==

CLASSES

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C++ the Object Based Paradigm

Object Oriented Programming

- Object-oriented programming (OOP) is a programming paradigm based upon objects (having both data and methods)
  that aims to incorporate the advantages of modularity and reusability.
- Objects, which are usually instances of classes,
  are used to interact with one another
  to design applications and computer programs.
- The important features of object–oriented programming are:
  - Bottom–up approach in program design
  - Programs organized around objects, grouped in classes
  - Focus on data with methods to operate upon object's data
  - Interaction between objects through functions
  - Reusability of design through creation of new classes
    by adding features to existing classes
- Some examples of object-oriented programming languages are:
  - C++, Java, Smalltalk, Delphi, C#, Perl, Python, Ruby, and PHP.

(source: http://www.tutorialspoint.com/object_oriented_analysis_design/ooad_object_oriented_paradigm.html)

Object:

- An object has state,
- exhibits some well-defined behaviour,
- and has a unique identity.

Class:

- A class describes a set of objects
  that share a common structure,
  and a common behaviour.
- A single object is an instance of a class.

Object-Oriented Analysis

- Object–Oriented Analysis (OOA) is the procedure of identifying software engineering requirements and developing software specifications in terms of a software system's object model, which comprises of interacting objects.
- The main difference between object-oriented analysis and other forms of analysis is that in object-oriented approach, requirements are organized around objects, which integrate both data and functions. They are modelled after real-world objects that the system interacts with. In traditional analysis methodologies, the two aspects - functions and data - are considered separately.

- The **primary tasks in object-oriented analysis** (OOA) are:
  - Identifying objects
  - Organizing the objects by creating object model diagram
  - Defining the internals of the objects, or object attributes
  - Defining the behavior of the objects, i.e., object actions
  - Describing how the objects interact

- The common models used in OOA are use cases and object models.

Object-Oriented Design

- Object–Oriented Design (OOD) involves implementation of the conceptual model produced during object-oriented analysis.
  In OOD, concepts in the analysis model, which are technology–independent,
  are mapped onto implementing classes,
  constraints are identified and interfaces are designed,
  resulting in a model for the solution domain, i.e.,
  a detailed description of how the system is to be built on concrete technologies.
- The implementation details generally include:
  - Restructuring the class data (if necessary),
  - Implementation of methods, i.e., internal data structures and algorithms,
  - Implementation of control, and
  - Implementation of associations.

(source: http://www.tutorialspoint.com/object_oriented_analysis_design/ooad_object_oriented_paradigm.html)

An example: a class Date

```
#include ...

...
class Date
{
public: // access specifier; users can only access the PUBLIC members
      Date();  // constructor; constructors have the name of the class
      Date(unsigned int y, unsigned int m,unsigned int d);
      Date(string yearMonthDay); // constructors can be overloaded
      void setYear(unsigned int y) ; // member function OR method
      void setMonth(unsigned int m) ;
      void setDay(unsigned int d) ;
      void setDate(unsigned int y, unsigned int m, unsigned int d) ;
      unsigned int getYear() ;
      unsigned int getMonth() ;
      unsigned int getDay() ;
      string getStr();  // get (return) date as a string
      void show();
private: // PRIVATE data & function members are hidden from the user
      unsigned int year; // data member
      unsigned int month;
      unsigned int day;
     // the date could have been represented internally as a string
     // the internal representation is hidden from the user
}; // NOTE THE SEMICOLON

Date::Date()  // constructors do not have a return type
{
// ... CONSTRUCTOR DEFINITION
}

Date::Date(unsigned int y, unsigned int m, unsigned int d)
{
   year = y;
   month = m;
   day   = d;
}
//... DEFINITION OF OTHER MEMBER FUNCTIONS

void Date::show()   //scope resolution is needed; other classes could have a show() method
{
// ...
}

int main()
{
      Date d1;
      Date d2(2011,03,18);
      Date d3("2011/03/18");

      d2.setDay(19);

      d2.show();

      string d2_str = d2.getStr();
      cout << d2_str << endl;

}
```

Classes in C++

- A class is a user-defined type.
- A class declaration specifies
  - the representation of objects of the class
  - and the set of operations that can be applied to such objects.

A *class* comprises:

- ***data members*** (or ***fields***, or ***attributes***) :
  each object of the class has its own copy of the data members (local state)
- ***member functions*** (or ***methods***):
  applicable to objects of the class

Data members

- describe the ***state*** of the objects
- they have a type, and are declared as:
  `type dataMemberId`

Member functions

- denote a **service** that objects offer to their clients
- the ***interface*** to such a service is specified by
  - its return type
  - and formal parameter(s):
    `returnType memberFunctId( formalParams )`
- In particular, a function with **`void`** return type
  usually indicates a function which modifies/shows the state of the object.

Access specifier

- a class may have several private and public sections
- keyword `public` marks the beginning of each public section
- keyword `private` marks the beginning of each private section
- by default, members (data and functions) are private
- normally, the **data members** are placed in **private** section(s)
  and the **function members** in **public** section(s)
- public members can be accessed by both member and nonmember functions

Constructor

- special function that is a member of the class and has the same name as the class
- does not have a return type
- is automatically called when an object of that class is created

```
/*
CLASSES
Fraction class (partial implementation)
TO DO:
- implement other arithmetic operations
*/

#include <iostream>
#include <iomanip>
#include <cctype>
#include <string>
#include <sstream>

using namespace std;

class Fraction
{
public: //access-specifier
      Fraction(); // default constructor; constructors have the same name of the class
      Fraction(int num, int denom); // constructor overloading; parameterized constructor
//    ~Fraction(); // destructor (sometimes not necessary, as in this case)
      void read();
      void setNumerator(int num);   // member function OR class method
      void setDenominator(int num); // mutator function
      int getNumerator() const; //const member functions can't modify the object that invokes it
      int getDenominator() const;   // accessor function
      bool isValid() const;
      void setValid(bool v);
      void show() const;
      void showAll() const;
      Fraction multiply(const Fraction &f);
      // Fraction divide(const Fraction &f);
      // Fraction sum(const Fraction &f);
      // Fraction subtract(const Fraction &f);
      void reduce();
private: //access-specifier
      int numerator; // data member OR attribute
      int denominator;
      bool valid; // fractions with denominator = 0    or   that
                  // were not read in the format "n/d" are considered invalid !!!
      int gcd(int x, int y) const; // can only be invoked inside class methods
};

// ------------------------------------------------------------------
// MEMBER FUNCTIONS DEFINITIONS
// ------------------------------------------------------------------

// Constructs a fraction with numerator=0 and denominator=1
// Constructors DO NOT HAVE A RETURN TYPE
Fraction::Fraction()  // :: is named the scope resolution operator
{
      numerator = 0;
      denominator = 1;
      valid = true;
}
```

```
// Constructs a fraction with numerator=num and denominator=denom
Fraction::Fraction(int num, int denom)
{
     numerator = num;
     denominator = denom;
     valid = (denominator != 0);
}
//------------------------------------------------------------------------
/* //UNCOMMENT AND INTERPRET WHAT HAPPENS
Fraction::~Fraction()
{
     cout << "fraction destroyed" << endl;
}
*/
//------------------------------------------------------------------------
// Reads a fraction; fraction must have format 'numerator' / 'denominator'
void Fraction::read()
{
    string fractionString;
    char fracSymbol;
    int num;
    int denom;

    cout << "n / d ? ";  // should not be done here …?
    getline(cin,fractionString);

    istringstream fractionStrStream(fractionString);
    valid = false;
    if (fractionStrStream >> num >> fracSymbol >> denom)
    {
      numerator = num;
      denominator = denom;
      valid = (fracSymbol == '/' && denom !=0);
    }
}
//------------------------------------------------------------------------
// Set fraction numerator to 'n'
void Fraction::setNumerator(int n)
{
     numerator = n;
}
//------------------------------------------------------------------------
// Set fraction denominator to 'n'
void Fraction::setDenominator(int n)
{
     denominator = n;
      valid = (denominator != 0);
}
//------------------------------------------------------------------------
// Set the valid fraction information
void Fraction::setValid(bool v)
{
     valid = v;
}
//------------------------------------------------------------------------
// Returns the fraction numerator
int Fraction::getNumerator() const
{
     return numerator;
}
```

```
//------------------------------------------------------------------------
// Returns the fraction denominator
int Fraction::getDenominator() const
{
      return denominator;
}
//------------------------------------------------------------------------
// Returns the valid fraction information
bool Fraction::isValid() const
{
      return valid;
}
//------------------------------------------------------------------------
// Multiply current fraction by fraction 'f'
Fraction Fraction::multiply(const Fraction &f)
{
      Fraction result;

      result.setNumerator(numerator * f.getNumerator());
      result.setDenominator(denominator * f.getDenominator());
      result.setValid(valid && f.isValid());

      result.reduce();

      return result;
}
//------------------------------------------------------------------------
void Fraction::reduce()
{
      if (valid)
      {
           int n = gcd(numerator,denominator);
           numerator = numerator / n;
           denominator = denominator / n;
      }
}
//------------------------------------------------------------------------
// Show fraction; format is 'numerator / denominator'
void Fraction::show() const
{
      cout << numerator << "/" << denominator;
}
//------------------------------------------------------------------------
// Show fraction; format is 'numerator / denominator' followed by
// 'valid/invalid' information
void Fraction::showAll() const
{
      show();
      cout << (valid ? " valid" : " invalid") << endl << endl;
}
//------------------------------------------------------------------------
```

```
// Compute greatest common divisor between 'x' and 'y'
// using Euclid's algorithm
int Fraction::gcd(int x, int y) const
{
     x = abs(x);  y=abs(y);  //  for dealing with negative numbers
     if (valid)
     {
          while (x != y)
          {
               if (x < y)
                    y = y - x;
               else
                    x = x - y;
          }
          return x;
     }
     else
          return 0; // impossible to calculate gcd
}
//-----------------------------------------------------------------------
// Defines and reads several fractions
// and executes some multiplication operations with them
int main()
{
     Fraction f1, f2(2,5), f3(5,7), f4(0,0), f5(1,0), f6, f7, f8;

     cout << "f1" << endl;
     f1.show(); cout << endl; //later on w'll see how to do: cout << f1; ☺
     f1.showAll();

    // f1.Fraction(1,2); // can't invoke constructor on existing object
    f1 = Fraction(1,2); // ... but can do this :-) EXPLICIT CONSTRUCTOR CALL
     cout << "f1 new" << endl;
     f1.show(); cout << endl;
     f1.showAll();

     cout << "f2" << endl;
     f2.show(); cout << endl;
     f2.showAll();

     cout << "f3" << endl;
     f3.show(); cout << endl;
     f3.showAll();

     cout << "f4" << endl;
     f4.show(); cout << endl;
     f4.showAll();

     cout << "f5" << endl;
     f5.show(); cout << endl;
     f5.showAll();

     cout << "f6 = f2 * f3" << endl;
     f6 = f2.multiply(f3);  // assignment is defined for objects; comparison (==) is not
     f6.show(); cout << endl;
     f6.showAll();

     f6.reduce();
     cout << "f6 reduced" << endl;
     f6.show(); cout << endl;
     f6.showAll();
    cout << "f7 = f2 * f4" << endl;
    f7 = f2.multiply(f4);
    f7.show(); cout << endl;
    f7.showAll();

    cout << "f8 - ";
    f8.read();
    cout << "f8" << endl;
    f8.show(); cout << endl;
    f8.showAll();

    cout << "f8 = f6 * f8" << endl;
    f8 = f6.multiply(f8);
    f8.show(); cout << endl;
    f8.showAll();

    return 0;
}
```

NOTES:

- **INCLUDE A DEFAULT CONSTRUCTOR IN YOUR CLASSES**
  SPECIALLY WHEN YOU DO CONSTRUCTOR OVERLOADING
  - If you define no constructor
    the compiler will define a default constructor that does nothing
  - But if you only define a constructor with arguments, ex:
    `Fraction(int num, int denom);`
    no default constructor will be defined by the compiler;
    so, the following declaration will be illegal
    `Fraction f1;`
  - Assigning a default value to all the parameters of a constructor
    is equivalent to define a default constructor:
    `Fraction(int num=0, int denom=1); // fraction with value zero`

- **... UNLESS YOU DON'T WANT TO HAVE A DEFAULT CONSTRUCTOR**
  - Ex: what should a default constructor for the **Date** class do …?

- To call a constructor without arguments do
  this → **`Fraction f1;`**
  not this → `Fraction f1();`

- A constructor behaves like a function that returns an object of its class type. That is what happens when you do
  `f1 = `**`Fraction(3,5);`**

```
/*
Classes

Fraction class (partial implementation)

SOLUTION SIMILAR TO THE PREVIOUS ONE, BUT USING the this POINTER

NOTE that by using this->
parameters can have the same name as the data members of the class
(not particularly useful...)

TO DO:
- implement reduceFraction
- implement other arithmetic operations
*/

#include <iostream>
#include <iomanip>
#include <cctype>
#include <string>
#include <sstream>
#include <cstdlib>

using namespace std;

class Fraction
{
public:
      Fraction(); // default constructor
      Fraction(int numerator, int denominator); // alternative constructor
      void read();
      void setNumerator(int numerator);
      void setDenominator(int numerator);
      int getNumerator() const;
      int getDenominator() const;
      bool isValid() const;
      void setValid(bool v);
      void show() const;
      void showAll() const;
      Fraction multiply(const Fraction &f);
      // Fraction divide(const Fraction &f);
      // Fraction sum(const Fraction &f);
      // Fraction subtract(const Fraction &f);
      // Fraction subtract(const Fraction &f);
      void reduce();
private:
      int numerator;
      int denominator;
      bool valid;
      int gcd(int x, int y) const;
};
//--------------------------------------------------------------------------

// Constructs a fraction with numerator=0 and denominator=1
Fraction::Fraction()
{
      numerator = 0;
      denominator = 1;
      valid = true;
}
//--------------------------------------------------------------------------
```

```
// Constructs a fraction with numerator and denominator equal to the
parameter values
Fraction::Fraction(int numerator, int denominator)
{
     this->numerator = numerator;      // when member data & parameters
     this->denominator = denominator; // have the same name(s)
     this->valid = (denominator != 0);// ALTERNATIVE: append _ to the name
}                                     // of each attribute; ex: _numerator
//--------------------------------------------------------------------------
// Reads a fraction; fraction must have format 'numerator' / 'denominator'
void Fraction::read()
{
    string fractionString;
    char fracSymbol;
    int numerator;
    int denominator;

    cout << "n / d ? ";
    getline(cin,fractionString);

    istringstream fractionStrStream(fractionString);
    this->valid = false;
    if (fractionStrStream >> num >> fracSymbol >> denom)
    {
      this->numerator = numerator;
      this->denominator = denominator;
      this->valid = (fracSymbol == '/' && denom !=0);
    }
}
//--------------------------------------------------------------------------
// Set fraction numerator to 'numerator' value
void Fraction::setNumerator(int numerator)
{
     this->numerator = numerator;
}
//--------------------------------------------------------------------------
// Set fraction denominator to 'denominator' value
void Fraction::setDenominator(int denominator)
{
     this->denominator = denominator;
      valid = (denominator != 0);
}
//--------------------------------------------------------------------------
// Set the valid fraction information
void Fraction::setValid(bool valid)
{
     this->valid = valid;
}
//--------------------------------------------------------------------------
// Returns the fraction numerator
int Fraction::getNumerator() const
{
     return numerator;
}
//--------------------------------------------------------------------------
// Returns the fraction denominator
int Fraction::getDenominator() const
{
     return denominator;
}
```

```
//------------------------------------------------------------------------
// Returns the valid fraction information
bool Fraction::isValid() const
{
      return valid;
}
//------------------------------------------------------------------------
// Multiply current fraction by fraction 'f'
Fraction Fraction::multiply(const Fraction &f)
{
      Fraction result;

      result.setNumerator(this->numerator * f.getNumerator());
      result.setDenominator(this->denominator * f.getDenominator());
      result.setValid(valid && f.isValid());

      return result;
}
//------------------------------------------------------------------------
void Fraction::reduce()
{
      if (valid)
      {
            int n = gcd(numerator,denominator);
            numerator = numerator / n;
            denominator = denominator / n;
      }
}
//------------------------------------------------------------------------
// Show fraction; format is 'numerator / denominator'
void Fraction::show() const
{
      cout << numerator << "/" << denominator;
}
//------------------------------------------------------------------------
// Show fraction; format is 'numerator / denominator' followed by
'valid/invalid' information
void Fraction::showAll() const
{
      show();
      cout << (valid ? " valid" : " invalid") << endl << endl;
}
//------------------------------------------------------------------------
// Compute greatest common divisor between 'x' and 'y'- Euclid's algorithm
int Fraction::gcd(int x, int y) const
{
     x = abs(x);  y=abs(y);
      if (valid)
      {
            while (x != y)
            {
                  if (x < y)
                        y = y - x;
                  else
                        x = x - y;
            }
            return x;
      }
      else
            return 0; // impossible to calculate gcd
}
```

```
//------------------------------------------------------------------------
// Defines and reads several fractions
// and executes some multiplication operations with them
int main()
{
    Fraction f1, f2(2,5), f3(5,7), f4(0,0), f5(1,0), f6, f7, f8;

    cout << "f1" << endl;
    f1.show(); cout << endl;
    f1.showAll();

    cout << "f2" << endl;
    f2.show(); cout << endl;
    f2.showAll();

    cout << "f3" << endl;
    f3.show(); cout << endl;
    f3.showAll();

    cout << "f4" << endl;
    f4.show(); cout << endl;
    f4.showAll();

    cout << "f5" << endl;
    f5.show(); cout << endl;
    f5.showAll();

    cout << "f6 = f2 * f3" << endl;
    f6 = f2.multiply(f3);
    f6.show(); cout << endl;
    f6.showAll();

    f6.reduce();
    cout << "f6 reduced" << endl;
    f6.show(); cout << endl;
    f6.showAll();


    cout << "f7 = f2 * f4" << endl;
    f7 = f2.multiply(f4);
    f7.show(); cout << endl;
    f7.showAll();

    cout << "f8 - ";
    f8.read();
    cout << "f8" << endl;
    f8.show(); cout << endl;
    f8.showAll();

    cout << "f8 = f6 * f8" << endl;
    f8 = f6.multiply(f8);
    f8.show(); cout << endl;
    f8.showAll();

    return 0;
}
```

```
/*
Application for library management

class Book and Library - preliminary definition and implementation
class User - not yet defined

Using static class attributes
*/

#include <iostream>
#include <string>
#include <vector>
#include <cstddef>

using namespace std;

typedef unsigned long IdentNum;

//----------------------------------------------------------------------

class Book
{
public:
      Book();                       //default constructor
      Book(string bookName);        //another constructor
      void setName(string bookName);
      IdentNum getId() const;
      string getName() const;
      void show() const;
private:
      static IdentNum numBooks; //static => only one copy for all objects
                                // no storage is allocated for numBooks
                                // numBooks must be defined outside the class
      IdentNum id; // each object has data members id and name
      string name;
};

//----------------------------------------------------------------------

class Library
{
public:
      Library(); //only the default constructor is declared
      void addBook(Book book);
      void showBooks() const;
private:
      vector<Book> books;
};
```

```
//--------------------------------------------------------------------------
// CLASS Book - MEMBER FUNCTIONS IMPLEMENTATION
//--------------------------------------------------------------------------

IdentNum Book::numBooks = 0; //static variable definition and initialization

//--------------------------------------------------------------------------

Book::Book()
{
      numBooks++;
      id = numBooks;
      name = "UNKNOWN BOOK NAME";
}

//--------------------------------------------------------------------------

Book::Book(string bookName)
{
      numBooks++;
      id = numBooks;
      name = bookName;
}

//--------------------------------------------------------------------------

IdentNum Book::getId() const
{
      return id;
}

//--------------------------------------------------------------------------

void Book::setName(string bookName)
{
      name = bookName;
}
//--------------------------------------------------------------------------

string Book::getName() const
{
      return name;
}
```

```cpp
//----------------------------------------------------------------------
// CLASS Library - MEMBER FUNCTIONS IMPLEMENTATION
//----------------------------------------------------------------------

Library::Library()
{
    books.clear();   // clear() is a method from vector class
}

//----------------------------------------------------------------------

void Library::addBook(Book b)
{
    books.push_back(b);
}

//----------------------------------------------------------------------

void Library::showBooks() const
{
    for (size_t i=0; i<books.size(); i++)
        cout << books[i].getId() << " - " << books[i].getName() << endl;
}

//----------------------------------------------------------------------
//----------------------------------------------------------------------

int main()
{
    Library lib;

    Book b1;   // which constructor is used in each case ?
    Book b2("My First C++ Book");

    lib.addBook(b1);
    lib.addBook(b2);

    Book b3;

    string bookName;
    cout << "Book name ? ";
    getline(cin,bookName);
    b3.setName(bookName);

    lib.addBook(b3);

    lib.showBooks();
}
```

- **What happens to the books when the application ends?**

```
/*
Application for library management
class Book and Library - preliminary definition and implementation
class User - not yet defined
Using static attributes and methods in class declaration
Saving library books in a file
*/
#include <iostream>
#include <string>
#include <vector>
#include <cstddef>
#include <fstream>
#include <sstream>
using namespace std;

//----------------------------------------------------------------------
// AUXILIARY TYPES - DEFINITION
//----------------------------------------------------------------------

typedef unsigned long IdentNum;

//----------------------------------------------------------------------
// CLASS Book - DEFINITION
//----------------------------------------------------------------------
class Book
{
public:
      Book(); // default constructor
      Book(string bookName); //another constructor
      void setId(IdentNum num);
      void setName(string bookName);
      IdentNum getId() const;
      string getName() const;
      void show() const;
      static void setNumBooks(IdentNum n); //static method
      static IdentNum getNumBooks();
      // NOTE: can´t be "static IdentNum getNumBooks() const;"
      // static methods can only refer other static members of the class
private:
      static IdentNum numBooks; //static attribute declaration
                                //static => only one copy for all objects
                                  // no storage is allocated for numBooks
                                  // numBooks must be defined outside the class
      IdentNum id;
      string name;
};

//----------------------------------------------------------------------
// CLASS Library - DEFINITION
//----------------------------------------------------------------------
class Library
{
public:
      Library();
      void addBook(Book book);
      void showBooks() const;
      void saveBooks(string filename);
      void loadBooks(string filename);
private:
      vector<Book> books;

};
```

```
//----------------------------------------------------------------------
// UTILITARY FUNCTIONS
// Note: in C++11 the are functions for converting numbers <-> strings
//        (see previous notes)
//----------------------------------------------------------------------

int string_to_int (string intStr)
{
      int n;
      istringstream intStream(intStr);
      intStream >> n;
      return n;
}

//----------------------------------------------------------------------

/*
string int_to_string(int n)
{
      ostringstream outstr;
      outstr << n;
      return outstr.str();
}
*/

//----------------------------------------------------------------------
// CLASS Book - STATIC ATTRIBUTE DEFINITION AND INITIALIZATION
//----------------------------------------------------------------------

IdentNum Book::numBooks = 0;
// static variables MUST BE DEFINED (space is reserved), outside the class body;
// in this case, initialization is optional; by default, global integers are set to zero

//----------------------------------------------------------------------
// CLASS Book - IMPLEMENTATION
//----------------------------------------------------------------------

Book::Book()
{
     // suggestion: do not increment numBooks is this case
     // useful for instantiating temporary books
      id = 0;
      name = "VOID";  // OR "" OR "UNKNOWN" ...
}

//----------------------------------------------------------------------

Book::Book(string bookName)
{
      numBooks++;
      id = numBooks;
      name = bookName;
}

//----------------------------------------------------------------------

IdentNum Book::getId() const
{
      return id;
}
```

```
//----------------------------------------------------------------------

string Book::getName() const
{
    return name;
}

//----------------------------------------------------------------------

IdentNum Book::getNumBooks() // NOTE: not "static IdentNum Book::getNumBooks()"
{
    return numBooks;
}
//----------------------------------------------------------------------

void Book::setNumBooks(IdentNum n) // NOTE: not "static void Book::setNumBooks(IdentNum n)"
{
    numBooks = n;
}

//----------------------------------------------------------------------

void Book::setId(IdentNum num)
{
    id = num;
}

//----------------------------------------------------------------------

void Book::setName(string bookName)
{
    name = bookName;
}

//----------------------------------------------------------------------

void Book::show() const
{
          cout << id << " - " << name << endl;
}

//----------------------------------------------------------------------
// CLASS Library - IMPLEMENTATION
//----------------------------------------------------------------------

Library::Library()
{
    books.clear();
}
//----------------------------------------------------------------------

void Library::addBook(Book b)
{
    books.push_back(b);
}

//----------------------------------------------------------------------
```

```
void Library::showBooks() const
{
      cout << "\n-----------BOOKS-----------\n";
      for (size_t i=0; i<books.size(); i++)
            cout << books[i].getId() << " - " << books[i].getName() << endl;
      cout << "---------------------------\n\n";

}

//----------------------------------------------------------------------

void Library::saveBooks(string filename)
{
      ofstream fout;

      fout.open(filename);
      if (fout.fail( ))
      {
            cout << "Output file opening failed.\n";
            exit(1);
      }

      fout << Book::getNumBooks() << " (last book ID)" << endl << endl;

      for (size_t i=0; i<books.size(); i++)
      {
            fout << books[i].getId() << endl;
            fout << books[i].getName() << endl << endl;
      }

      cout << books.size()  << " books saved in file " << filename << endl;

      fout.close();
}

void Library::loadBooks(string filename)
{
      ifstream fin;
      IdentNum numBooks;
      string bookIdStr;
      string emptyLine;
      //IdentNum bookId;
      string bookName;

      // a static method may be called independent of any object,
      // by using the class name and the scope resolution operator
     // but may also be called in connection with an object (see end of main() function)
      Book::setNumBooks(0);

      books.clear();

      fin.open(filename);
      if (fin.fail( ))
      {
            cout << "Input file opening failed.\n";
            exit(1);
      }
     fin >> numBooks; fin.ignore(100,'\n');
     getline(fin,emptyLine);
     cout << "'numBooks' obtained from file " << filename << ": " <<
numBooks  << endl;

     for (size_t i=0; i<numBooks; i++)
     {
          getline(fin,bookIdStr); //NOTE: compare with Library::saveBooks()
          //bookId = string_to_int(bookIdStr);
          getline(fin,bookName);
          getline(fin,emptyLine);

          Book b(bookName);
          books.push_back(b);
     }

     cout << books.size() << " books loaded from file " << filename <<
endl;

     fin.close();
}

//-----------------------------------------------------------------------
//-----------------------------------------------------------------------

int main()
{
     Library lib;

     Book b1("My First C++ Book");
     Book b2("My Second C++ Book");
     lib.addBook(b1);
     lib.addBook(b2);
     cout << "2 books added to the library\n";

     lib.showBooks();

     lib.saveBooks("bookfile.txt");

     lib.loadBooks("bookfile.txt");

     Book b3("Big C++");
     lib.addBook(b3);
     cout << "1 book added to the library\n";

     lib.showBooks();
     //cout << "numBooks = " << b1.getNumBooks() << endl; // b1.getNumBooks() is a valid call

     lib.saveBooks("bookfile.txt");

}
```

In Library class, an alternative implementation could define:
    vector<*Book> books;

Do you see any advantage / disadvantage ?

Think what happens when you add a **User class.**

Separate compilation & Abstract Data Types (ADTs)

Until now ... small programs

- code placed into a single file
- typical layout
  - initial comments – what is the program purpose
  - included header files
  - constants
  - typedef's and classes
  - function prototypes (if any)
  - global variables (if any)
  - function / class implementation (+ comments)

When programs get larger or you work in a team ...

- need to separate code into separate source files
- reasons for separating code
  - only those files that you changed need to be recompiled
  - each programmer is solely responsible for a separate set of files (editing of common files is avoided)

C++ allows you to divide a program into parts

- each part can be stored into a separate file
- each part can be compiled separately
- a class definition can be stored separately from a program
- this allows you to use the class in multiple programs

Header files (interface)

- files that define types or functions that are needed in other files
- are a path of communication between the code
- contain
  - definitions of constants
  - definitions of types / classes
  - declarations of non-member functions
  - declarations of global variables

Implementation files

- contain
  - definitions of member functions
  - definitions of nonmember functions
  - definitions of global variables

Abstract Data Types (ADTs)

- An ADT is a class defined to separate
  the interface and the implementation
- All member variables are private
- The class definition along with the function and operator declarations
  are grouped together as the interface of the ADT
- Group the implementation of the operations together and
  make them available to the programmer using the ADT
- The public part of the class definition is part of the ADT interface
- The private part of the class definition is part of the ADT implementation
  - This hides it from those using the ADT
- C++ does not allow splitting the public and private parts of
  the class definition across files
- The entire class definition is usually in the interface file

Example: a Book ADT interface

- The Book ADT interface is stored in a file named book.h
- The .h suffix means this is a header file
- Interface files are always header files
- A program using book.h must include it using an include directive
  - #include "book.h"

#include < > OR #include " " ?

- To include a predefined header file use < ..... >
  - #include <iostream>
- < ..... > tells the compiler to look where the system stores predefined header files
- To include a header file you wrote use "....."
  - #include "book.h"
- " ..... " usually causes the compiler to look in the current directory for the header file

The Implementation File

- Contains the definitions of the ADT functions
- Usually has the same name as the header file but a different suffix
- Since our header file is named book.h,
  the implementation file is named book.cpp
- The implementation file requires an include directive to include the interface file:
  - #include "book.h"

The Application File

- The application file is the file that contains the program that uses the ADT
  - It is also called a driver file
  - Must use an include directive to include the interface file:
    - #include "book.h"

Running The Program

- Basic steps required to run a program:
  (details vary from system to system)
  - Compile the implementation file
  - Compile the application file
  - Link the files to create an executable program using a utility called a linker
    - Linking is often done automatically

Compile book.h ?

- The interface file is not compiled separately
  - The preprocessor replaces any occurrence of #include "book.h"
    with the text of book.h before compiling
  - Both the implementation file and the application file contain #include "book.h"
    - The text of book.h is seen by the compiler in each of these files
    - There is no need to compile book.h separately

Why Three Files?

- Using separate files permits
  - The ADT to be used in other programs
    without rewriting the definition of the class for each
  - Implementation file to be compiled once
    even if multiple programs use the ADT
  - Changing the implementation file
    does not require changing the program using the ADT

Reusable Components

- An ADT coded in separate files can be used over and over
- The reusability of such an ADT class
  - Saves effort since it does not need to be
    - Redesigned
    - Recoded
    - Retested
  - Is likely to result in more reliable components

Multiple Classes

- A program may use several classes
  - Each could be stored in its own interface and implementation files
  - Some files can "include" other files, that include still others
  - It is possible that the same interface file could be included in multiple files
  - C++ does not allow multiple declarations of a class
  - The #ifndef directive can be used to prevent multiple declarations of a class

Using #ifndef directive

- Consider this code in the interface file

```
#ifndef BOOK_H
#define BOOK_H
// the Book class definition goes here
#endif
```

- To prevent multiple declarations of a class, we can use these directives:
  - **#define BOOK_H**
    - adds BOOK_H to a list indicating BOOK_H has been seen
  - **#ifndef BOOK_H**
    - checks to see if BOOK_H has been defined
  - **#endif**
    - if BOOK_H has been defined, skip to #endif

- The first time a #include "book.h" is found,
  BOOK_H and the class are defined
- The next time a #include "book.h" is found,
  all lines between #ifndef and #endif are skipped

- NOTE: **#pragma once** is a non-standard but widely supported preprocessor directive designed to cause the current source file to be included only once in a single compilation; as it is non-standard (yet) its use is not recommended.

Why BOOK_H ?

- BOOK_H is the normal convention for creating an identifier to use with #ifndef
  - it is the file name in all caps
  - use ' _ ' instead of ' . '
- You may use any other identifier, but will make your code more difficult to read

Defining Libraries

- You can create your own libraries of functions
  - You do not have to define a class to use separate files
  - If you have a collection of functions…
    - Declare them in a header file with their comments
    - Define them in an implementation file
    - Use the library files just as you use your class interface and implementation files

```
//----------------------------------------------------------------------
// SEPARATE COMPILATION EXAMPLE - STEP BY STEP
//----------------------------------------------------------------------
```

```
//================================================================================
// SOLUTION 1 (sc1.sln) - Date class definition and implementation
//================================================================================

//================================================================================
// FILE: Date.h
//================================================================================
class Date
{
public:
  Date();
  Date(int year, int month, int day);
  void show() const;
private:
  int year, month, day;
};

//================================================================================
//================================================================================
// FILE: Date.cpp
//================================================================================
#include <iostream>
#include "Date.h"

Date::Date()
{
  this->year = this->month = this->day = 0; // an invalid date !
}
//================================================================================
Date::Date(int year, int month, int day)
{
  this->year = year;
  this->month = month;
  this->day = day;
}
//================================================================================
void Date::show() const
{
  std::cout << this->year << '-' << this->month << '-' << this->day;
}
//================================================================================

// TODO:
// Build > Compile
// see the Date.obj file in C:\.....\sc01\sc01\Debug
```

NOTE:

- **To compile the functions without having a main() function, in Visual Studio, use Build > Compile (Ctrl+F7)**

```
//================================================================================
// SOLUTION 2 (sc2.sln) - add main() to sc1
//================================================================================
//================================================================================
// FILE: main.cpp
//================================================================================
#include <iostream>
#include "Date.h"

using namespace std;

int main()
{
  Date d1;
  Date d2(2016, 4, 21);

  cout << "d1 = ";
  d1.show();
  cout << endl;

  cout << "d2 = ";
  d2.show();
  cout << endl << endl;
}

//================================================================================
// SOLUTION 3 (sc3.sln) - add Person class definition and implementation to sc2
//                        modify main()
//================================================================================
//================================================================================
// FILE: Person.h
//================================================================================
#include <string>

class Person
{
public:
  Person();
  Person(std::string name, int age);
  void show() const;
private:
  std::string name;
  int age;
};

//================================================================================
//================================================================================
// FILE: Person.cpp
//================================================================================
#include <iostream>
#include "Person.h"

Person::Person()
{
  this->name = "NO_NAME";
  this->age = 0;
}
```

```cpp
//================================================================================
Person::Person(std::string name, int age)
{
  this->name = name;
  this->age = age;
}

//================================================================================
void Person::show() const
{
  std::cout << this->name << " - " << this->age;
}
//================================================================================

//================================================================================
// FILE:main.cpp
//================================================================================
#include <iostream>
#include "Date.h"
#include "Person.h"

using namespace std;

int main()
{
  Date d1;
  Date d2(2016, 4, 21);

  cout << "d1 = ";
  d1.show();
  cout << endl;

  cout << "d2 = ";
  d2.show();
  cout << endl << endl;

  //--------------------

  Person p1;
  Person p2("Rui Silva",18);

  cout << "p1 = ";
  p1.show();
  cout << endl;

  cout << "p2 = ";
  p2.show();
  cout << endl << endl;
}
```

```
//================================================================================
// SOLUTION 4 (sc4.sln) – add Date attribute to Person class
//================================================================================
//================================================================================
// FILE: Person.h (new version)
//================================================================================
#include <string>
#include "Date.h"   // NOTE THIS

class Person
{
public:
  Person();
  Person(std::string name, Date birthDate);   // NOTE THIS
  void show() const;
private:
  std::string name;
  // int age;       // NOTE THIS
  Date birthDate;   // NOTE THIS
};

//================================================================================
//================================================================================
// FILE: Person.cpp (new version)
//================================================================================
#include <iostream>
#include "Person.h"

Person::Person()
{
  this->name = "NO_NAME";
  //this->age = 0;
  this->birthDate = Date();      // NOTE THIS
}
//================================================================================
Person::Person(std::string name, Date birthDate)  // NOTE THIS
{
  this->name = name;
  //this->age = age;             // NOTE THIS
  this->birthDate = birthDate;   // NOTE THIS
}
//================================================================================
void Person::show() const
{
  std::cout << this->name << " - ";
  (this->birthDate).show();
}
//================================================================================
//================================================================================
// FILE:main.cpp (new version
//================================================================================
#include <iostream>
#include "Date.h"
#include "Person.h"

using namespace std;

int main()
{
  Date d1;
  Date d2(2016, 4, 21);
  cout << "d1 = ";
  d1.show();
  cout << endl;

  cout << "d2 = ";
  d2.show();
  cout << endl << endl;

  //--------------------

  Person p1;
  Person p2("Rui Silva",d2);

  cout << "p1 = ";
  p1.show();
  cout << endl;

  cout << "p2 = ";
  p2.show();
  cout << endl << endl;
}
```

NOTE THE COMPILATION ERROR: 'Date' : 'class' type redefinition

```
//============================================================================
// SOLUTION 5 (sc5.sln) – solving the 'Date' : 'class' type redefinition problem
//============================================================================
//============================================================================
// FILE: Date.h (new version)
//============================================================================
#ifndef DATE_H   // NOTE THIS     ALTERNATIVE: #pragma once
#define DATE_H   // NOTE THIS

class Date
{
public:
  Date();
  Date(int year, int month, int day);
  void show() const;
private:
  int year, month, day;
};

#endif   // NOTE THIS

//============================================================================
// FILE: Person.h (new version)
//============================================================================
#ifndef PERSON_H   // NOTE THIS
#define PERSON_H   // NOTE THIS

#include <string>
#include "Date.h"

class Person
{
public:
  Person();
  Person(std::string name, Date birthDate);
  void show() const;
```

```
private:
  std::string name;
  // int age;
  Date birthDate;
};

#endif             // NOTE THIS

//================================================================================
// SOLUTION 6 (sc6.sln) - adding an auxiliar function
//================================================================================
//================================================================================
// FILE: Auxilar.h
//================================================================================
#ifndef AUXILAR_H
#define AUXILAR_H

#include <string>

void readString(std::string message, std::string & name);

#endif

//================================================================================
// FILE: Auxilar.cpp
//================================================================================
#include <iostream>
#include <string>
#include "Auxiliar.h"

void readString(std::string message, std::string & s)
{
  do
  {
    std::cout << message;
    std::getline(std::cin, s);
  } while (s == "");
}

//================================================================================
// FILE: main.cpp (new version)
//================================================================================
#include <iostream>
#include "Date.h"
#include "Person.h"
#include "Auxiliar.h"   // NOTE THIS

using namespace std;

int main()
{
  Date d1;
  Date d2(1998, 4, 21);

  cout << "d1 = ";
  d1.show();
  cout << endl;

  cout << "d2 = ";
  d2.show();
  cout << endl << endl;
  //--------------------

  Person p1;
  Person p2("Rui Silva",d2);

  cout << "p1 = ";
  p1.show();
  cout << endl;

  cout << "p2 = ";
  p2.show();
  cout << endl << endl;

  //--------------------
  // NOTE THIS
  std::string name;
  readString("What is the newborn name ? ", name);
  //Date d3 = Date(2016, 11, 23);
  Person p3(name, Date(2016,11,23));
  cout << "p3= ";
  p3.show();
  cout << endl << endl;
}
```

Separate compilation - another example

```
//==========================================================================
// DEFS.H  (no DEFS.CPP)
//--------------------------------------------------------------------------

#ifndef DEFS_H
#define DEFS_H

typedef unsigned int IdentNum;

#endif
//==========================================================================

//==========================================================================
// USER.H
//--------------------------------------------------------------------------

#ifndef USER_H
#define USER_H

#include <string>
#include <vector>
#include "defs.h"

using namespace std;

class User {

private:
      static IdentNum numUsers; //total number of users - used to obtain ID of each new user
      IdentNum ID; // unique user identifier (unsigned integer)
      string name; // user name
      bool active; // only active users can request books
      vector<IdentNum> requestedBooks; // books presently loaned to the user

public:
      //constructors
      User();
      User(string name);

      //get methods
      IdentNum getID() const;
      string getName() const;
      bool isActive() const;
      vector<IdentNum> getRequestedBooks() const;

      bool hasBooksRequested() const;

      //set methods
      void setID(IdentNum userID);
      void setName (string userName);
      void setActive(bool status);
      void setRequestedBooks(const vector<IdentNum> &booksRequestedByUser);
      static void setNumUsers(IdentNum num);

      void borrowBook(IdentNum bookID);
      void returnBook(IdentNum bookID);
};
```

```
#endif

//============================================================================


//============================================================================
// BOOK.H
//----------------------------------------------------------------------------

#ifndef BOOK_H
#define BOOK_H

#include <string>

#include "defs.h"

using namespace std;

class Book {

private:
      static IdentNum numBooks; //total number of books - used to obtain ID of each new book
      IdentNum ID; // unique book identifier (unsigned integer)
      string title; // book title
      string author; // book author OR authors
      unsigned int numAvailable; // number of available items with this title

public:
      //constructors
      Book();
      Book(string bookTitle, string bookAuthor, unsigned int bookQuantity);

      //get methods
      IdentNum getID() const;
      string getTitle() const;
      string getAuthor() const;
      unsigned int getNumAvailable() const;

      //set methods
      void setID(IdentNum bookID);
      void setTitle(string bookTitle);
      void setAuthor(string bookAuthor);
      void setNumAvailable(unsigned int numBooks);
      static void setNumBooks(IdentNum num);

      void addBooks(int bookQuantity);
      void loanBook();
      void returnBook();
};

#endif


//============================================================================
//=========================================================================
// LIBRARY.H
//-------------------------------------------------------------------------

#ifndef LIBRARY_H
#define LIBRARY_H

#include <string>
#include <vector>

#include "defs.h"
#include "book.h"
#include "user.h"

using namespace std;

class Library {

private:
      vector<User> users; // all users that are registered or were registered in the library
      vector<Book> books; // all books that are registered or were registered in the library
      string filenameUsers; // name of the file where users are saved at the end of each program run
      string filenameBooks; // name of the file where books are saved at the end of each program run

public:
      // constructors
      Library();
      Library(string fileUsers, string fileBooks);

      // get functions
      User getUserByID(IdentNum userID) const;
      Book getBookByID(IdentNum bookID) const;

      // user management
      void addUser(User);

      // book management
      void addBook(Book);

      // loaning management
      void loanBook(IdentNum, IdentNum);
      void returnBook(IdentNum, IdentNum);

      // file management methods
      void loadUsers();
      void loadBooks();
      void saveUsers();
      void saveBooks();

      // information display
      void showUsers() const;
      void showUsers(string str) const;
      void showBooks() const;
      void showBooks(string str) const;
      void showAvailableBooks() const;
};

#endif

//=========================================================================
//=========================================================================
// USER.CPP
//-------------------------------------------------------------------------
#include "user.h"

      // to do ...

//=========================================================================

//=========================================================================
// BOOK.CPP
//-------------------------------------------------------------------------
#include "library.h"

      // to do ...

//=========================================================================

//=========================================================================
// LIBRARY.CPP
//-------------------------------------------------------------------------
#include "library.h"

Library::Library(string fileUsers, string fileBooks)
{
      // to do ...
}

//=========================================================================


//=========================================================================
// MAIN.CPP
//-------------------------------------------------------------------------
#include <iostream>

#include "library.h"

using namespace std;

int main ()
{
      Library library("users.txt","books.txt");

      do
      {
            //show menu
            cout << "#### Menu ####\n\n";
            cout << "1 - New user\n";
            cout << "2 - New book\n";
            // ...
            cout << "0 - Exit\n";
            // TO DO
            // read user option
            // execute user option

      } while (...);
}

//=========================================================================
```

Separate compilation – yet another example

Declaring and defining global variables in multiple source file programs

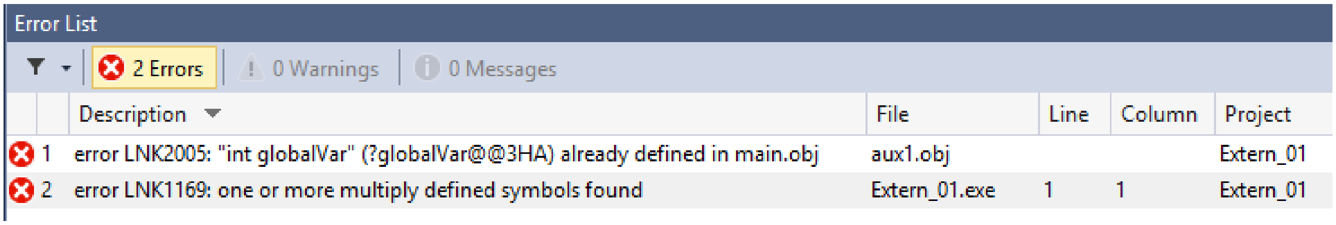
- First of all, it is important to understand the difference between defining a variable and declaring a variable:
  - A variable is defined when the compiler allocates the storage for the variable.
  - A variable is declared when the compiler is informed that a variable exists (and which is its type);
    it does not allocate the storage for the variable at that point.
- You may declare a variable multiple times (though once is sufficient);
  you may define it only once within a given scope.

Using the extern keyword

- Using extern is useful when the program you're building consists of multiple source files linked together,
  where some of the variables defined, for example, in source file **file1.c**
  need to be referenced in other source files, such as **file2.c**.

- The best way to declare and define global variables is
  - to use a header file **file3.h** to contain an **extern** declaration of the variable.
  - The header is included by the one source file that defines the variable (ex: **file3.cpp**) and by all the source files that reference the variable.
  - For each program,
    one source file (and only one source file) defines the variable.
    Similarly, one header file (and only one header file) should declare the variable.

```
//==================================================
// aux1.h

#ifndef AUX1_H
#define AUX1_H

int globalVar = 1000;

void f1();

#endif

//==================================================
// aux1.cpp

#include <iostream>
#include "aux1.h"

using namespace std;

void f1()
{
  cout << "globalVar = " << globalVar << endl;
}

//==================================================
// main.cpp

#include <iostream>
#include "aux1.h"

using namespace std;

int main()
{
  cout << "Global Var = " << globalVar << endl;
  f1();
}

//==================================================
```



		Description	File	Line	Column	Project
✖	1	error LNK2005: "int globalVar" (?globalVar@@3HA) already defined in main.obj	aux1.obj			Extern_01
✖	2	error LNK1169: one or more multiply defined symbols found	Extern_01.exe	1	1	Extern_01

```
//==================================================
// aux1.h

#ifndef AUX1_H
#define AUX1_H

extern int globalVar;

void f1();

#endif

//==================================================
// aux1.cpp

#include <iostream>
#include "aux1.h"

using namespace std;

int globalVar = 1000;

void f1()
{
  cout << "globalVar = " << globalVar << endl;
}

//==================================================
// main.cpp

#include <iostream>
#include "aux1.h"

using namespace std;

int main()
{
  cout << "Global Var = " << globalVar << endl;
  f1();
}

//==================================================
```