Topic 9

C++ Review Part IV:
More on IO Streams

資料結構與程式設計

Data Structure and Programming

11.20.2019

1

What we have learned…

- iostream, fstream
  - Header files, classes, objects
- I/O stream manipulator
  - Most of them are sticky

2

Key Concept #1: User-Defined Stream Manipulators

- Programmers can create their own stream manipulators
  - Interface: an ostream member function is defined as manipulator ---
    ostream& operator << (ostream& (*p)(ostream&));
  - cf: ostream& operator << (int);
- [e.g.] Output stream manipulators
  - Must have return type and parameter type as `ostream&`
  - e.g.

```
ostream& myEndl(ostream& os) {
   return (os << endl << “Ric> “);
}
================================
int main() {
   cout << myEndl;
}
```

3

Key Concept #2: Formatted vs. Unformatted I/O

- Formatted I/O
  - “High-level”, bytes are grouped into meaningful units
    - Integers, floating-point numbers, characters, etc.
    - Satisfactory for most I/O other than high-volume file processing
  - I/O operations are sensitive to data types
    - Improper data cannot “sneak” through
  - Using operators “<<“ and “>>”, I/O manipulators
- Unformatted I/O
  - Low-level, individual bytes are the items of interest
  - High-speed, high-volume
  - Not particularly convenient for programmers
  - Member functions (e.g. get, getline, put, read, write...)
  - May have portability problem

4

Type-Safe I/O (Formatted I/O)

- << and >> operators are overloaded to accept data of specific types
  - Attempts to input or output a user-defined type that << and >> have NOT been overloaded will result in compiler errors
- If unexpected data is processed, error bits are set
  - User may test the error bits to determine I/O operation success or failure
- ostream& operator <<
  - Does not print out until '\n" or "flush()" is called
- istream& operator >>
  - Stop at white space, but not process until '\n' is entered

Recall: Overloading "<<" operator for user-defined types

```
class MyClass {
   // friend to "global domain"
   //        so that it can be accessed by "<<(cout, m)"
   friend ostream& operator <<
         (ostream& os, const MyClass& m);
}; // Why friend? friend to whom???

ostream& operator << (ostream& os, const MyClass& m) {
   os << m._dataMember1 << " is "  << m._dataMember2...
   return os; // Why return "os"? Return to whom?
}

int main()
{
   MyClass m(100);
   cout << m << endl;
}
```

“friend” is NOT a must, just a custom

```
class MyClass {

   ~~ostream& operator <<~~
         ~~(ostream& os, const MyClass& m);~~
};

ostream& operator << (ostream& os, const MyClass& m) {
   os << m.getData1() << “ is ”  << m.getData2()...
   return os;
}

int main()
{
   MyClass m(100);
   cout << m << endl;
}
```

Not a member function!!

However, it is a good practice to add a friend entry in the class so that users can be aware of that such overloading exists.

Try this...

◆
```
int i;
while (true) {
   cin >> i;
   // ... do something on i,
   // for example:
   cout << i << endl;
}
```

➔ What will you see if we enter the char ‘a’?

Key Concept #3: I/O Stream State Bits

- Control the state of the stream (as ios data members)
  - `failbit`
    - Set if input data is of wrong type (format error)
    - Data still remains in stream buffer
    - Usually can be recovered
  - `badbit`
    - Set if stream extraction operation fails (more serious)
    - Usually difficult to recover
  - `eofbit`
    - Set if the end of file is reached during stream input
  - goodbit
    - ! (failbit | badbit | eofbit)

I/O Stream State Bits

- Functions
  - bool eof() const;
    - Returns `true` when end-of-file has occurred
    - [What's wrong??] while (!infile.eof()) { infile >> ch; ... }
  - good(), fail(), bad()
  - rdstate() // read state bits
  - clear(iostate state=ios::goodbit)
    - Sets the specified bit for the stream
    - Default argument is `goodbit`
    - Examples

      `cin.clear();`
      - Clears `cin` and sets `goodbit`

      `cin.clear( ios::failbit );`
      - Sets `failbit`
  - setstate(iostate state) ➔ clear(rdstate() | state)

To fix the previous problem...

◆
```
int i;
while (true) {
   cin >> i;
   while (cin.fail()) {
      cin.clear();
      string str;
      cin >> str; // to eat the input
      cerr << "Error: " << str
           << " is NOT an int!!" << endl;
      cin >> i;
   }
   cout << i << endl;
}
```

Or simply...

◆
```
int i;
while (cin >> i) {
   cout << i << endl;
}
```

➔ Shouldn't (cin >> i) return cin as "istream&"?

➔ Then, what does "while (cin)" mean?

➔ Which member function does it call?

Key Concept #4: Use “while (fstream)” to check EOF or badbit

◆ What does this do?

```
int main()
{
   ifstream inf(“aaa.txt");
   char ch;
   while (inf >> ch) cout << ch;
}
```

◆ ios::operator void* ( ) const

- Converted to void*; return NULL if failbit or badbit is set
- (ref) User-defined type conversion

Recall: Type-casting operator ➔ operator void* ()?? Return type?

```
class A {
public:  A(int i = 0): _d(i) {}
   operator void* () const {
      return (_d != 0)? (void*)this: NULL; }
private: int _d;
};

int main() {
   A a(10);
   A b(0);
   if (a) { cout << "Yes" << endl; }
   else cout << "No" << endl;
   if (b) { cout << "Yes" << endl; }
   else cout << "No" << endl;
}
```

operator void*() vs. void* operator () ??

- Try this:
```
class A {
public:  A(const string& s = 0): _s(s) {}
   operator int () const { return _s.size(); }
private: string _s;
};
int main() {
   A a("Hello");
   int s = a; cout << s << endl;
   cout << (int)a << endl;
   cout << int(a) << endl;
}
```
- operator void*() is type-casting
  - A a;
    void *p = a;
- void* operator() () is operator overloading
  - A a;
    void *p = a();

Practice #1

- Define a `class A` with a private data member "`int _data`"
  - Define a type casting member function to convert `class A` object to `int` (i.e. return `_data`).
  - Define a type casting member function to convert `class A` object to `bool` (i.e. check (`_data != 0`)). Can it co-exist with `int` convertor?
  - Define a `class B` which contains a data member "`int *_ptr`". Write a type casting member function to convert `class A` object to `B` (by setting `_ptr` as the address of `A::_data`)
- In `main()`, instantiate a `class A` object and call the above convertors to check the implementation

Key Concept #5: Flags for I/O Stream Printing Format

- ◆ Member function `flags()`
  - With no argument
    - Returns a value of type `fmtflags`
      - Represents the current format settings
  - With a `fmtflags` as an argument
    - Sets the format settings as specified
    - Returns the prior state settings as a `fmtflags`
  - Initial return value may differ across platforms
  - Type `fmtflags` is of class `ios_base`

What will be the output?

```
int main() {
   int i = 100;
   ofstream outf("ttt");
   outf << showbase << hex << i << endl;
   ios_base::fmtflags origFlags = outf.flags();
   outf.close();

   ifstream inf("ttt");
   inf.flags(origFlags);
   inf >> i;
   cout << setw(10) << right << i << endl;
}
```

◆What's the content in "ttt"?

Key Concept #6: Unformatted I/O

◆ Think: sometimes you just want to read/write a file as a "stream of bytes"
- To have better performance in I/O processing
- You don't care/know about the type of each piece of data

➔ Read data in first. Process it later in program.

➔ Unformatted I/O

◆ Use member functions to do file accesses

istream::get

1. With no arguments
   - int get ();
   - Returns one character input from the stream
     - Any character, including white-space and non-graphic characters
   - Returns `EOF` when end-of-file is encountered
2. With a character-reference argument
   - istream& get (char& c);
   - Stores input character in the character-reference argument
   - Returns a reference to the `istream` object

istream::get

3. With three arguments: a character array, a size limit and a delimiter (default delimiter is `'\n'`)
   - istream& get (char* s, streamsize n);
     istream& get (char* s, streamsize n, char delim);
     istream& get (streambuf& sb);
     istream& get (streambuf& sb, char delim);
   - Reads and stores characters in the character array
   - Terminates at one fewer characters than the size limit or upon reading the delimiter
     - Delimiter is left in the stream, NOT placed in array
   - Null character is inserted after end of input in array
   - [note] "streamsize" may be platform dependent, usually signed int or signed long.

Try this...

```
int main() {
   char str[5];
   while (true) {
      cin.get(str, 5, ' ');
      cout << str << endl;
   }
}
```

- Try to enter:
  - `12 345 67`

Anything wrong?

Key Concept #7: Be aware of “failbit”

◆ When “cin.get()” fails to read in any character, the **failbit** is set. [Revised]

```
int main() {
   char str[5];
   while (true) {
      cin.get(str, 5, ‘ ’);
      if (cin.fail()) {
         cin.clear();  char ch = cin.get();
         cout << “Clearing... ‘” << ch << “’\n”;
      }
      else  cout << str << endl;
   }
}
```

◆ Try again...
- `12 345 67`
- `89  100`

23

What about...

```
int main() {
   char str[5];
   while (cin.get(str, 5, ‘ ’)) {
      cout << str << endl;
   }
}
```

◆ Try to enter:
- `12 345 67`

Anything wrong?

只print 12 ???

24

Key Concept #8: istream::getline

- istream& getline (char* s, streamsize n);
  istream& getline (char* s, streamsize n, char delim);
  - Similar to the three-argument version of `get`
    - Except the delimiter <u>*is* removed from the stream</u>
  - Three arguments: a character array, a size limit and a delimiter (default delimiter is `'\n'`)
    - Reads and stores characters in the character array
    - Terminates at <u>one fewer characters</u> than the size limit or upon reading the delimiter
      - Delimiter is removed from the stream, but not placed in the array
    - Null character is inserted after end of input in array

Key Concept #9: ostream::put

- ostream& put (char c); // unformatted
  - Outputs a character
  - Returns a reference to the same `ostream` object
    - Can be cascaded
  - Can be called with a numeric expression that represents an ASCII value
  - Examples
    - `cout.put( 'A' );`
    - `cout.put( 'A' ).put( '\n' );`
    - `cout.put( 65 );` // What's the output?

Key Concept #10:
More “aggressive” unformatted I/O functions

- istream& read (char* s, streamsize n);
  - Inputs some number of bytes to a character array
  - If fewer characters are read than the designated number, `failbit` is set
  - Null character is NOT inserted after end of input in array
- [Example]:

```
int main() {
   char str[10];
   while (true) {
      cin.read(str, 10);
      cout << “str is: ” << str << endl;
   }
}
```

- Try this:
  - 12345
  - 67890   Anything potential problem??

Again, be aware of “`failbit`”...

- [Revised example]:

```
Content in “fff”
123456789012345
```

```
int main() {
   ifstream fin(“fff”);
   char str[~~10~~]; 11
   while (true) {
      fin.read(str, 10);
      str[fin.gcount()] = 0;
      cout << “str is: ” << str << endl;
      if (fin.fail())
         break;
   }
}
```

Key Concept #11: ostream::write()

- ostream& write (const char* s , streamsize n);
  - Outputs some number of bytes from a character array
- Examples:
  - cout.write("1234567890", 5) << endl;
  - cout.write("12345", 10) << endl;
  - cout.write("12345\n7890", 10) << endl;
  - cout.write("12345\07890", 10) << endl;
- Be aware of the “size” you write!!
- Take care of NULL, EOF,... etc.
- Similar for “ofstream::write()”

Practice #2

- Write a “file copy” program for fun!
  - Copy an arbitrary executable file to this practice directory
  - Declare an `ifstream` object `inf` to open this executable file. Remember to read in as `ios::binary`.
  - Declare an `ofstream` object `outf` for the copied executable. Name the file as you like. Remember to read in as `ios::binary`.
  - Use “`inf.read()`” and “`outf.write()`” to read in and write out the file. Set the `streamsize` to 100. Be aware to take care of the last few bytes of the file.
  - Test if the executable has been successfully copied! You may need to “`chmod +x`” to make it executable.
- Make the input and output files as arguments of this program (Hint: see “`argc`” and “`argv`” in `main()` of homework)
- Print out some progressing message (e.g. |/-\|…) so that you can “see” that the file is being copied. You need to insert some delay on purpose to make it visible.

Key Concept #12: More istream member functions

- istream& ignore (streamsize n = 1, int delim = EOF);
  - Reads and discards a designated number of characters or terminates upon encountering a designated delimiter
- istream& putback (char c);
  - Places previous character obtained by a `get` from the input stream back into the stream
- int peek ( );
  - Returns the next character in the input stream, but does not remove it from the stream

Key Concept #13: Tying an Input Stream to an Output Stream

- `istream` member function `tie`
  - ostream* tie ( ) const;
    - Returns a pointer to the tied output stream
  - ostream* tie (ostream* tiestr);
    - Ties the istream object to *tiestr* and returns a pointer to the ostream object previously tied
- Synchronizes an `istream` and an `ostream`
  - Ensures outputs appear before their subsequent inputs
- By default, the standard objects cin, cerr and clog are tied to cout (Why?)
  - Examples
    - `cin.tie( &cout );`
      - Ties standard input to standard output
      - C++ performs this operation automatically
    - `inputStream.tie( 0 );`
      - Unties `inputStream` from the `ostream` it is tied to

istream::tie Example

```
int main () {
  ostream *prevstr;
  ofstream ofs;
  ofs.open ("test.txt");
  cout << "tie example:" << endl;
  *(cin.tie()) << "This is inserted into cout";
  prevstr = cin.tie(&ofs);
  *(cin.tie()) << "This is inserted into the file";
  cin.tie (prevstr);
  ofs.close(); return 0;
}
```

Key Concept #14: ostream or ostream*

- Why do the argument and return type of "istream::tie()" have the type "ostream*", not "ostream"?
- Why not:
  - cin.tie(cout);
  - cin.tie() << "blah, blah..." << endl;
- You cannot "copy" a stream object!!
  - Use "pointer" or "reference" instead

Key Concept #15: File-position pointer

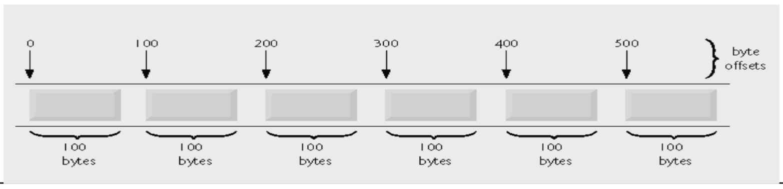
- The **byte number** of the next byte to be read or written
- `seekg()` for ifstream and
  `seekp()` for ofstream
  - Repositions the file-position pointer to the specified location
  - Two prototypes
    - seekg(pos) or seekg(offset, direction)
- `tellg()` for ifstream and
  `tellp()` for ofstream
  - Returns current position of the file-position pointer as type long

Seek direction

- `ios::beg` – default, position relative to the beginning
  `ios::cur` – relative to current position
  `ios::end` – relative to the end
- `Examples`
  - `fileObject.seekg( n );`
    - Position to the *n*th byte of `fileObject`
  - `fileObject.seekg( n, ios::cur );`
    - Position *n* bytes forward in `fileobject`
  - `fileObject.seekg( n, ios::end );`
    - Position *n* bytes back from end of `fileObject`
  - `fileObject.seekg( 0, ios::end );`
    - Position at end of `fileObject`

Key Concept #16: Random-Access Files

- Necessary for instant-access applications
  - Such as transaction-processing systems
    - cf: use “>>”, “<<“ for *sequential file* access
  - A record can be inserted, deleted or modified without affecting other records
- Various techniques can be used
  - Require that all records be of the same length, arranged in the order of the record keys
    - Program can calculate the exact location of any record
      - Base on the record size and record key



可像array一樣直接找index算出檔案位置，就不用一個一個找了

Key Concept #17: Use “read” and “write” for Random-Access Files

- istream& read(char *str, streamsize nBytes)
  - Read a number of bytes from the current file position in the stream into an object
- ostream& write
  (const char *str, streamsize nBytes)
  - Writes a number of bytes from a location in memory to the stream

Random-Access Files

```
int main() {
  StudentRecord rec;
  ofstream outf("studentRecord.dat");
  for (int i = 0; i < numRecords; ++i) {
    cin >> rec;
    outf.write(reinterpret_cast<const char *>(&rec),
               sizeof(StudentRecord));
  }
  outf.close();
  ifstream inf("studentRecord.txt");
  for (int i = 0; i < numRecords; ++i)
    inf.read(reinterpret_cast<char *>(&rec),
             sizeof(StudentRecords));
}
```

Operator `reinterpret_cast`

StudentRecord rec;
outf.write(reinterpret_cast<const char *>(&rec),
sizeof(StudentRecord));

➔

- Casts a pointer of one type to an unrelated type
  - Also converts between pointer and integer types
- Is performed at compile time
  - Does not change the value of the object pointed to
- May lead to serious execution-time errors

Practice #3

- Refer to the example in p39, define a `class StudentRecord` of size at least 256 Bytes. Randomly generate one million objects of this class.
  - Open a file "`studentDB.dat`" for write
  - Whenever an object is generated, write it to "`studentDB.dat`" by "`write()`" and "`reinterpret_cast`"
  - Use text editor to view "`studentDB.dat`". What do you see?
- Write another program to look up the i-th data in "`studentDB.dat`".
  - Use "`seekg()`" to position to the i-th data.
  - Use "`read()`" to read in the object and `cout` it.

Key Concept #18: String Stream (Stream of string)

- Ref: "sprint()" in C
  – print something to a string
- Sometimes we would like to compose a string from different sources
  - E.g. Compose displayed names with IDs

```
ostringstream  st;
for (int i = 0; i < n; i++) {
   st << "Member" << i;
   _name = st.str();
}
```

==> Actually, this is not correct…

More examples on String Stream

```
// #include <sstream>
int main()
{
   int i;
   cin >> i;

   ostringstream  st;
   st << i << " square is " << i * i;

   string str = st.str();

   cout << str << endl;
}
// What's the output??
```

String Stream

```
int main()
{
   int i;
   cin >> i;

   ostringstream  st;
   st << i << " square is " << i * i;
   string str = st.str();
   cout << str << endl;


   st << i << " is " << i;
   str = st.str();
   cout << str << end
}
// What's the output??
// How to clear the previous string? clear()?
```

The Solution is.... ^^|||

```
int main()
{
   int i;
   cin >> i;

   ostringstream  st;
   st << i << " square is " << i * i;
   string str = st.str();
   cout << str << endl;

   st.str("");
   st << i << " is " << i;
   str = st.str();
   cout << str << end
}
```

Key Concept #19: class streambuf

- A *stream buffer* is an object in charge of performing the reading and writing operations of the *stream* object it is associated with.
  - The stream delegates all such operations to its associated *stream buffer* object, which is an intermediary between the *stream* and its *controlled input and output sequences*.
- All *stream* objects, no matter whether buffered or unbuffered, have an associated *stream buffer*. Some *stream buffer* types may then be set to either use an intermediate *buffer* or not.

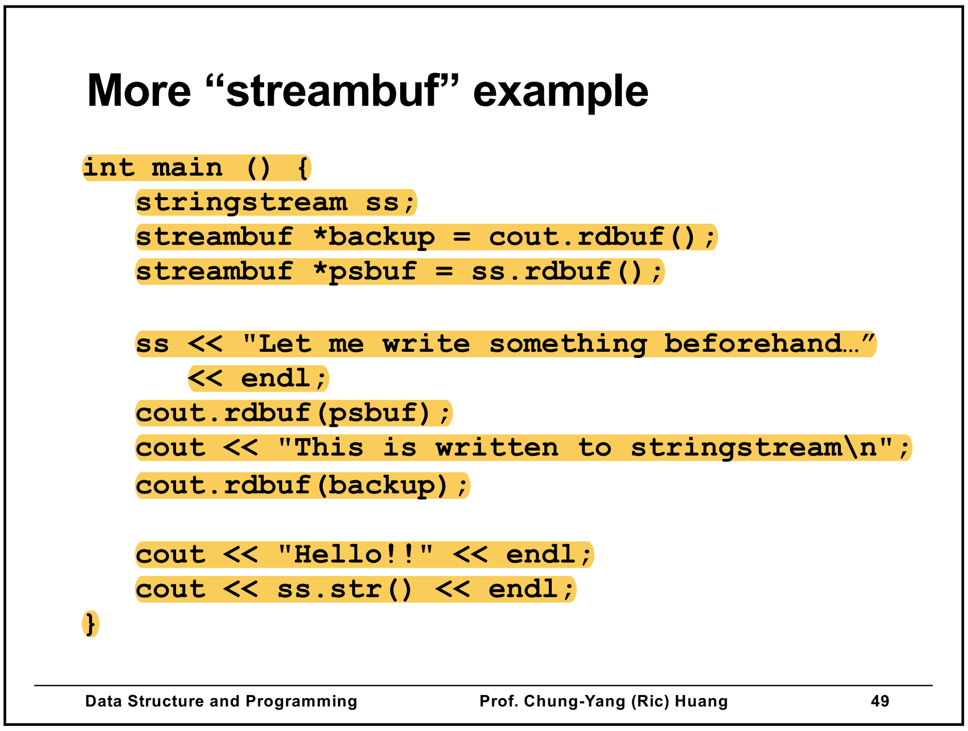
*ref: www.cplusplus.com

Key Concept #20: ios::rdbuf()

- There are many member functions for class "streambuf"... to many to cover in this class.
- "ios::rdbuf()": to get or set streambuf for a stream object
  - streambuf* rdbuf() const;
    - To get the streambuf
  - streambuf* rdbuf (streambuf* sb);
    - To set the streambuf

"ios::rdbuf" example

```
int main () {
   ofstream filestr("test.txt");
   streambuf *backup = cout.rdbuf();
   streambuf *psbuf
   = filestr.rdbuf();
   cout.rdbuf(psbuf);
   cout <<
      "This is written to the file\n";
   cout.rdbuf(backup);
   cout << "This is written to stdout\n";
}
```



More “streambuf” example

```
int main () {
    stringstream ss;
    streambuf *backup = cout.rdbuf();
    streambuf *psbuf = ss.rdbuf();

    ss << "Let me write something beforehand…”
        << endl;
    cout.rdbuf(psbuf);
    cout << "This is written to stringstream\n";
    cout.rdbuf(backup);

    cout << "Hello!!" << endl;
    cout << ss.str() << endl;
}
```