Input/output

Victor Eijkhout, Susan Lindsey

Fall 2023
last formatted: September 26, 2023

1. I/O, what's it about?

Input: getting data from keyboard or file into your program.

Output: getting data from your program to screen or file.

The fmtlib library

2. Simple example

The basic usage is:

```
int i=2;
format("string {} brace expressions",i);
```

Format string, and arguments.

3. Displaying the format result

Use `cout` or (C++23) `print`:

```cpp
// io/fmtbasic.cpp
  cout << format("{}\n",2);
  string hello_string = format
    ("{} {}!","Hello","world");
  cout << hello_string << '\n';
  print
    ("{0}, {0}
    {1}!\n","Hello","world");
```

Output:
```
2
Hello world!
Hello, Hello world!
```

4. **Right align**

Right-align with > character and width:

```cpp
// io/fmtlib.cpp
  for (int i=10; i<2000000000;
  i*=10)
    fmt::print("{:>6}\n",i);
```

```
Output:

    10
   100
  1000
 10000
100000
1000000
10000000
100000000
1000000000
1410065408
1215752192
```

5. Padding character

Other than space for padding:

```
Code:
// io/fmtlib.cpp
  for (int i=10; i<2000000000;
  i*=10)
    fmt::print("{0:.>6}\n",i);
```

```
Output:
....10
...100
..1000
.10000
100000
1000000
10000000
100000000
1000000000
1410065408
1215752192
```

6. Number bases

```
Code:
1 // io/fmtlib.cpp
2    fmt::print
3      ("{0} = {0:b} bin\n",17);
4    fmt::print
5      ("   = {0:o} oct\n",17);
6    fmt::print
7      ("   = {0:x} hex\n",17);
```

```
Output:
17 = 10001 bin
   = 21 oct
   = 11 hex
```

7. Float and fixed

Floating point or normalized exponential with e specifier
fixed: use decimal point if it fits, $m.n$ specification

```
Code:
1 // io/fmtfloat.cpp
2   x = 1.234567;
3   for (int i=0; i<6; ++i) {
4     fmt::print
5       ("{0:.3e}/{0:7.4}\n",x);
6     x *= 10;
7   }
```

```
Output:
1.235e+00/  1.235
1.235e+01/  12.35
1.235e+02/  123.5
1.235e+03/   1235
1.235e+04/1.235e+04
1.235e+05/1.235e+05
```

Formatted stream output

8. Formatted output

From `iostream`: `cout` uses default formatting.

Possible manipulation in `iomanip` header: pad a number, use limited precision, format as hex, etc.

9. Default unformatted output

```
Code:

// io/io.cpp
for (int i=1; i<200000000; i*=10)
  cout << "Number: " << i << '\n';
```

```
Output:

Number: 1
Number: 10
Number: 100
Number: 1000
Number: 10000
Number: 100000
Number: 1000000
Number: 10000000
Number: 100000000
```

10. Reserve space

You can specify the number of positions, and the output is right aligned in that space by default:

```cpp
// io/width.cpp
#include <iomanip>
using std::setw;
  /* ... */
  cout << "Width is 6:" << '\n';
  for (int i=1; i<200000000; i*=10)
    cout << "Number: "
         << setw(6) << i << '\n';
  cout << '\n';

  // `setw' applies only once:
  cout << "Width is 6:" << '\n';
  cout << ">"
       << setw(6) << 1 << 2 << 3 <<
  '\n';
  cout << '\n';
```

```
Output:

Width is 6:
Number:      1
Number:     10
Number:    100
Number:   1000
Number:  10000
Number: 100000
Number: 1000000
Number: 10000000
Number: 100000000

Width is 6:
>     123
```

11. Padding character

Normally, padding is done with spaces, but you can specify other characters:

```
Code:
1 // io/formatpad.cpp
2 #include <iomanip>
3 using std::setfill;
4 using std::setw;
5    /* ... */
6  for (int i=1; i<200000000; i*=10)
7    cout << "Number: "
8          << setfill('.')
9          << setw(6) << i
10         << '\n';
```

```
Output:

Number: .....1
Number: ....10
Number: ...100
Number: ..1000
Number: .10000
Number: 100000
Number: 1000000
Number: 10000000
Number: 100000000
```

Note: single quotes denote characters, double quotes denote strings.

12. Left alignment

Instead of right alignment you can do left:

```
Code:
1 // io/formatleft.cpp
2 #include <iomanip>
3 using std::left;
4 using std::setfill;
5 using std::setw;
6     /* ... */
7   for (int i=1; i<200000000; i*=10)
8     cout << "Number: "
9          << left << setfill('.')
10         << setw(6) << i << '\n';
```

```
Output:
Number: 1.....
Number: 10....
Number: 100...
Number: 1000..
Number: 10000.
Number: 100000
Number: 1000000
Number: 10000000
Number: 100000000
```

13. Number base

Finally, you can print in different number bases than 10:

```
Code:

1  // io/format16.cpp
2  #include <iomanip>
3  using std::setbase;
4  using std::setfill;
5    /* ... */
6    cout << setbase(16)
7         << setfill(' ');
8    for (int i=0; i<16; ++i) {
9      for (int j=0; j<16; ++j)
10       cout << i*16+j << " " ;
11     cout << '\n';
12   }
```

```
Output:

0 1 2 3 4 5 6 7 8 9 a b c d e f
10 11 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f
20 21 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f
30 31 32 33 34 35 36 37 38 39 3a 3b 3c 3d 3e 3f
40 41 42 43 44 45 46 47 48 49 4a 4b 4c 4d 4e 4f
50 51 52 53 54 55 56 57 58 59 5a 5b 5c 5d 5e 5f
60 61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f
70 71 72 73 74 75 76 77 78 79 7a 7b 7c 7d 7e 7f
80 81 82 83 84 85 86 87 88 89 8a 8b 8c 8d 8e 8f
90 91 92 93 94 95 96 97 98 99 9a 9b 9c 9d 9e 9f
a0 a1 a2 a3 a4 a5 a6 a7 a8 a9 aa ab ac ad ae af
b0 b1 b2 b3 b4 b5 b6 b7 b8 b9 ba bb bc bd be bf
c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 ca cb cc cd ce cf
d0 d1 d2 d3 d4 d5 d6 d7 d8 d9 da db dc dd de df
```

Exercise 1

Make the first line in the above output align better with the other lines:

```
00 01 02 03 04 05 06 07 08 09 0a 0b 0c 0d 0e 0f
10 11 12 13 14 15 16 17 18 19 1a 1b 1c 1d 1e 1f
20 21 22 23 24 25 26 27 28 29 2a 2b 2c 2d 2e 2f
etc
```

Exercise 2

Use integer output to print real numbers aligned on the decimal:

```
 Code:
1 // io/quasifix.cpp
2 string quasifix(double);
3 int main() {
4    for ( auto x : { 1.5, 12.32,
         123.456, 1234.5678 } )
5      cout << quasifix(x) << '\n';
```

```
Output:
   1.5
  12.32
 123.456
1234.5678
```

Use four spaces for both the integer and fractional part; test only
with numbers that fit this format.

14. **Hexadecimal**

Hex output is useful for addresses (chapter **??**):

```cpp
// pointer/coutpoint.cpp
  int i;
  cout << "address of i, decimal: "
       << (long)&i << '\n';
  cout << "address of i, hex    : "
       << std::hex << &i << '\n';
```

```
Output:

address of i, decimal:
    140732703427524
address of i, hex    :
    0x7ffee2cbcbc4
```

Back to decimal:

```cpp
cout << hex << i << dec << j;
```

Floating point formatting

15. **Floating point precision**

Use `setprecision` to set the number of digits before and after decimal point:

```cpp
// io/formatfloat.cpp
#include <iomanip>
using std::left;
using std::setfill;
using std::setw;
using std::setprecision;
    /* ... */
  x = 1.234567;
  for (int i=0; i<10; ++i) {
    cout << setprecision(4) << x <<
      '\n';
    x *= 10;
  }
```

```
Output:

1.235
12.35
123.5
1235
1.235e+04
1.235e+05
1.235e+06
1.235e+07
1.235e+08
1.235e+09
```

This mode is a mix of fixed and floating point. See the `scientific` option below for consistent use of floating point format.

16. **Fixed point precision**

Fixed precision applies to fractional part:

```
Code:
1 // io/fix.cpp
2   x = 1.234567;
3   cout << fixed;
4   for (int i=0; i<10; ++i) {
5     cout << setprecision(4) << x <<
      '\n';
6     x *= 10;
7   }
```

```
Output:
1.2346
12.3457
123.4567
1234.5670
12345.6700
123456.7000
1234567.0000
12345670.0000
123456700.0000
1234567000.0000
```

(Notice the rounding)

17. **Aligned fixed point output**

Combine width and precision:

```cpp
// io/align.cpp
  x = 1.234567;
  cout << fixed;
  for (int i=0; i<10; ++i) {
    cout << setw(10) <<
     setprecision(4) << x
          << '\n';
    x *= 10;
  }
```

```
Output:

    1.2346
   12.3457
  123.4567
 1234.5670
12345.6700
123456.7000
1234567.0000
12345670.0000
123456700.0000
1234567000.0000
```

18. **Scientific notation**

Combining width and precision:

```cpp
// io/iof.cpp
  x = 1.234567;
  cout << scientific;
  for (int i=0; i<10; ++i) {
    cout << setw(10) <<
     setprecision(4)
        << x << '\n';
    x *= 10;
  }
  cout << '\n';
```

Output:
```
1.2346e+00
1.2346e+01
1.2346e+02
1.2346e+03
1.2346e+04
1.2346e+05
1.2346e+06
1.2346e+07
1.2346e+08
1.2346e+09
```

File output

19. Text output to file

Use:

```cpp
// io/fio.cpp
#include <fstream>
using std::ofstream;
    /* ... */
  ofstream file_out;
  file_out.open
    ("fio_example.out");
    /* ... */
  file_out << number << '\n';
  file_out.close();
```

```
Output:

echo 24 | ./fio ; \
        cat
    fio_example.out
A number please:
Written.
24
```

Compare: cout is a stream that has already been opened to your terminal 'file'.

20. Binary output

Binary output: write your data byte-by-byte from memory to file.
(Why is that better than a printable representation?)

```
Code:

// io/fiobin.cpp
ofstream file_out;
file_out.open
  ("fio_binary.out",ios::binary);
/* ... */
file_out.write(
  (char*)(&number),4);
```

```
Output:

echo 25 | ./fiobin ; \
        od
  fio_binary.out
A number please:
  Written.
0000000    000031
  000000
0000004
```

Cout on classes (for future reference)

21. Redefine less-less

If you want to output a class that you wrote yourself, you have to define how the << operator deals with your class.

```cpp
// stl/ostream.cpp
class container {
    /* ... */
  int value() const {
    /* ... */
  };
    /* ... */
ostream &operator<<(ostream &os,const container &i) {
  os << "Container: " << i.value();
  return os;
};
    /* ... */
  container eye(5);
  cout << eye << '\n';
```