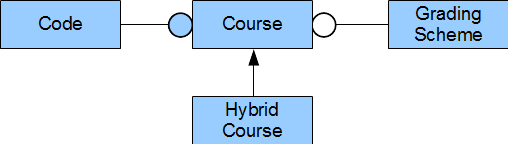
**Input and Output Operators**

The relationships between classes that object-oriented languages support include compositions and associations.  Both of these relationships are more loosely coupled than friendship.  A *composition* is a relationship in which one class *has* another class, while an *association* is a relationship in which one class *uses* another class.  In relationship diagrams, associations appear as open circles and compositions as filled circles.  The diagram below shows that Code uses the Calendar (to determine availability), while each Course has a Course Code class.



Associations are more loosely coupled than compositions.  Typical examples of associations are relationships between the stream-based input and output library classes that support the C++ language and our own custom classes.  To create these relationships, we overload the insertion and extraction operators as helper operators that take stream objects as their left operands and objects of our class type as their right operands.

This chapter describes the stream-based input/output library and shows how to overload the insertion and extraction operators for objects of our custom classes.  This chapter shows how to define file objects and use them to store and retrieve variables of fundamental type.  The chapter concludes by introducing the standard library's string class, which manages character stream input of user-defined length.

Stream Library Overview

The stream-based input/output library that supports the core C++ language overloads two operators for extracting values from an input stream and inserting values into an output stream:

* >> (extract from an input stream)
* << (insert into an output stream)

The library embeds its class definitions in the standard namespace (std).  To access those instances of these classes that the library predefines, we prefix their identifiers with the namespace identifier and the scope resolution operator (std::).

For example,

|  |  |
| --- | --- |
| #include <iostream>  int main() {  int x;  std::cout << "Enter an integer : ";  std::cin >> x;  std::cout << "You entered " << x << std::endl;  } | Enter an integer : 3  You entered 3 |

Standard I/O

The iostream system header file contains the definitions for streaming from and to standard devices.

|  |
| --- |
| #include <iostream> |

This header file includes the definitions of the

* std::istream class - for processing input from the standard input device
* std::ostream class - for processing output to the standard output devices

This header file also predefines the standard input and output objects:

* std::istream
  + std::cin - standard input
* std::ostream
  + std::cout - standard output
  + std::cerr - standard error
  + std::clog - standard log

We use these objects directly and don't need to redefine them.

File I/O

The fstream system header file contains the definitions for streaming from and to files.

|  |
| --- |
| #include <fstream> |

This header file includes the definitions of the

* std::ifstream class - for processing input from a file stream
* std::ofstream class - processing output to a file stream
* std::fstream class - processing input from and output to a file stream

These three classes manage communication between file streams containing 8-bit characters and system memory.  They provide access to a file stream through separate input and output buffers.

Design Considerations

In overloading the insertion and extraction operators for our class types, good design suggests:

* providing flexibility in the selection of stream objects
* resolving scope on classes and objects defined in header files
* enabling cascading as implemented for fundamental types

Selection of Stream Objects

To enable selection of the stream objects by the client code, we upgrade our display() member function to receive a modifiable reference to an object of std::ostream type.  The changes to the header file are shown on the left and the implementation file on the right:

|  |  |
| --- | --- |
| // Student.h  #include <iostream> // for  // std::ostream  const int NG = 20;  class Student {  int no;  float grade[NG];  int ng;  public:  Student();  Student(int);  Student(int, const float\*, int);  void display(std::ostream&)  const;  }; | // Student.cpp  #include <cstring>  #include "Student.h"  using namespace std;  // ...  void Student::display(ostream&  os) const {  if (no > 0) {  os << no << ":\n";  os.setf(ios::fixed);  os.precision(2);  for (int i = 0; i < ng; i++) {  os.width(6);  os << grade[i] << endl;  }  os.unsetf(ios::fixed);  os.precision(6);  } else {  os << "no data available"  << endl;  }  } |

With this upgrade the client code can choose the destination stream (cout, cerr, or clog).

Header Files

A header files may be included alongside other header files written by other developers.  To avoid conflicts between the header files included in an implementation file, we follow certain guidelines:

* include system header files before custom header files
* insert namespace directives after all header files
* resolve the scope of any identifier in a header file at the identifier itself

The preferred method of coding header files is shown on the right:

|  |  |
| --- | --- |
| // Student.h  #include <iostream>  using namespace std; // POOR DESIGN  const int NG = 20;  class Student {  int no;  float grade[NG];  int ng;  public:  Student();  Student(int);  Student(int, const float\*, int);  void display(ostream& os) const;  }; | // Student.h  #include <iostream> // GOOD DESIGN  const int NG = 20;  class Student {  int no;  float grade[NG];  int ng;  public:  Student();  Student(int);  Student(int, const float\*, int);  void display(std::ostream& os)  const;  }; |

Exposing all of the names in any namespace as on the left may lead to unnecessary conflicts with new names or conflicts when several header files are included in an implementation file.  Resolving scope in the display() function's parameter list identifies the class used with its namespace, without exposing any name in that namespace.

Cascading

The following expression is a cascaded expression

|  |
| --- |
| std::cout << x << y << z << std::endl; |

Cascading support enables concatenation of operations where the leftmost operand serves as the left operand for every operation in a compound expression.

The cascaded expression above expands to two simpler sub-expressions executed in the following order:

|  |
| --- |
| std::cout << x;  std::cout << y << z << std::endl; |

The cascaded sub-expression

|  |
| --- |
| std::cout << y << z << std::endl; |

expands to two simpler sub-expressions executed in the following order:

|  |
| --- |
| std::cout << y;  std::cout << z << std::endl; |

Finally, the cascaded sub-expression

|  |
| --- |
| std::cout << z << std::endl; |

expands into two simpler sub-expressions executed in the following order:

|  |
| --- |
| std::cout << z;  std::cout << std::endl; |

Enabling cascading requires that we return a modifiable reference to the left operand.

Returning a modifiable reference from a function lets the client code use the return value as the left operand for the operator on its right.

File I/O Operators

The stream library does not predefine any file objects as instances of the file stream classes.  To create file objects, we need to define them ourselves and connect them to a named file.  A file object is an instance of one of the file stream classes.  When used with the insertion or extraction operators on a connected file, a file object streams the data in formatted form.

File Connections

We can connect a file object to a file for reading, writing or both.  The object's destructor closes the connection.

Input File Objects

To create a file object for reading we define an instance of the std::ifstream class.  This class includes a no-argument constructor as well as one that receives the address of a C-style null-terminated string containing the file name.

For example,

|  |
| --- |
| // Create a File for Reading  // createFileReading.cpp  #include <fstream>  int main() {  std::ifstream f("input.txt"); // connects fin to input.txt for reading  // ...  } |

To connect a file to an existing file object, we call the open() member function on the object.

For example,

|  |
| --- |
| // Connect to a File for Reading  // connectFileReading.cpp  #include <fstream>  int main() {  std::ifstream fin; // defines a file object named fin  fin.open("input.txt"); // connects input.txt to fin  // ...  } |

Output File Objects

To create a file object for writing we define an instance of the std::ofstream class.  This class includes a no-argument constructor as well as one that receives the address of a C-style null-terminated string containing the name of the file.

For example,

|  |
| --- |
| // Writing to a File  // writeFile.cpp  #include <fstream>  int main() {  std::ofstream fout("output.txt"); // connects fout to output.txt for writing  // ...  } |

To connect a file to an existing file object, we call the open() member function on the object.

For example,

|  |
| --- |
| // Connect to a File for Writing  // connectFileWriting.cpp  #include <fstream>  int main() {  std::ofstream fout; // create a file object named fout  std::ofstream fout("output.txt"); // connects fout to output.txt for writing  // ...  } |

Confirming a File Connection

The is\_open() member function called on a file object returns the current state of the object's connection to a file:

|  |
| --- |
| #include <iostream>  #include <fstream>  std::ofstream fout("output.txt"); // connects output.txt to fout for output  if (!fout.is\_open()) {  std::cerr << "File is not open" << std::endl;  } else {  // file is open  // ...  } |

Streaming Fundamental Types

The standard input/output library overloads the extraction and insertion operators for each fundamental type for the file stream classes with a file objects as left operands.

Reading From a File

A file object reads from a file under format control using the extraction operator in the same way as the standard input object (cin) reads using the extraction operator.

Consider a file with a single record: 12 34 45 abc  The output from the following program is shown on the right:

|  |  |
| --- | --- |
| // Reading a File  // readFile.cpp  #include <iostream>  #include <fstream>  int main() {  int i;  std::ifstream f("input.txt");  if (f.is\_open()) {  while (f) {  f >> i;  if (f)  std::cout << i << ' ';  else  std::cout << "\n\*\*Bad input\*\*\n";  }  }  } | 12 34 45  \*\*Bad input\*\* |

The file stream class definition overload the bool conversion operator to return false if the object is not ready for further streaming.  A stream object is not ready for further streaming if it has encountered an error and has not been cleared.  the topic of error states and clearing errors is covered later in the chapter entitled [Input and Output Refinements](https://mwatler.github.io/sep101/Week12/InputOutputRefinements.docx).

Writing to a File

A file object writes to a file under format control using the insertion operator in the same way as the standard output objects (cout, cerr and clog) write using the insertion operator.

For example, the contents of the file created by the following program are shown on the right

|  |  |
| --- | --- |
| // Writing to a File  // writeFile.cpp  #include <iostream>  #include <fstream>  int main() {  int i;  std::ofstream f("output.txt");  if (f.is\_open()) {  f << "Line 1" << std::endl; // record 1  f << "Line 2" << std::endl; // record 2  f << "Line 3" << std::endl; // record 3  }  } | Line 1  Line 2  Line 3 |

String Class

The examples in these notes have been limited to input data that fits within pre-allocated memory.  In the case of character string input, the user determines the number of characters to enter and pre-allocation of the required memory is not possible.  A user entering more characters than allocated memory can accept may cause a stream failure.

The Problem

Consider the user inputting a comment on a student's transcript.  Since we only know how much memory to allocate for the comment after receiving the complete text, we cannot allocate that memory at compile-time or run-time before accepting the comment.

The Solution

The standard library's string class allocates the required amount of memory dynamically during the input process itself.  A std::string object can accept as many characters as the user enters.  The helper function std::getline() extracts the characters from the input stream.

The prototype for this helper function is

std::istream& getline(std::istream&, std::string&, char);

The first parameter receives a modifiable reference to the std::istream object, the second parameter receives a modifiable reference to the std::string object and the third parameter receives the character delimiter for terminating extraction (newline by default).

The <string> header file contains the class definition with this prototype.  The class definition includes two member functions for converting its internal data into a C-style null-terminated string:

* std::string::length() - returns the number of characters in the string
* std::string::c\_str() - returns the address of the C-style null-terminated version of the string

C-Style Example

The following client code extracts an unknown number of characters from the standard input stream, stores them in a C-style null-terminated string and displays the character string on the standard output object in five steps:

1. define a string object to accept the input
2. extract the input using the std::getline() helper function
3. query the string object for the memory required
4. allocate dynamic memory for the requisite C-style null-terminated string
5. copy the data from the string object to the allocated memory
6. deallocate the allocated memory

|  |
| --- |
| // String Class example  // string.cpp  #include <iostream>  #include <string>  int main( ) {  char\* s;  std::string str;  std::cout << "Enter a string : ";  if (std::getline(std::cin, str)) {  s = new char [str.length() + 1];  std::strcpy(s, str.c\_str());  std::cout << "The string entered is : >" << s << '<' << std::endl;  delete [] s;  }  } |

Summary

* the standard library includes overloaded extraction and insertion operators for file objects as left operands and fundamental types as right operands
* an input file object is an instance of an ifstream class
* an output file object is an instance of an ofstream class
* the string class of the standard library manages the memory requirements for storing a user-defined character string of any length