DM560

Introduction to Programming in C++

Input/Output Streams: Customizing

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[*Based on slides by Bjarne Stroustrup*]

Outline

1. Formatting
2. Files
3. Positioning
4. String Streams

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 (Chapters 4, 10)
- Streams (Chapters 10-11)
- Graphics and GUI (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

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Output Formats

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	Name	Digits:
10	decimal	0 1 2 3 4 5 6 7 8 9
8	octal	0 1 2 3 4 5 6 7
16	hexadecimal	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)
```

Base Manipulators

"Sticky" manipulators

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

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

Other manipulators

```
// 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

defaultfloat	`iostream` chooses best format using `n` digits (this is the default)
fixed	no exponent; `n` digits after the decimal point
scientific	one digit before the decimal point plus exponent; `n` digits after

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

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

Precision Manipulator

Precision (the default is 6)

defaultfloat	precision is the number of digits
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";
```

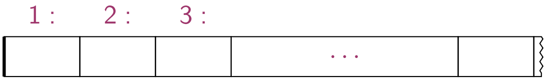
```
// results:
123456|123456|  123456|123456|
1234.56|1234.56| 1234.56|1234.56|
asdfgh|asdfgh|  asdfgh|asdfgh|
```

Obervation

⇝ 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

Outline

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:

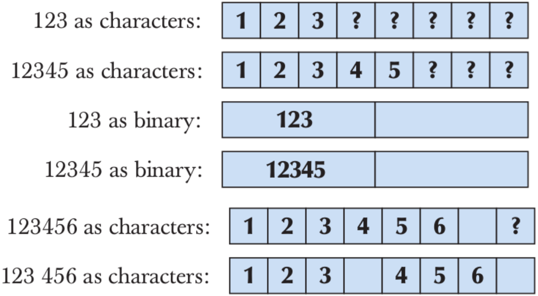
```
ios_base::app     // append (i.e., output adds to the end of the file)
ios_base::ate     // 'at end' (open and seek to end)
ios_base::binary  // binary mode - beware of system specific behavior
ios_base::in      // for reading
ios_base::out     // for writing
ios_base::trunc   // truncate file to 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

- If `123` is stored as an integer (ie, a binary number) it occupies 4 bytes.
- If ``` ``123'' ``` is stored as a string it occupies 3 characters (actually 4). Chars have variable length but it simplifies to think they occupy one byte.



- 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

Binary Files

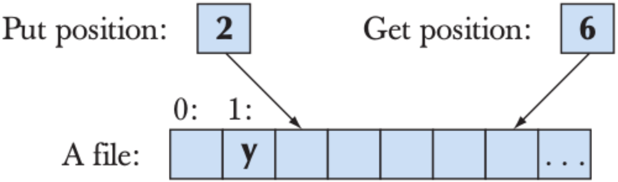
```
int main()       // use binary input and output
{
   cout << "Please enter input file name\n";
   string iname;
   cin >> iname;
   ifstream ifs {iname,ios_base::binary};       // note: binary
   if (!ifs) error("can't open input file ", iname);

   cout << "Please enter output file name\n";
   string oname;
   cin >> oname;
   ofstream ofs {oname,ios_base::binary};       // note: binary
   if (!ofs) error("can't open output file ", oname);

   vector<int> v;   // read from binary bytes from file:
   for (int i; ifs.read(as_bytes(i),sizeof(int)); )     v.push_back(i);
   //...
   for(int i=0; i<v.size(); ++i)
      ofs.write(as_bytes(v[i]),sizeof(int));    // note: writing binary bytes
   return 0;
}
// For now, treat as_bytes() as a primitive
// Warning!  Beware transferring between different systems
```

Outline

Positioning in a Filestream




```
fstream fs {name};        // open for input and output
// ...
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

Outline

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: ",s);
    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()
```

- Document yourself on `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

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

```
for (char ch; 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?
...
```

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

C++14

- Binary literals
  0b1010100100000011

- Digit separators
  0b1010'1001'0000'0011
  Can also be used for for decimal, octal, and hexadecimal numbers

- User-Defined Literals (UDLs) in the standard library
  - Time: `2h+10m+12s+123ms+3456ns`
  - Complex: `2+4i`

Summary

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