More C++ :
Vectors, Classes, Inheritance, Templates

with content from cplusplus.com, codeguru.com

Vectors

- vectors in C++
  - basically <u>arrays</u> with enhancements
    - <u>indexed</u> similarly
    - <u>contiguous</u> memory
  - some changes
    - defined differently
    - can be resized without explicit memory allocation
    - contains methods, such as size()

Vectors

- using vectors
  - must include **`<vector>`**
  - template, so must be instantiated with <u>type</u>
  - qualified with **`std::`**

```
std::vector<int> v;     // declares a vector of integers
```

  - can be simplified in small projects

```
#include <vector>
using namespace std;
//...
vector<int> v;          // no need to prepend std:: any more
```

C++ Standard Arrays vs. Vectors

```cpp
size_t size = 10;
int sarray[10];
int *darray = new int[size];
// do something with them:
for(int i=0; i<10; ++i){
    sarray[i] = i;
    darray[i] = i;
}
// don't forget to delete darray when you're done
delete [] darray;
```

```cpp
#include <vector>
//...
size_t size = 10;
std::vector<int> array(size);    // make room for 10 integers,
                                 // and initialize them to 0
// do something with them:
for(int i=0; i<size; ++i){
    array[i] = i;
}
// no need to delete anything
```

Vector Length

- previous program does not check for valid index, which enhances <u>performance</u>
- using **`at`** function will check index

```
std::vector<int> array;
try{
    array.at(1000) = 0;
}
catch(std::out_of_range o){
    std::cout<<o.what()<<std::endl;
}
```

Vector Length

- vectors can grow
  - certain amount of space allocated initially
  - once that space runs out, new space is allocated and the values are copied over

```
#include <vector>
#include <iostream>
//...
std::vector<char> array;
char c = 0;
while(c != 'x'){
  std::cin>>c;
  array.push_back(c);
}
```

Vector Size

- use **`pushback(el)`** to grow the size dynamically
- use **`resize`** to set or reset the size of the array

Vector Size

- use the **`size()`** method for loops

```
for (i = 0; i < array.size(); i++)
   array[i] = 0;
```

Classes

- classes
  - fancy struct's
  - expanded concept of data structures
    - data
    - methods (functions)
  - object
    - instantiation of a class
    - type/variable ⇔ class/object
  - defined with keyword **`class`** (or **`struct`**)

Classes

- members are listed under access specifiers
  - **`private`**
    - members accessible only from within the class
  - **`protected`**
    - members accessible to class or derived classes
  - **`public`**
    - members accessible anywhere the object is visible
- by default, access is private

Classes

- example

```
class Rectangle {
    int width, height;
  public:
    void set_values (int,int);
    int area (void);
} rect;
```

  - declares a class, **`Rectangle`**
  - declares an object, **`rect`**
  - class contains 4 members
    - 2 private data
    - 2 public methods (declarations only, not definitions)

Classes

- members are accessed through <u>objects</u>

```
rect.set_values (3,4);
myarea = rect.area();
```

- <u>public</u> methods can be accessed directly using . operator
  - similar to struct's

Classes

– example

```
// classes example
#include <iostream>
using namespace std;

class Rectangle {
    int width, height;
  public:
    void set_values (int,int);
    int area() {return width*height;}
};

void Rectangle::set_values (int x, int y) {
  width = x;
  height = y;
}

int main () {
  Rectangle rect;
  rect.set_values (3,4);
  cout << "area: " << rect.area();
  return 0;
}
```

notes:

- declaration vs. definition
- inline function
- encapsulation
- data hiding

– output

```
area: 12
```

Classes

– example with 2 variables

```
// example: one class, two objects
#include <iostream>
using namespace std;

class Rectangle {
    int width, height;
  public:
    void set_values (int,int);
    int area () {return width*height;}
};

void Rectangle::set_values (int x, int y) {
  width = x;
  height = y;
}

int main () {
  Rectangle rect, rectb;
  rect.set_values (3,4);
  rectb.set_values (5,6);
  cout << "rect area: " << rect.area() << endl;
  cout << "rectb area: " << rectb.area() << endl;
  return 0;
}
```

notes:

each object has its own set of data/methods

no parameters needed for call to area

– output

```
rect area: 12
rectb area: 30
```

Classes

- what would happen if we called **`area`** before setting values?
  - undetermined result
- constructors
  - automatically called when a new object is created
  - initializes values, allocates memory, etc.
  - constructor name same as class name
  - no return type
  - cannot be called explicitly

Classes

– example

```
// example: class constructor
#include <iostream>
using namespace std;

class Rectangle {
    int width, height;
  public:
    Rectangle (int,int);
    int area () {return (width*height);}
};

Rectangle::Rectangle (int a, int b) {
  width = a;
  height = b;
}

int main () {
  Rectangle rect (3,4);
  Rectangle rectb (5,6);
  cout << "rect area: " << rect.area() << endl;
  cout << "rectb area: " << rectb.area() << endl;
  return 0;
}
```

notes:

results same as before

set_values omitted

values passed to constructor

– output

```
rect area: 12
rectb area: 30
```

Classes

- constructors can be overloaded
  - different number of parameters
  - different parameter types
- implicit default constructor defined if no other constructor defined
  - takes no parameters
  - called when object is declared but no parameters are passed to the constructor
  - cannot call default constructor with parentheses
    - represents a function declaration

```
Rectangle rectb;   // ok, default constructor called
Rectangle rectc(); // oops, default constructor NOT called
```

Classes

- member initialization
  - can be done in constructor body or member initialization

```
class Rectangle {
    int width,height;
  public:
    Rectangle(int,int);
    int area() {return width*height;}
};
```

- constructor can be defined normally

```
Rectangle::Rectangle (int x, int y) { width=x; height=y; }
```

- or with member initialization

```
Rectangle::Rectangle (int x, int y) : width(x) { height=y; }
```

```
Rectangle::Rectangle (int x, int y) : width(x), height(y) { }
```

Classes

- for simple types, doesn't matter if initialization is defined or by default
- for member objects (whose type is a class)
  - if not initialized after the colon, they are default-constructed
  - default construction may not be possible if no default constructor defined for class
  - use member initialization list instead

Classes

– example

```
// member initialization
#include <iostream>
using namespace std;

class Circle {
    double radius;
  public:
    Circle(double r) : radius(r) { }
    double area() {return radius*radius*3.14159265;}
};

class Cylinder {
    Circle base;
    double height;
  public:
    Cylinder(double r, double h) : base (r), height(h) {}
    double volume() {return base.area() * height;}
};

int main () {
  Cylinder foo (10,20);

  cout << "foo's volume: " << foo.volume() << '\n';
  return 0;
}
```

Cylinder class has member of type class Circle and needs to call Circle constructor in member initialization list

Classes

- operator overloading
  - allows operators, such as + or *, to be defined for user-defined types
  - defined like member functions, but prepended with keyword **`operator`**

<table>
<tr><th colspan="13">Overloadable operators</th></tr>
<tr><td>+</td><td>-</td><td>*</td><td>/</td><td>=</td><td><</td><td>></td><td>+=</td><td>-=</td><td>*=</td><td>/=</td><td><<</td><td>>></td></tr>
<tr><td><<=</td><td>>>=</td><td>==</td><td>!=</td><td><=</td><td>>=</td><td>++</td><td>--</td><td>%</td><td>&</td><td>^</td><td>!</td><td>|</td></tr>
<tr><td>~</td><td>&=</td><td>^=</td><td>|=</td><td>&&</td><td>||</td><td>%=</td><td>[]</td><td>()</td><td>,</td><td>->*</td><td>-></td><td>new</td></tr>
<tr><td colspan="2">delete</td><td colspan="2">new[]</td><td colspan="2">delete[]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Classes

– operator overloading example

```
// overloading operators example
#include <iostream>
using namespace std;

class CVector {
  public:
    int x,y;
    CVector () {};
    CVector (int a,int b) : x(a), y(b) {}
    CVector operator + (const CVector&);
};

CVector CVector::operator+ (const CVector& param) {
  CVector temp;
  temp.x = x + param.x;
  temp.y = y + param.y;
  return temp;
}

int main () {
  CVector foo (3,1);
  CVector bar (1,2);
  CVector result;
  result = foo + bar;
  cout << result.x << ',' << result.y << '\n';
  return 0;
}
```

example: equivalent

```
c = a + b;
c = a.operator+ (b);
```

Classes

- **`this`**
  - pointer to current object
  - used within a class method to refer to the object that called it

- example

```
Rectangle::Rectangle (int width, int height)  {
    this -> width = width;
    this -> height = height;
}
```

Classes

- templates
  - parameterized class

```
template <class T>
class mypair {
     T values [2];
  public:
     mypair (T first, T second)
     {
       values[0]=first; values[1]=second;
     }
};
```

  - can be used to store elements of type **`int`**

```
mypair<int> myobject (115, 36);
```

  - or type **`float`**

```
mypair<double> myfloats (3.0, 2.18);
```

Classes

- destructor
  - opposite of constructor
  - called when an object's <u>lifetime</u> ends
  - performs <u>cleanup</u>, such as memory deallocation
  - returns nothing, not even void
  - name same as class name, but preceded by ~
  - implicit default destructor provided if none defined

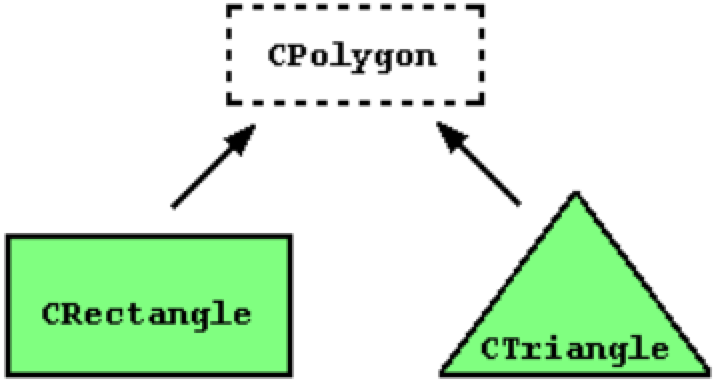
Classes

– destructor example

```
// destructors
#include <iostream>
#include <string>
using namespace std;

class Example4 {
    string* ptr;
  public:
    // constructors:
    Example4() : ptr(new string) {}
    Example4 (const string& str) : ptr(new string(str)) {}
    // destructor:
    ~Example4 () {delete ptr;}
    // access content:
    const string& content() const {return *ptr;}
};

int main () {
  Example4 foo;
  Example4 bar ("Example");

  cout << "bar's content: " << bar.content() << '\n';
  return 0;
}
```

Inheritance

- inheritance
  - allows classes to be extended
  - derived classes retain characteristics of the base class
  - avoids replicated code by allowing common properties to be contained in one class and then used by other classes



  - **Polygon** contains common members; **Rectangle** and **Triangle** contain common members plus specific features

Inheritance

- inheritance example
  - derived classes contain **`width, height, set_values`**
  - output

```
20
10
```

```
// derived classes
#include <iostream>
using namespace std;

class Polygon {
  protected:
    int width, height;
  public:
    void set_values (int a, int b)
      { width=a; height=b;}
 };

class Rectangle: public Polygon {
  public:
    int area ()
      { return width * height; }
 };

class Triangle: public Polygon {
  public:
    int area ()
      { return width * height / 2; }
  };

int main () {
  Rectangle rect;
  Triangle trgl;
  rect.set_values (4,5);
  trgl.set_values (4,5);
  cout << rect.area() << '\n';
  cout << trgl.area() << '\n';
  return 0;
}
```

Inheritance

- inheritance
  - access types and inheritance

Access	public	protected	private
members of the same class	yes	yes	yes
members of derived class	yes	yes	no
not members	yes	no	no

  - inherited members have same access permissions as in base class

```
Polygon::width              // protected access
Rectangle::width            // protected access

Polygon::set_values()       // public access
Rectangle::set_values()     // public access
```

since

```
class Rectangle: public Polygon { /* ... */ }
```

Virtual Methods

- virtual methods
  - can be redefined in <u>derived</u> classes, while preserving its calling signature
  - declared with keyword **`virtual`**

Virtual Methods

– virtual method example

```
// virtual members
#include <iostream>
using namespace std;

class Polygon {
  protected:
    int width, height;
  public:
    void set_values (int a, int b)
      { width=a; height=b; }
    virtual int area ()
      { return 0; }
};

class Rectangle: public Polygon {
  public:
    int area ()
      { return width * height; }
};

class Triangle: public Polygon {
  public:
    int area ()
      { return (width * height / 2); }
};
```

```
int main () {
  Rectangle rect;
  Triangle trgl;
  Polygon poly;
  Polygon * ppoly1 = &rect;
  Polygon * ppoly2 = &trgl;
  Polygon * ppoly3 = &poly;
  ppoly1->set_values (4,5);
  ppoly2->set_values (4,5);
  ppoly3->set_values (4,5);
  cout << ppoly1->area() << '\n';
  cout << ppoly2->area() << '\n';
  cout << ppoly3->area() << '\n';
  return 0;
}
```

`area` declared virtual – derived classes will redefine it

```
20
10
0
```

Virtual Methods

- virtual methods
  - if **`virtual`** keyword removed, all derived class calls to **`area`** method through pointers to base class would return 0
  - virtual methods redefined in derived classes
    - non-virtual methods can also be redefined in derived classes
    - but, if virtual, a <u>pointer</u> to the base class can access the redefined virtual method in the derived class
  - a class that declares or inherits a virtual function is <u>polymorphic</u>
  - note that **`Poly`** is a class, too, and objects can be declared with it

Virtual Methods

- abstract base class
  - similar to base class in previous example
  - can only be used as base class
  - can have virtual methods without definition
    - pure virtual function
    - appended with **=0**

Classes

- abstract base class

```
// abstract class CPolygon
class Polygon {
  protected:
    int width, height;
  public:
    void set_values (int a, int b)
      { width=a; height=b; }
    virtual int area () =0;
};
```

  - cannot be used to declare objects

```
Polygon mypolygon;   // not working if Polygon is abstract base class
```

  - can be used to create pointers to it and take advantage of polymorphic features

```
Polygon * ppoly1;
Polygon * ppoly2;
```

Inheritance

– abstract base class example

```
// abstract base class
#include <iostream>
using namespace std;

class Polygon {
  protected:
    int width, height;
  public:
    void set_values (int a, int b)
      { width=a; height=b; }
    virtual int area (void) =0;
};

class Rectangle: public Polygon {
  public:
    int area (void)
      { return (width * height); }
};

class Triangle: public Polygon {
  public:
    int area (void)
      { return (width * height / 2); }
};
```

```
int main () {
  Rectangle rect;
  Triangle trgl;
  Polygon * ppoly1 = &rect;
  Polygon * ppoly2 = &trgl;
  ppoly1->set_values (4,5);
  ppoly2->set_values (4,5);
  cout << ppoly1->area() << '\n';
  cout << ppoly2->area() << '\n';
  return 0;
}
```

```
20
10
```