

Intermediate Programming

Day 26

Outline

- Exercise 25
- References
- Dynamic Memory Allocation
- Review questions

Exercise 25

Complete the `abbreviate` function.

```
abbrev.cpp
...
string abbreviate( string word )
{
    string result;
    bool last_was_vowel = false;

    for( size_t i=0 ; i<word.size() ; i++ )
    {
        bool cur_is_vowel = is_vowel( word[i] );

        if( !cur_is_vowel ) result.push_back( word[i] );
        else if( !last_was_vowel ) result.push_back( '\\' );

        last_was_vowel = cur_is_vowel;
    }

    return result;
}
...
```

Exercise 25

Invoke the `abbreviate` function.

abbrev.cpp

```
...
int main( int argc , char **argv )
{
    if( argc!=3 )
    {
        cerr << "Usage: abbrev <infile> <outfile>" << endl;
        return 1;
    }

    ifstream in( argv[1] );
    ofstream out( argv[2] );
    string line;
    while( getline( in , line ) )
    {
        stringstream ss(line);
        string word;
        while( ss >> word ) out << abbreviate( word ) << " ";
        out << endl;
    }

    return 0;
}
```

Exercise 25

Determine and count the token types.

classify.cpp

```
...
int main( void )
{
    ...
    string token;
    while( cin >> token )
    {
        stringstream sstream( token );
        double fp ; int i ; string s;

        if( ( sstream >> i ) && !( sstream >> s ) ) sum_i += i;
        else
        {
            sstream = stringstream( token );
            if( sstream >> fp ) sum_fp += fp;
            else
            {
                sstream = stringstream( token );
                if( sstream >> s ) ntok++ , ntok_c += s.length();
            }
        }
    }
    ...
}
```

Exercise 25

Count the frequencies of the different letters.

```
...
struct Bucket
{
    char letter;
    unsigned count;
};
int main( int argc , char **argv )
{
    if( argc!=2 ) ...

    ifstream in( argv[1] );
    char c;
    vector< Bucket > hist;
    hist.resize( 26 );
    for( unsigned int i=0 ; i<26 ; i++ )
    {
        hist[i].count = 0;
        hist[i].letter = 'a'+i;
    }

    while( in.get(c) )
    {
        if( c>='a' && c<='z' ) hist[c-'a'].count++;
        else if( c>='A' && c<='Z' ) hist[c-'A'].count++;
    }
    ...
}
```

Exercise 25

Sort and print the frequencies.

letter_freq.cpp

```
...
struct Bucket
{
    char letter;
    unsigned count;
};

bool compare_buckets( const Bucket &left , const Bucket &right )
{
    return left.count>right.count;
}

int main(int argc, char **argv)
{
    ...
    vector< Bucket > hist;
    ...
    sort( hist.begin() , hist.end() , compare_buckets );

    for( unsigned int i=0 ; i<hist.size() && hist[i].count ; i++ )
        cout << hist[i].letter << ": " << hist[i].count << endl;
    ...
}
```

Outline

- Exercise 25
- **References**
- Dynamic Memory Allocation
- Review Questions

References

- In C, we could pass arguments by *value* or by *address*
 - By value
 - creates a copy of the contents
 - By address
 - allows us to modify the callee's variables
 - requires dereferencing to access

```
main.c
#include <stdio.h>
void swap( int *a , int *b )
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
int main( void )
{
    int i1 = 1 , i2 = 2;
    swap( &i1 , &i2 );
    printf( "%d %d\n" , i1 , i2 );
    return 0;
}
```

```
>> ./a.out
2 1
>>
```

References

- C++ also allows us to pass arguments by *reference*
 - Look like values
 - no need to dereference
 - Act like pointers
 - function sees the argument, not a copy
 - Unlike pointers:
 - A reference can't be NULL
 - A reference must be initialized when it's declared
 - A reference cannot be reassigned

```
main.cpp
#include <iostream>
void swap( int &a , int &b )
{
    int tmp = a;
    a = b;
    b = tmp;
}
int main( void )
{
    int i1 = 1 , i2 = 2;
    swap( i1 , i2 );
    std::cout << i1 << " " << i2 << std::endl;
    return 0;
}
```

```
>> ./a.out
2 1
>>
```

References

- C++ also allows us to pass arguments by *reference*
 - References are declared using a "&" after the type / class they refer to

```
main.cpp
#include <iostream>
int main( void )
{
    int i = 1 , j =10;
    int &r = i;
    r = j;
    std::cout << i << std::endl;
    return 0;
}
```

References

- C++ also allows us to pass arguments by *reference*
 - References are declared using a "&" after the type / class they refer to
 - Must be defined as soon as they are declared

```
main.cpp
#include <iostream>
int main( void )
{
    int i = 1 , j =10;
    int &r = i;
    r = j;
    std::cout << i << std::endl;
    return 0;
}
```

References

- C++ also allows us to pass arguments by *reference*
 - References are declared using a "&" after the type / class they refer to
 - Must be defined as soon as they are declared
 - Note that the line "r=j";
 - Does **not** make r a reference to j
 - It copies the contents of j into what r refers to

```
main.cpp
#include <iostream>
int main( void )
{
    int i = 1 , j =10;
    int &r = i;
    r = j;
    std::cout << i << std::endl;
    return 0;
}
```

```
>> ./a.out
10
>>
```

References

- C++ also allows us to pass arguments by *reference*
 - We saw this before:
 - The `getline` function takes a **reference** to a `string`
 - This allows the method to set `line` with the value of the next line of text read in from the stream

```
main.cpp
#include <iostream>
#include <cctype>
#include <string>
int main( void )
{
    std::string line;
    while( std::getline( std::cin , line ) )
        std::cout << line << std::endl;
    return 0;
}
```

```
>> echo "the quick brown fox" | ./a.out
the quick brown fox
>>
```

References

- C++ also allows us to pass arguments by *reference*
 - As with pointers, this allows a function to affect multiple output values

```
main.cpp
#include <iostream>
void Set2And3( int &a , int &b )
{
    a=2 , b=3;
}
int main( void )
{
    int i1 , i2;
    Set2And3( i1 , i2 );
    std::cout << i1 << " " << i2 << std::endl;
    return 0;
}
```

```
>> ./a.out
2 3
>>
```

References

- C++ also allows us to pass arguments by *reference*
 - We can also return a reference

```
main.cpp
#include <iostream>
using namespace std;
int &minref( int &a , int &b )
{
    if( a<b ) return a;
    else     return b;
}
int main( void )
{
    int a = 5, b = 10;
    int& min = minref( a , b );
    min = 12;
    cout << "a=" << a << " , b=" << b << " , min=" << min << endl;
}

```

```
>> ./a.out
a=12, b=10, min=12
>>

```


References

- C++ also allows us to pass arguments by *reference*
 - We can also return a reference
 - The object receiving the reference must be declared on the same line as the function call

```
main.cpp
#include <iostream>
using namespace std;
int &minref( int &a , int &b )
{
    if( a<b ) return a;
    else     return b;
}
int main( void )
{
    int a = 5, b = 10;
    int &min = minref( a , b );
    min = 12;
    cout << "a=" << a << " , b=" << b << " , min=" << min << endl;
}

```

```
>> ./a.out
a=12, b=10, min=12
>>

```

References

- C++ also allows us to pass arguments by *reference*

- We can also return a reference

- The object receiving the reference must be declared on the same line as the function call
 - Do not return a reference to a variable on the function's call stack!
 - Otherwise we would be returning a reference to something that is no longer in existence when the function returns

```
main.cpp
#include <iostream>
using namespace std;
int &minref( int a , int b )
{
    if( a<b ) return a;
    else     return b;
}
int main( void )
{
    int a = 5, b = 10;
```

```
>> g++ -std=c++11 -Wall -Wextra main.cpp
main.cpp: In function int& minref(int, int) :
main.cpp:3:18: warning: reference to local variable a returned [-Wreturn-local-addr]
  int& minref( int a , int b )
                  ^
>>
```

References

- C++ also allows us to pass arguments by *reference*
 - If a reference is declared **const**, its value cannot be changed
 - We could have protected the value using pass-by-value but that would duplicate the contents of the object

References

- C

main.cpp

```
#include <iostream>
#include <map>
#include <string>

void print( const std::map< int , std::string >& map )
{
    for( std::map< int , std::string >::const_iterator it=map.cbegin() ; it!=map.cend() ; ++it )
        std::cout << it->first << " : " << it->second << std::endl;
}

int main( void )
{
    int id;
    std::string name;
    std::map< int , std::string > id2name;
    while( std::cin >> id >> name ){ id2name[ id ] = name; }
    print( id2name );
    return 0;
}
```

Outline

- Exercise 25
- References
- **Dynamic Memory Allocation**
- Review Questions

Dynamic Memory Allocation

- In C, we allocate memory on the heap using `malloc`:

```
void * malloc( size_t size );
```

- This function does not need to know the type of the data
- Just the size of the memory we were requesting

- Similarly, we deallocate memory from the heap using `free`:

```
void free( void * ptr );
```

- This function does not need to know the type of the data
- Just the location that we are freeing

Dynamic Memory Allocation

- In C++, we need to know the data-type to invoke the constructor*
- We do this using the `new` operator:

`<DataType> * new DataType(<ConstructorParams>);`

- This allocates memory for a single object and invokes the constructor
 - Though primitive types (e.g. ints, chars, etc.) do not have constructors, we can use `new` to allocate them on the heap (they will not be initialized)

Note that `new` is not a function, i.e. it does not take arguments in parentheses.

```
main.cpp
#include <iostream>
#include <string>
using std::string;
int main( void )
{
    string * strPtr = new string( "Hello" );
    std::cout << *strPtr << std::endl;
    ...
    return 0;
}
```

Dynamic Memory Allocation

- In C++, we need to know the data-type to invoke the destructor*
- We do this using the `delete` operator:

`delete <DataType>*;`

- This invokes the destructor of the object
 - Though primitive types (e.g. ints, chars, etc.) do not have destructors, we can use `delete` to deallocate them from the heap
- And deallocates its memory

Note that `delete` is not a function, i.e. it does not take arguments in parentheses.

```
main.cpp
#include <iostream>
#include <string>
using std::string;
int main( void )
{
    string * strPtr = new string( "Hello" );
    std::cout << *strPtr << std::endl;
    delete strPtr;
    return 0;
}
```


Dynamic Memory Allocation

- We allocate **arrays** of objects using `new[]`:

```
<DataType> * new DataType[<NumElems>];
```

- This allocates memory for a `NumElems` objects
- And invokes the **default** constructor* for each one

- And we deallocate using `delete[]`:

```
delete[] <DataType>*;
```

- This invokes the destructor* for each object
- And then deallocates the memory for the entire array of objects

Dynamic Memory All

rectangle.h

```
#ifndef RECTANGLE_INCLUDED
#define RECTANGLE_INCLUDED
class Rectangle
{
public:
    double w , h;
    Rectangle( void );
    void print( void ) const;
    double area( void ) const ;
};
#endif // RECTANGLE_INCLUDED
```

main.cpp

```
#include <iostream>
#include "rectangle.h"

int main( void )
{
    int count;
    std::cout << "Rectangle Count: ";
    std::cin >> count;
    Rectangle **r = new Rectangle*[count];
    for( int i=0 ; i<count ; i++ )
    {
        int w , h;
        std::cout << "Width: " ; std::cin >> w;
        std::cout << "Height: " ; std::cin >> h;
        r[i] = new Rectangle();
        r[i]->width = w;
        r[i]->height = h;
    }
    for( int i=0 ; i<count ; i++ ) r[i]->print();
    for( int i=0 ; i<count ; i++ ) delete r[i];
    delete[] r;
    return 0;
};
```

Dynamic Memory All

- Memory allocated with **new** must be deallocated with **delete**

main.cpp

```
#include <iostream>
#include "rectangle.h"

int main( void )
{
    int count;
    std::cout << "Rectangle Count: ";
    std::cin >> count;
    Rectangle **r = new Rectangle*[count];
    for( int i=0 ; i<count ; i++ )
    {
        int w , h;
        std::cout << "Width: " ; std::cin >> w;
        std::cout << "Height: " ; std::cin >> h;
        r[i] = new Rectangle();
        r[i]->width = w;
        r[i]->height = h;
    }
    for( int i=0 ; i<count ; i++ ) r[i]->print();
    for( int i=0 ; i<count ; i++ ) delete r[i];
    delete[] r;
    return 0;
};
```

Dynamic Memory All

- Memory allocated with **new** must be deallocated with **delete**
- Memory allocated with **new[]** must be deallocated with **delete[]**
 - We are deleting an array of **pointers** to **Rectangle** objects
⇒ The **Rectangle** destructor is not called

main.cpp

```
#include <iostream>
#include "rectangle.h"

int main( void )
{
    int count;
    std::cout << "Rectangle Count: ";
    std::cin >> count;
    Rectangle **r = new Rectangle*[count];
    for( int i=0 ; i<count ; i++ )
    {
        int w , h;
        std::cout << "Width: " ; std::cin >> w;
        std::cout << "Height: " ; std::cin >> h;
        r[i] = new Rectangle();
        r[i]->width = w;
        r[i]->height = h;
    }
    for( int i=0 ; i<count ; i++ ) r[i]->print();
    for( int i=0 ; i<count ; i++ ) delete r[i];
    delete[] r;
    return 0;
};
```

Dynamic Memory All

- Memory allocated with `new` must be deallocated with `delete`
- Memory allocated with `new[]` must be deallocated with `delete[]`

Note that since `r[i]` is a pointer to a `Rectangle`, we access its members using the `->` operator

main.cpp

```
#include <iostream>
#include "rectangle.h"

int main( void )
{
    int count;
    std::cout << "Rectangle Count: ";
    std::cin >> count;
    Rectangle **r = new Rectangle*[count];
    for( int i=0 ; i<count ; i++ )
    {
        int w , h;
        std::cout << "Width: " ; std::cin >> w;
        std::cout << "Height: " ; std::cin >> h;
        r[i] = new Rectangle();
        r[i]->width = w;
        r[i]->height = h;
    }
    for( int i=0 ; i<count ; i++ ) r[i]->print();
    for( int i=0 ; i<count ; i++ ) delete r[i];
}
```

Dynamic Memory All

We could also do this without
memory allocation/deallocation
using STL **vectors**

main.cpp

```
#include <iostream>
#include "rectangle.h"

int main( void )
{
    int count;
    std::cout << "Rectangle Count: ";
    std::cin >> count;
    std::vector< Rectangle > r;
    for( int i=0 ; i<count ; i++ )
    {
        int w , h;
        std::cout << "Width: " ; std::cin >> w;
        std::cout << "Height: " ; std::cin >> h;
        r.push_back( Rectangle() );
        r[i].width = w;
        r[i].height = h;
    }
    for( int i=0 ; i<count ; i++ ) r[i].print();
    return 0;
};
```

Dynamic Memory All

We could also do this without memory allocation/deallocation using STL **vectors**

main.cpp

```
#include <iostream>
#include "rectangle.h"

int main( void )
{
    int count;
    std::cout << "Rectangle Count: ";
    std::cin >> count;
    std::vector< Rectangle > r( count );
    for( int i=0 ; i<count ; i++ )
    {
        std::cout << "Width: " ; std::cin >> r[i].width;
        std::cout << "Height: " ; std::cin >> r[i].height;
    }
    for( int i=0 ; i<count ; i++ ) r[i].print();
    return 0;
};
```

Outline

- Exercise 25
- References
- Dynamic Memory Allocation
- Review questions

Review questions

1. What is a C++ *reference*?

An alias for an existing variable

Review questions

2. When should you use C++ references?

1. To allow a function to affect multiple outputs (w/o pointers).
2. To pass data to a function without incurring the cost of a copy.

Review questions

3. What is the difference between a pointer and a reference?

Can't be **NULL**, must be initialized immediately, can't be changed

Review questions

4. How do you dynamically allocate memory in C++?

`new` or `new[]`

Review questions

5. How do you free memory in C++?

`delete` or `delete[]`

Exercise 26

- Website -> Course Materials -> Exercise 26