Parasol
Smarter computing.
Texas A&M University

Chapter 11
Customizing I/O

Bjarne Stroustrup

www.stroustrup.com/Programming

Overview

- Input and output
- Numeric output
  - Integer
  - Floating point
- File modes
  - Binary I/O
  - Positioning
- String streams
- Line-oriented input
  - Character input
  - Character classification

Kinds of I/O

- Individual values
  - See Chapters 4, 10
- Streams
  - See Chapters 10-11
- Graphics and GUI
  - See Chapters 12-16
- Text
  - Type driven, formatted
  - Line oriented
  - Individual characters
- Numeric
  - Integer
  - Floating point
  - User-defined types

Observation

- As programmers we prefer regularity and simplicity
  - But, our job is to meet people's expectations
- People are very fussy/particular/picky about the way their output looks
  - They often have good reasons to be
  - Convention/tradition rules
    - What does 110 mean?
    - What does 123,456 mean?
    - What does (123) mean?
  - The world (of output formats) is weirder than you could possibly imagine

Output formats

Parasol
Smarter computing.
Texas A&M University

- Integer values

1234	(decimal)
2322	(octal)
4d2	(hexadecimal)

- Floating point values

1234.57	(general)
1.2345678e+03	(scientific)
1234.567890	(fixed)

- Precision (for floating-point values)

1234.57	(precision 6)
1234.6	(precision 5)

- Fields

|12|	(default for | followed by **12** followed by |)
| 12|	(**12** in a field of 4 characters)

Numerical Base Output

- You can change "base"
  - Base 10 == decimal; digits: 0 1 2 3 4 5 6 7 8 9
  - Base 8 == octal; digits: 0 1 2 3 4 5 6 7
  - Base 16 == hexadecimal; digits: 0 1 2 3 4 5 6 7 8 9 a b c d e f

```
// simple test:
        cout << dec << 1234 << "\t(decimal)\n"
                << hex << 1234 << "\t(hexadecimal)\n"
                << oct << 1234 << "\t(octal)\n";
// The '\t' character is "tab" (short for "tabulation character")

// results:
        1234    (decimal)
        4d2     (hexadecimal)
        2322    (octal)
```

“Sticky” Manipulators

- You can change “base”
  - Base 10 == decimal; digits: 0 1 2 3 4 5 6 7 8 9
  - Base 8 == octal; digits: 0 1 2 3 4 5 6 7
  - Base 16 == hexadecimal; digits: 0 1 2 3 4 5 6 7 8 9 a b c d e f

```
// simple test:
    cout << 1234 << '\t'
              << hex << 1234 << '\t'
              << oct << 1234 << '\n';
    cout << 1234 << '\n';       // the octal base is still in effect

// results:
    1234      4d2      2322
    2322
```

Other Manipulators

- You can change "base"
  - Base 10 == decimal; digits: 0 1 2 3 4 5 6 7 8 9
  - Base 8 == octal; digits: 0 1 2 3 4 5 6 7
  - Base 16 == hexadecimal; digits: 0 1 2 3 4 5 6 7 8 9 a b c d e f

```
// simple test:
    cout << 1234 << '\t'
            << hex << 1234 << '\t'
            << oct << 1234 << endl;         // '\n'
    cout << showbase << dec;  // show bases
    cout << 1234 << '\t'
            << hex << 1234 << '\t'
            << oct << 1234 << '\n';
// results:
    1234      4d2      2322
    1234      0x4d2    02322
```

Floating-point Manipulators

- You can change floating-point output format
  - general – **iostream** chooses best format using **n** digits (this is the default)
  - **scientific** – one digit before the decimal point plus exponent; **n** digits after **.**
  - **fixed** – no exponent; **n** digits after the decimal point

```
// simple test:
cout << 1234.56789 << "\t\t(general)\n"          //  \t\t  to line up columns
     << fixed << 1234.56789 << "\t(fixed)\n"
     << scientific << 1234.56789 << "\t(scientific)\n";
```

```
// results:
1234.57              (general)
1234.567890          (fixed)
1.234568e+03         (scientific)
```

Precision Manipulator

- Precision (the default is 6)
  - general – precision is the number of digits
    - Note: the **general** manipulator is not standard, just in std_lib_facilities_3.h
  - **scientific** – precision is the number of digits after the . (dot)
  - **fixed** – precision is the number of digits after the . (dot)

```
// example:
    cout << 1234.56789 << '\t' << fixed << 1234.56789 << '\t'
                << scientific << 1234.56789 << '\n';
    cout << general << setprecision(5)
                << 1234.56789 << '\t' << fixed << 1234.56789 << '\t'
                << scientific << 1234.56789 << '\n';
    cout << general << setprecision(8)
                << 1234.56789 << '\t' << fixed << 1234.56789 << '\t'
                << scientific << 1234.56789 << '\n';
```

```
// results (note the rounding):
    1234.57     1234.567890         1.234568e+03
    1234.6      1234.56789          1.23457e+03
    1234.5679           1234.56789000       1.23456789e+03
```

Output field width

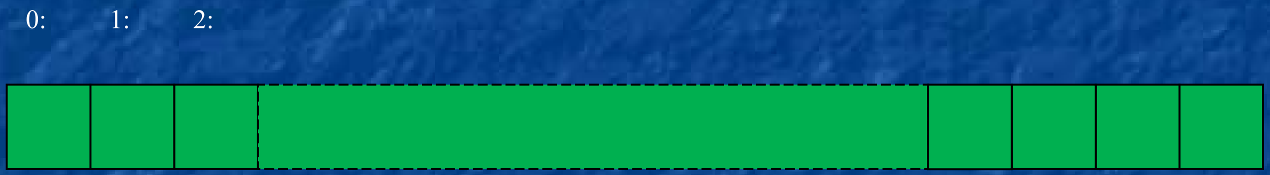
- A width is the number of characters to be used for the next output operation
  - Beware: width applies to next output only (it doesn't "stick" like precision, base, and floating-point format)
  - Beware: output is never truncated to fit into field
    - (better a bad format than a bad value)

```
// example:
    cout << 123456 <<'|'<< setw(4) << 123456 << '|'
            << setw(8) << 123456 << '|' << 123456 << "|\n";
    cout << 1234.56 <<'|'<< setw(4) << 1234.56 << '|'
            << setw(8) << 1234.56 << '|' << 1234.56 << "|\n";
    cout << "asdfgh" <<'|'<< setw(4) << "asdfgh" << '|'
            << setw(8) << "asdfgh" << '|' << "asdfgh" << "|\n";
// results:
    123456|123456|  123456|123456|
    1234.56|1234.56| 1234.56|1234.56|
    asdfgh|asdfgh|  asdfgh|asdfgh|
```

Observation

- This kind of detail is what you need textbooks, manuals, references, online support, etc. for
  - You **always** forget some of the details when you need them

A file

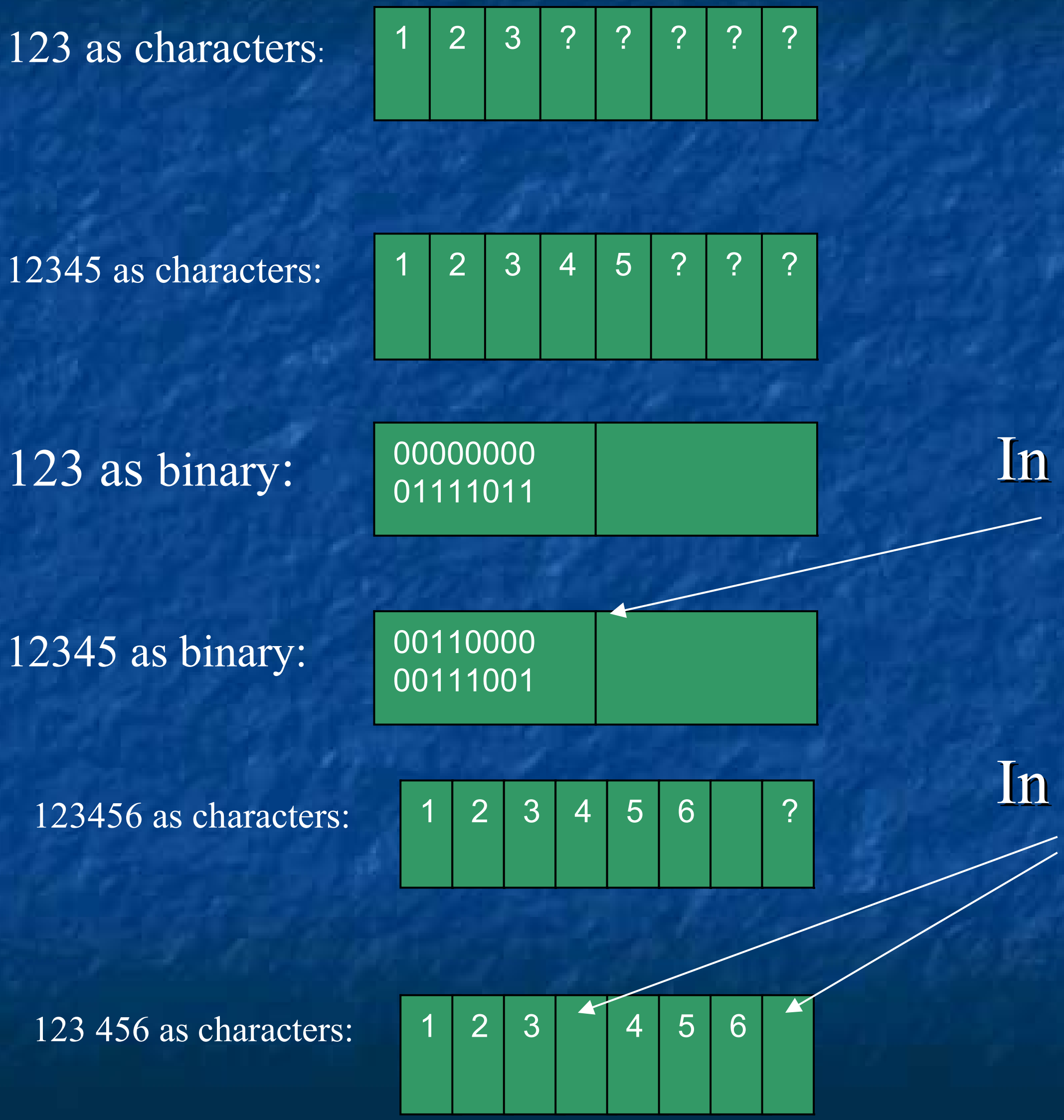


- At the fundamental level, a file is a sequence of bytes numbered from 0 upwards
- Other notions can be supplied by programs that interpret a "file format"
  - For example, the 6 bytes "123.45" might be interpreted as the floating-point number 123.45

File open modes

- By default, an **ifstream** opens its file for reading
- By default, an **ofstream** opens its file for writing.
- Alternatives:
  - **ios_base::app** *// append (i.e., output adds to the end of the file)*
  - **ios_base::ate** *// "at end" (open and seek to end)*
  - **ios_base::binary** *// binary mode – beware of system specific behavior*
  - **ios_base::in** *// for reading*
  - **ios_base::out** *// for writing*
  - **ios_base::trunc** *// truncate file to 0-length*
- A file mode is optionally specified after the name of the file:
  - **ofstream of1(name1);** *// defaults to ios_base::out*
  - **ifstream if1(name2);** *// defaults to ios_base::in*
  - **ofstream ofs(name, ios_base::app);** *// append rather than overwrite*
  - **fstream fs("myfile", ios_base::in|ios_base::out);** *// both in and out*

Text vs. binary files



In binary files, we use sizes to delimit values

In text files, we use separation/termination characters

Text vs. binary

- Use text when you can
  - You can read it (without a fancy program)
  - You can debug your programs more easily
  - Text is portable across different systems
  - Most information can be represented reasonably as text
- Use binary when you must
  - E.g. image files, sound files

Parasol
Smarter computing.
Texas A&M University

Binary files

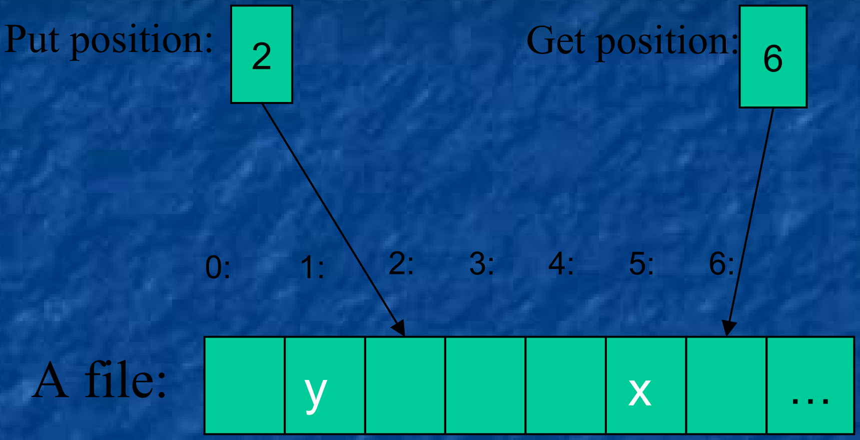
```
int main()          // use binary input and output
{
     cout << "Please enter input file name\n";
     string name;
     cin >> name;
     ifstream ifs(name.c_str(),ios_base::binary);      // note: binary
                                                       // c_str() not needed in C++1
     if (!ifs) error("can't open input file ", name);

     cout << "Please enter output file name\n";
     cin >> name;
     ofstream ofs(name.c_str(),ios_base::binary);     // note: binary
                                                       // c_str() not needed in C++1
     if (!ofs) error("can't open output file ",name);

     // "binary" tells the stream not to try anything clever with the bytes
```

Binary files

```
    vector<int> v;

    // read from binary file:
    int i;
    while (ifs.read(as_bytes(i),sizeof(int)))          // note: reading bytes
            v.push_back(i);

    // … do something with v …

    // write to binary file:
    for(int i=0; i<v.size(); ++i)
            ofs.write(as_bytes(v[i]),sizeof(int));      // note: writing bytes
    return 0;
}
```

*// For now, treat **as_bytes()** as a primitive*
// Warning! Beware transferring between different systems

Positioning in a filestream



```
fstream fs(name.c_str());          // open for input and output
                                   // c_str() not needed in C++11
// …
fs.seekg(5);     // move reading position ('g' for 'get') to 5 (the 6th character)
char ch;
fs>>ch;          // read the x and increment the reading position to 6
cout << "sixth character is " << ch << '(' << int(ch) << ")\n";
fs.seekp(1);     // move writing position ('p' for 'put') to 1 (the 2nd character)
fs<<'y';         // write and increment writing position to 2
```

Positioning

- Whenever you can
  - Use simple streaming
    - Streams/streaming is a very powerful metaphor
    - Write most of your code in terms of "plain" **istream** and **ostream**
  - Positioning is far more error-prone
    - Handling of the end of file position is system dependent and basically unchecked

String streams

A **stringstream** reads/writes from/to a **string** rather than a file or a keyboard/screen

```
double str_to_double(string s)
        // if possible, convert characters in s to floating-point value
{
    istringstream is(s);    // make a stream so that we can read from s
    double d;
    is >> d;
    if (!is) error("double format error");
    return d;
}

double d1 = str_to_double("12.4");                  // testing
double d2 = str_to_double("1.34e-3");
double d3 = str_to_double("twelve point three");  // will call error()
```

String streams

- See textbook for ostringstream
- String streams are very useful for
  - formatting into a fixed-sized space (think GUI)
  - for extracting typed objects out of a string

Type vs. line

- Read a string

```
string name;
cin >> name;                // input: Dennis Ritchie
cout << name << '\n';       // output: Dennis
```

- Read a line

```
string name;
getline(cin,name);          // input: Dennis Ritchie
cout << name << '\n';       // output: Dennis Ritchie
// now what?
// maybe:
istringstream ss(name);
ss>>first_name;
ss>>second_name;
```

Characters

- You can also read individual characters

```
char ch;
while (cin>>ch) {        // read into ch, skipping whitespace characters
    if (isalpha(ch)) {
    // do something
    }
}

while (cin.get(ch)) {   // read into ch, don't skip whitespace characters
    if (isspace(ch)) {
    // do something
    }
    else if (isalpha(ch)) {
    // do something else
    }
}
```

Character classification functions

- If you use character input, you often need one or more of these (from header **<cctype>**):

isspace(c)	*// is **c** whitespace? (' ', '\t', '\n', etc.)*
isalpha(c)	*// is **c** a letter? ('a'..'z', 'A'..'Z') note: not '_'*
isdigit(c)	*// is **c** a decimal digit? ('0'..'9')*
isupper(c)	*// is **c** an upper case letter?*
islower(c)	*// is **c** a lower case letter?*
isalnum(c)	*// is **c** a letter or a decimal digit?*

etc.

Line-oriented input

- Prefer >> to **getline()**
  - i.e. avoid line-oriented input when you can

- People often use **getline()** because they see no alternative
  - But it easily gets messy
  - When trying to use **getline()**, you often end up
    - using >> to parse the line from a **stringstream**
    - using **get()** to read individual characters

Standardization

- What?
- Who?
- How?
- C++11
  - -std=c++11 for GCC and Clang
- C++14
  - It's almost here

C++14

- Binary literals
  - **0b1010100100000011**
- Digit separators
  - **0b1010'1001'0000'0011**
  - Also for decimal, octal, and hexadecimal
- User-Defined Literals (UDLs) in the standard library
  - Time: **2h+10m+12s+123ms+3456ns**
  - Complex: **2+4i**
- Manipulators
  - **cout << defaultfloat << 123.456e-12;** *// what the book calls "general"*
  - **cout << hexfloat << 123.456e-12;**

Next lecture

- Graphical output
  - Creating a window
  - Drawing graphs