;
  return 0;
}
```

Output:

```
j = 1, *pi = 1, *ref = 1
j = 1, *pi = 2, *ref = 2
```

Call by Reference

- Reference arguments are special case of reference variable

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

int f(int& i) {
  ++i;
  return i;
}

int main() {
  int j = 7;
  cout << f(j) << endl;
  cout << j << endl;
  return 0;
}
```

Output:

```
8
8
```

Call by Reference

- Variable i is a local variable in the function f. Its type is "int reference" and it is created when f is called
- In the call f(j), i is created similarly to the construction: `int& i = j;`
- So within the function f, i will be an alias of the variable j, and i cannot be binded to another variable
- But every time the function is called, a new variable i is created and it can be a reference to a different variable / object

Why Call by Reference?

There are two reasons:

1. The function caller wants the function to be able to change the value of passed arguments
2. For efficiency:
   - If you pass a function argument by value, the function gets a local copy of the argument
   - For large objects, copying is expensive; on the other hand, passing an object by reference does not require copying, only a memory address (since reference is similar to pointer)

Example

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

void swap(char& y, char& z) {
  char temp = y;
  y = z;
  z = temp;
}

int main() {
  char a = 'y';
  char b = 'n';
  swap(a, b);
  cout << a << b << endl;
  return 0;
}
```

Output:

```
ny
```

const: References as Function Arguments

- You can express your intention to leave a reference argument of your function unchanged by making it const
- This has two advantages:
  - First, if you accidentally try to modify the argument in your function, the compiler will catch the error!

```
void cbr(int& i) {
  i += 10; // Fine
}

void cbcr(const int& j) {
  j += 10; // Error!
}
```

const: References as Function Arguments (Cont'd)

- Second, you can call a function that has a const reference parameter with both const and non-const arguments
- Conversely, a function that has a non-const reference parameter can only be called with non-const arguments

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

void cbr(int& i) {
  cout << i << endl;
}

void cbcr(const int& i) {
  cout << i << endl;
}

int main() {
  int i = 50;
  const int j = 100;
  cbr(i);
  cbcr(i);
  cbr(j);  // Error
  cbcr(j);
  return 0;
}
```

Pointer vs. Reference

A reference can be thought of as a special kind of pointer, but there are 3 big differences to remember!

- A pointer can point to nothing (nullptr), but a reference is always bound to a variable / object
  - No need to check nullptr when using reference ;)
- A pointer can point to different variables / objects at different times (through assignments). A reference is always bound to the same variable / object.
  - Assignments to a reference do NOT change the variable / object it refers to but only the value of the referenced object
- The name of a pointer refers to the pointer variable. The * or $->$ (details of operator $->$ will be covered later) operators have to be used to access the object. The name of a reference always refers to the same object. There are no special operators. ;)

Example - Pointers and References

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

void func1(int* p1) { (*pi)++; }
void func2(int& ri) { ri++; }

int main() {
  int i = 1;
  cout << "i = " << i << endl;
  // call using address of i
  func1(&i);
  cout << "i = " << i << endl;
  // call using i
  func2(i);
  cout << "i = " << i << endl;
  return 0;
}
```

Output:

```
i = 1
i = 2
i = 3
```

Further Reading

- Read Chapter 6 & 8 of "C++ How to Program" or Chapter 3 of "C++ Primer" textbook

That's all!

Any question?