

DM560
Introduction to Programming in C++

Input/Output Streams

Marco Chiarandini

Department of Mathematics & Computer Science
University of Southern Denmark

[Based on slides by Bjarne Stroustrup]

Outline

1. Input and Output Streams
2. Reading from a File
3. Example: Error Handling
4. User-Defined Output

Outline

- Fundamental I/O concepts
- Files
 - Opening
 - Reading and writing streams
- I/O errors
- Reading a single integer

Outline

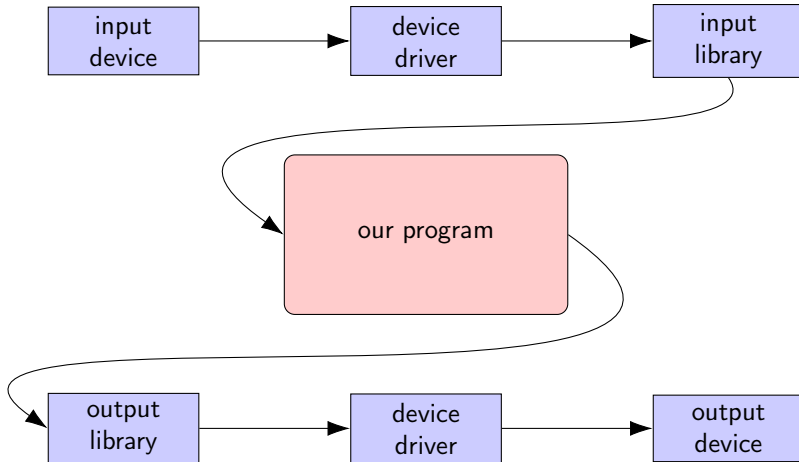
1. Input and Output Streams

2. Reading from a File

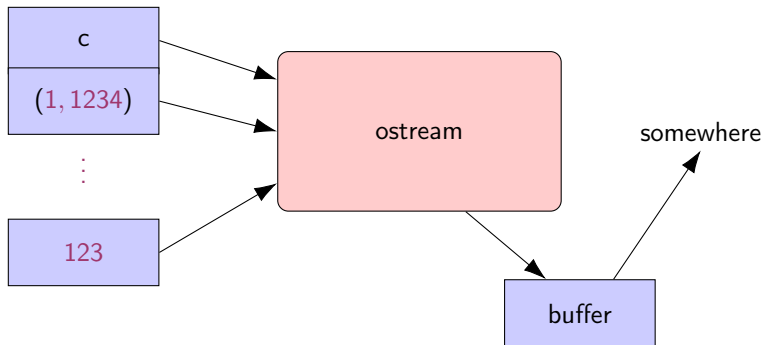
3. Example: Error Handling

4. User-Defined Output

Input and Output



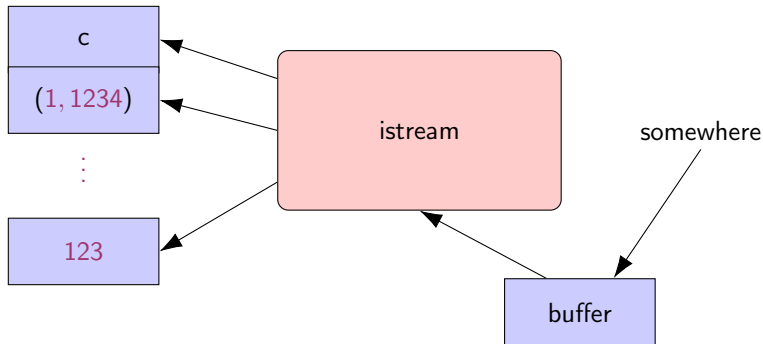
The Stream Model



An **ostream**

- turns values of various types into character sequences
- sends those characters somewhere (e.g., console, file, main memory, another computer)

The Stream Model



An **istream**

- turns character sequences into values of various types
- gets those characters from somewhere (e.g., console, file, main memory, another computer)

The Stream Model

Reading and writing

- Of typed entities
 - `<<` (output) and `>>` (input) plus other operations
 - Type safe
 - Formatted
- Typically stored (entered, printed, etc.) as text
But not necessarily (e.g. see binary streams chp. 11)
- Extensible: You can define your own I/O operations for your own types
- A stream can be attached to any I/O or storage device

Files

- We turn our computers on and off
The contents of our main memory is transient
- We keep what we want to preserve on **disks** and similar **permanent storage**
- A **file** is a sequence of bytes stored in **permanent storage**
 - A file has a **name**
 - The data on a file has a **format**
- We can read/write a file if we know its name and format

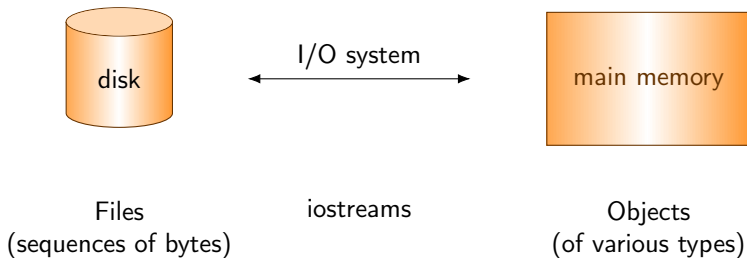
A File



- At the fundamental level, a file is a sequence of bytes numbered from 0 upwards
- Other notions can be supplied by programs that interpret a [file format](#):
For example, the 6 bytes "123.45" might be interpreted as the floating-point number 123.45

Files

General model:



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Files

- To **read** a file
 - We must know its name
 - We must **open it** (for reading)
 - Then we can **read**
 - Then we must **close it** (typically done implicitly)
- To **write** a file
 - We must name it
 - We must **open it** (for writing) or **create** a new file of that name
 - Then we can **write** it
 - We must **close it** (typically done implicitly)

Opening a File for Reading

```
// ...  
int main()  
{  
    cout << "Please enter input file name: ";  
    string iname;  
    cin >> iname;  
    ifstream ist {iname};    // ifstream is an "input stream from a file"  
                             // defining an ifstream with a name string  
                             // opens the file of that name for reading  
    if (!ist) error("can't open input file ", iname);  
    // ...  
}
```

Opening a File for Writing

```
// ...  
cout << "Please enter name of output file: ";  
string oname;  
cin >> oname;  
ofstream ofs {oname};    // ofstream is an "output stream from a file"  
                          // defining an ofstream with a name string  
                          // opens the file with that name for writing  
if (!ofs) error("can't open output file ", oname);  
// ...  
}
```

Reading from a File

- Suppose a file contains a sequence of pairs representing hours and temperature readings

```
0 60.7  
1 60.6  
2 60.3  
3 59.22
```

- The hours are numbered 0..23
- No further format is assumed (Maybe we can do better than that, but not just now)
- Termination
 - Reaching the end of file terminates the read
 - Anything unexpected in the file terminates the read (e.g., q)

Reading a File

```
struct Reading {           // a temperature reading
    int hour;              // hour after midnight [0:23]
    double temperature;
};

vector<Reading> temps;    // create a vector to store the readings

int hour;
double temperature;
while (ist >> hour >> temperature) {                // read
    if (hour < 0 || 23 < hour) error("hour out of range"); // check
    temps.push_back( Reading{hour,temperature} );    // store
}
```

I/O Error Handling

- Sources of errors
 - Human mistakes
 - Files that fail to meet specifications
 - Specifications that fail to match reality
 - Programmer errors
 - ...
- `iostream` reduces all errors to one of four states
 - `good()` //the operation succeeded
 - `eof()` //we hit the end of input ("end of file")
 - `fail()` //something unexpected happened
 - `bad()` //something unexpected and serious happened

Sample Integer Read "Failure"

- Ended by “terminator character”
 - 1 2 3 4 5 *
 - State is `fail()`
- Ended by format error
 - 1 2 3 4 5.6
 - State is `fail()`
- Ended by “end of file”
 - 1 2 3 4 5 end of file
 - 1 2 3 4 5 Control-Z (Windows)
 - 1 2 3 4 5 Control-D (Unix)
 - State is `eof()`
- Something really bad
 - Disk format error
 - State is `bad()`

I/O Error Handling

```
void fill_vector(istream& ist, vector<int>& v, char terminator)
{
    // read integers from ist into v until we reach eof() or terminator
    for (int i; ist >> i; )    // read until "some failure"
        v.push_back(i);        // store in v
    if (ist.eof()) return;      // fine: we found the end of file
    if (ist.bad()) error("ist is bad"); // stream corrupted; let's get out of here!

    if (ist.fail()) {           // clean up the mess as best we can and report the problem
        ist.clear();            // clear stream state, so that we can look for terminator
        char c;
        ist >> c;                // read a character, hopefully terminator
        if (c != terminator) {   // unexpected character
            ist.unget();          // put that character back
            ist.clear(ios_base::failbit); // set the state back to fail()
        }
    }
}
```

Throw an Exception for `bad()`

```
// How to make ist throw if it goes bad:  
ist.exceptions(ist.exceptions() | ios_base::badbit);  
  
// can be read as  
// "set ist's exception mask to whatever it was plus badbit"  
// or as "throw an exception if the stream goes bad"
```

Given that, we can simplify our input loops by no longer checking for bad

Simplified Input Loop

```
void fill_vector(istream& ist, vector<int>& v, char terminator)
{
    // read integers from ist into v until we reach eof() or terminator
    for (int i; ist >> i; )
        v.push_back(i);
    if (ist.eof()) return;          // fine: we found the end of file

    // not good() and not bad() and not eof(), ist must be fail()
    ist.clear();                   // clear stream state
    char c;
    ist >> c;                      // read a character, hopefully terminator
    if (c != terminator) {         // ouch: not the terminator, so we must fail
        ist.unget();               // maybe my caller can use that character
        ist.clear(ios_base::failbit); // set the state back to fail()
    }
}
```

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Reading a Single Value

```
// first simple and flawed attempt:

cout << "Please enter an integer in the range 1 to 10 (inclusive):\n";
int n = 0;
while (cin>>n) {                                // read
    if (1<=n && n<=10) break;    // check range
    cout << "Sorry, "
         << n
         << " is not in the [1:10] range; please try again\n";
}

// use n here
```

Three kinds of problems are possible

- the user types an out-of-range value
- getting no value (end of file)
- the user types something of the wrong type (here, not an integer)

Reading a Single Value

What do we want to do in those three cases?

- handle the problem in the code doing the read?
- throw an exception to let someone else handle the problem (potentially terminating the program)?
- ignore the problem?

Reading a single value

- Is something we often do many times
- We want a solution that is very simple to use

Handle Everything: What a Mess!

```
cout << "Please enter an integer in the range 1 to 10 (inclusive):\n";
int n = 0;
while (cin >> n) {
    if (cin) {    // we got an integer; now check it:
        if (1<=n && n<=10) break;
        cout << "Sorry, " << n << " is not in the [1:10] range; please try again\n";
    }
    else if (cin.fail()) {    // we found something that wasn't an integer
        cin.clear();    // we'd like to look at the characters
        cout << "Sorry, that was not a number; please try again\n";
        for (char ch; cin>>ch && !isdigit(ch); )    // throw away non-digits
            /* nothing */ ;
        if (!cin) error("no input");    // we didn't find a digit: give up
        cin.unget();    // put the digit back, so that we can read the number
    }
    else
        error("no input");    // eof or bad: give up
}
// if we get here n is in [1:10]
```

The Mess: Trying to Do Everything at Once

- Problem: We have all mixed together
 - reading values
 - prompting the user for input
 - writing error messages
 - skipping past “bad” input characters
 - testing the input against a range
- Solution: Split it up into logically separate parts

What Do We Want?

What logical parts do we want?

- `int get_int(int low, int high);` read an int in `[low..high]` from cin
- `int get_int();` read an int from cin so that we can check the range int
- `void skip_to_int();` we found some “garbage” character so skip until we find an int

Separate functions that do the logically separate actions

Skip “Garbage” and Get (Any) Integer

```
void skip_to_int()
{
    if (cin.fail()) {        // we found something that wasn't an integer
        cin.clear();         // we'd like to look at the characters
        for(char ch; cin>>ch; ) { // throw away non-digits
            if (isdigit(ch) || ch=='-') {
                cin.unget();    // put the digit back, to read the number
                return;
            }
        }
    }
    error("no input");      // eof or bad: give up
}
```

Skip “Garbage” and Get (Any) Integer

```
void skip_to_int()
{
    if (cin.fail()) {        // we found something that wasn't an integer
        cin.clear();         // we'd like to look at the characters
        for(char ch; cin>>ch; ) { // throw away non-digits
            if (isdigit(ch) || ch=='-') {
                cin.unget();    // put the digit back, to read the number
                return;
            }
        }
    }
    error("no input");      // eof or bad: give up
}
```

```
int get_int()
{
    int n = 0;
    while (true) {
        if (cin >> n) return n;
        cout << "Sorry, that was not a number; please try again\n";
        skip_to_int();
    }
}
```

Get Integer in Range

```
int get_int(int low, int high)
{
    cout << "Please enter an integer in the range "
          << low << " to " << high << " (inclusive):\n";
    while (true) {
        int n = get_int();
        if (low<=n && n<=high) return n;
        cout << "Sorry, "
              << n << " is not in the [" << low << ':' << high
              << "]" range; please try again\n";
    }
}
```

Get Integer in Range

```
int get_int(int low, int high)
{
    cout << "Please enter an integer in the range "
          << low << " to " << high << " (inclusive):\n";
    while (true) {
        int n = get_int();
        if (low<=n && n<=high) return n;
        cout << "Sorry, "
              << n << " is not in the [" << low << ':' << high
              << "]" << " range; please try again\n";
    }
}
```

Usage:

```
int n = get_int(1,10);
cout << "n: " << n << endl;

int m = get_int(2,300);
cout << "m: " << m << endl;
```


Get Integer in Range

```
int get_int(int low, int high)
{
    cout << "Please enter an integer in the range "
          << low << " to " << high << " (inclusive):\n";
    while (true) {
        int n = get_int();
        if (low<=n && n<=high) return n;
        cout << "Sorry, "
              << n << " is not in the [" << low << ':' << high
              << "]" range; please try again\n";
    }
}
```

Usage:

```
int n = get_int(1,10);
cout << "n: " << n << endl;

int m = get_int(2,300);
cout << "m: " << m << endl;
```

~> Problem: the [dialog](#) is built into the read operations

What Do We Really Want?

- That's often the really important question
- Ask it repeatedly during software development
- As you learn more about a problem and its solution, your answers improve

```
// parameterize by integer range and "dialog"

int strength = get_int(1, 10,
                      "enter strength",
                      "Not in range, try again");
cout << "strength: " << strength << endl;

int altitude = get_int(0, 50000,
                      "please enter altitude in feet",
                      "Not in range, please try again");
cout << "altitude: " << altitude << "ft. above sea level\n";
```

Parametrize

```
int get_int(int low, int high, const string& greeting, const string& sorry)
{
    cout << greeting << ": [" << low << ':' << high << "]\n";
    while (true) {
        int n = get_int();
        if (low<=n && n<=high) return n;
        cout << sorry << ": [" << low << ':' << high << "]\n";
    }
}
```

Incomplete parameterization: `get_int()` still “blabbers”

- “utility functions” should not produce their own error messages
- Serious library functions do not produce error messages at all
They **throw exceptions** (possibly containing an error message)

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User-Defined Output: Operator <<()

```
ostream& operator<<(ostream& os, const Date& d)
{
    return os << '(' << d.year()
               << ',' << d.month()
               << ',' << d.day() << ')';
}
```

User-Defined Output: Operator <<()

```
ostream& operator<<(ostream& os, const Date& d)
{
    return os << '(' << d.year()
               << ',' << d.month()
               << ',' << d.day() << ')';
}
```

Use:

```
void do_some_printing(Date d1, Date d2)
{
    cout << d1;           // means operator<<(cout,d1) ;

    cout << d1 << d2;
    // means (cout << d1) << d2;
    // means (operator<<(cout,d1)) << d2;
    // means operator<<((operator<<(cout,d1)), d2) ;
}
```

User-Defined Input: Operator >>()

```
istream& operator>>(istream& is, Date& dd)
// Read date in format: ( year , month , day )
{
    int y, d, m;
    char ch1, ch2, ch3, ch4;
    is >> ch1 >> y >> ch2 >> m >> ch3 >> d >> ch4;
    if (!is) return is;    // we didn't get our values, so just leave
    if (ch1!='(' || ch2!=',' || ch3!=',' || ch4!=')') {    // oops: format error
        is.clear(ios_base::failbit);    // something wrong: set state to fail()
        return is;    // and leave
    }
    dd = Date{y,Month(m),d};    // update dd
    return is;    // and leave with is in the good() state
}
```

Summary

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