File Input/Output Streams in C++

CS 16: Solving Problems with Computers I
Lecture #10

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Announcements

- **Homework #9 due today**
- Homework #10 is out

- **Midterm #2** is on **Thursday, 5/18**
  - That's next week!

- **Names on Homework Assignments!!!**

Outline

Chapter 6 in textbook

- I/O Data Streams and File I/O
- An introduction to Objects
  - Member functions
- Handling File I/O Errors

Objects

- Objects are special variables that have their own special-purpose functions
  - There's more to them than that, but more on this later…

- Example: String length can be gotten with

```
stringname.size()
```

- These are called ***member functions***

I/O Streams

- **I/O** = program Input and Output
  - Delivered to your program via a ***stream object***
  - A stream is a **flow of data**

- Input can be from the **keyboard (cin)** or a **computer file**
- Output can be from the **screen (cout)** or a **computer file**

- Input stream → Data flows **into** the program
- Output stream ← Data flows **out** of the program

Why Use Files?

4 Good Reasons:

- Files allow you to store data permanently and conveniently!
- Data output to a file lasts after the program ends
  - You can usually view them without the need of a C++ program
- An input file can be used over and over
  - No typing of data again and again for testing
- Files allow you to deal with larger data sets

File I/O

- **Read (input) from a file**
  - Usually done from beginning to the end of file (not always)
    - No backing up to read something again (but it's OK to start over)
    - Similar to how it's done from the keyboard

- **Write (output) to a file**
  - Usually done from beginning to end of file (not always)
    - No backing up to write something again (but it's OK to start over)
    - Similar to how it's done to the screen

Stream Variables for File I/O

You have to use "stream variables" for file I/O:

- Must be **declared** before it can be used

- Must be **initialized** before it can contain valid data
  - Initializing a stream means *connecting it to a file*
  - The value of the stream variable is really the filename it is connected to

- Can have their values changed
  - Changing a stream value means disconnecting from one file and then connecting to another

Streams and Assignment

- Streams use special built-in (member) functions instead of the assignment operator to change values

- ***Example***:

```
streamObjectX.open(“addressBook.txt”);
streamObjectX.close();
```

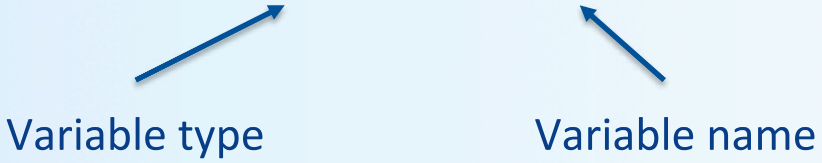
Declaring An **Input-file** Stream Variable

- Input-file streams are of type **ifstream**
- Type **ifstream** is defined in the **fstream** library
- You must use *include* statement and *using* directives

```
#include <fstream>
using namespace std;
```

- Declare an input-file stream variable with:

```
ifstream in_stream;
```



Variable type

Variable name

Declaring An
Output-file Stream Variable

- Ouput-file streams of are type **ofstream**

- Type **ofstream** is defined in the **fstream** library
- Again, you must use the *include* and *using* directives

```
#include <fstream>
using namespace std;
```

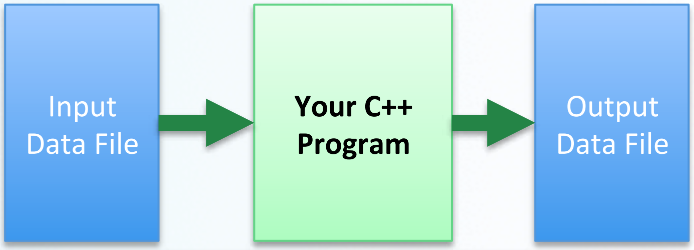
- Declare an input-file stream variable using

```
ofstream out_stream;
```

Variable type

Variable name

Connecting To A File



Input Data File

Your C++ Program

Output Data File

- Once a stream variable is declared, you connect it to a file
  - – Connecting a stream to a file means "opening" the file
  - – Use the *open* function of the stream object

```
in_stream.open("infile.dat");
```

Double quotes

Period

File name on the disk

Must include a true path (relative or absolute)

Using The Input Stream

- Once connected to a file, get input from the file using the extraction operator (**>>**)
  - Just like with **cin**

Example:

```
ifstream in_stream;
in_stream.open(“infile.dat”);
int one_number, another_number;

in_stream >> one_number >> another_number;

in_stream.close();
```

The inputs are read from the infile.dat file separated by either spaces or newline characters

DEMO!

Using The Output Stream

- An output-stream works similarly using the insertion operator (**<<**)
  - Just like with **cout**

Example:

```
ofstream out_stream;
out_stream.open(“outfile.dat”);

out_stream << “one number = ” << num1
           << “, another number = ” << num2;


out_stream.close();
```

The output gets written in the outfile.dat file

DEMO!

The **External File Name**

- Must be the name of a file that the operating system uses
- Be compliant with naming conventions on your system
  - Example: Don't call an input **text** file ***XYZ.jpg***
- Make sure the path is true
  - If the file is local to your program, then no path is needed
  - Otherwise use either relative or absolute path names

  Example: **`infile.open("../MyDirectory/inputFile_42.txt");`**

Closing a File

- After using a file, it should be closed using the .close() function
  - This *disconnects* the stream from the file
  - Close files to reduce the chance of a file being corrupted if the program terminates abnormally

- ***Example:*** `in_stream.close();`

- **It is important to close an output file if your program later needs to read input from the output file**

- The system will automatically close files if you forget ***as long as your program ends normally!***

Member Functions

Member function: function associated with an object

- ***.open()*** is a member function of **in_stream** in the previous examples
  - **in_stream** is an object of class **ifstream**

- Likewise, a ***different .open()*** is a member function of **out_stream** in the previous examples
  - Despite having the same name!
  - **out_stream** is an object of class **ofstream**

For a list of member functions for I/O stream classes, also see:

http://www.cplusplus.com/reference/fstream/ifstream/

http://www.cplusplus.com/reference/fstream/ofstream/

Classes vs. Objects

- A class is a complex data type that

  contains variables and functions

  - Example: **ifstream**, **ofstream**, **string** are C++ classes

- When you call up a class to use it in a program you ***instantiate*** it as an object

  - Example:

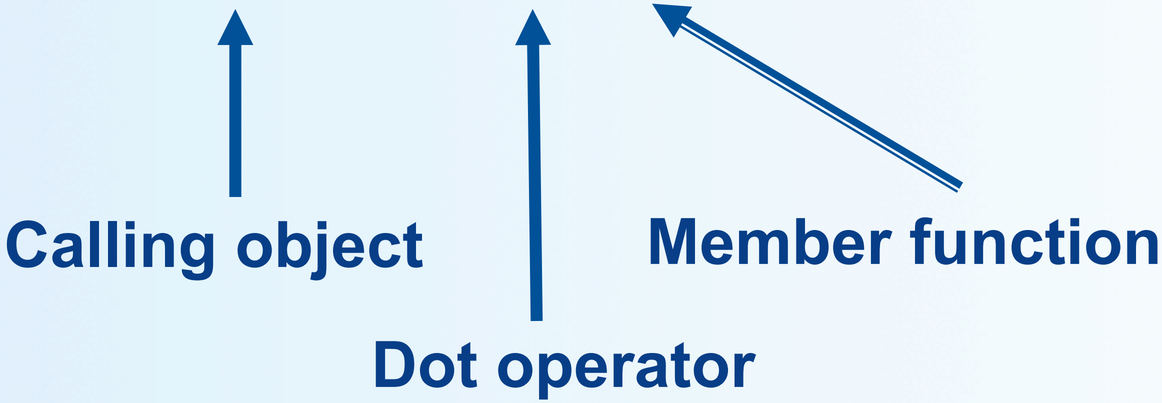
    ```
    ifstream MyInputStream;
    // MyInputStream is an object of class ifstream
    ```

Calling a Member Function

- Calling a member function requires specifying the object containing the function

- The calling object is separated from the member function by the dot operator

- Example: `in_stream.open("infile.dat");`



Calling object

Member function

Dot operator

Errors On Opening Files

- Opening a file can fail for several reasons
  - The file might not exist
  - The name might be typed incorrectly
  - Other reasons

- **Caution**: You may not see an error message if the call to open fails!!
  - Program execution usually continues!

Catching Stream Errors

- Member function **fail()**, can be used to test the success of a stream operation

- `fail()` returns a Boolean type (True or False)

- `fail()` returns True (1)
  if the stream operation failed

Halting Execution

- When a stream open function fails, it is generally best to stop the program

- The function **exit()**, halts a program
  - `exit(n)` returns its argument (n) to the operating system
  - `exit(n)` causes program execution to stop
  - `exit(n)` is NOT a member function! It's a function defined in **cstdlib**

- Exit requires the include and using directives

```
#include <cstdlib>
using namespace std;
```

Using **fail** and **exit**

- **Immediately following the call to open**, check that the operation was successful:

```
in_stream.open("stuff.dat");
if( in_stream.fail( ) )
  {
          cout << "Input file opening failed.\n";
          exit(1); // Program quits right here!
   }
```

Techniques for File I/O

- When reading input from a file

  do not include prompts or **echo the input**

- Unlike when you're reading from a keyboard
  - The lines

    ```
    cout << "Enter the number: ";
    cin  >> the_number;
    cout << "The number you entered is << the_number;
    ```

    become just one line when doing a file input read:

    ```
    in_file >> the_number;
    ```

  - The input file must contain *just* the data that's expected
    - So you have to be familiar with how the input file is organized

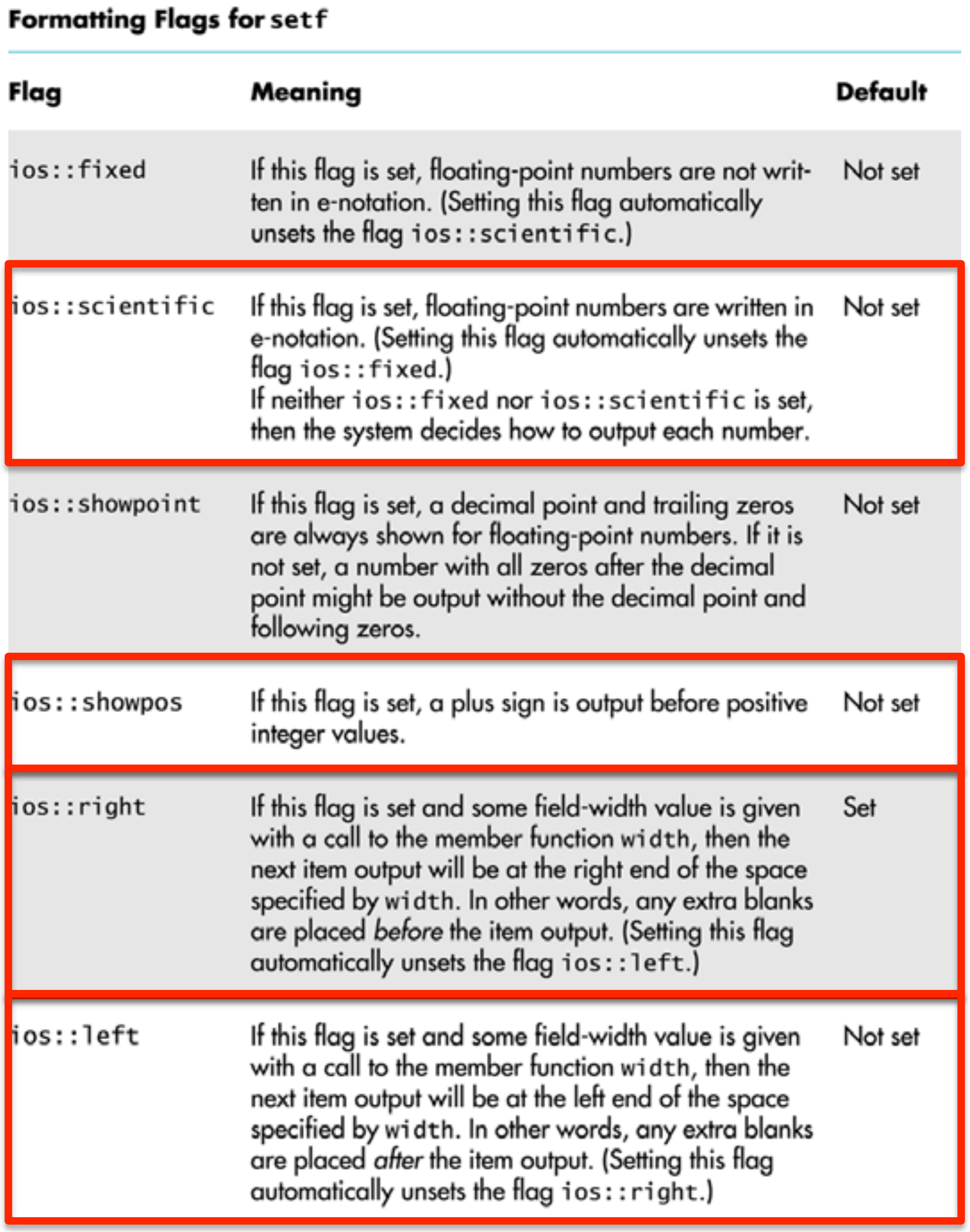
Formatting Output to Files

- Format output to the screen with:

```
cout.setf(ios::fixed);
cout.setf(ios::showpoint);
cout.precision(2);
```

- Similarly, format output to a file using out_stream with:

```
out_stream.setf(ios::fixed);
out_stream.setf(ios::showpoint);
out_stream.precision(2);
```



Formatting Flags for `setf`

Flag	Meaning	Default
`ios::fixed`	If this flag is set, floating-point numbers are not written in e-notation. (Setting this flag automatically unsets the flag `ios::scientific`.)	Not set
`ios::scientific`	If this flag is set, floating-point numbers are written in e-notation. (Setting this flag automatically unsets the flag `ios::fixed`.) If neither `ios::fixed` nor `ios::scientific` is set, then the system decides how to output each number.	Not set
`ios::showpoint`	If this flag is set, a decimal point and trailing zeros are always shown for floating-point numbers. If it is not set, a number with all zeros after the decimal point might be output without the decimal point and following zeros.	Not set
`ios::showpos`	If this flag is set, a plus sign is output before positive integer values.	Not set
`ios::right`	If this flag is set and some field-width value is given with a call to the member function `width`, then the next item output will be at the right end of the space specified by `width`. In other words, any extra blanks are placed *before* the item output. (Setting this flag automatically unsets the flag `ios::left`.)	Set
`ios::left`	If this flag is set and some field-width value is given with a call to the member function `width`, then the next item output will be at the left end of the space specified by `width`. In other words, any extra blanks are placed *after* the item output. (Setting this flag automatically unsets the flag `ios::right`.)	Not set

Creating Space in Output

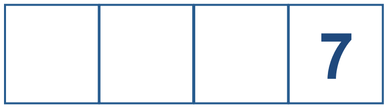
- The **width member** function specifies the number of spaces for the next item
  - Applies *only to the next item of output*

Example:

- To print the digit 7 in four spaces and use

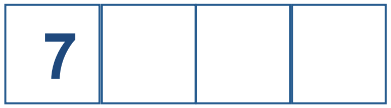
```
out_stream.width(4);
out_stream << 7 << endl;
```

Three of the spaces will be blank:



.setf(ios::right)

default



.setf(ios::left)

Not Enough Width?

- What if the argument for width is too small?
  - Such as specifying `cout.width(3);` when the value to print is **3456.45**

- The entire item is always put in output
  - If too few spaces are specified, as many more spaces as needed are used
  - In the example above, the value is still printed as if the `cout.width(3);` was not there.

Unsetting Flags

- Any flag that is set, may be unset
- Use the **unsetf** function
  - Example:

```
cout.unsetf(ios::showpos);
```

causes the program to stop printing plus signs on positive numbers

Manipulators

- A function called in a nontraditional way

- Manipulators, in turn, call member functions
  - May or may not have arguments

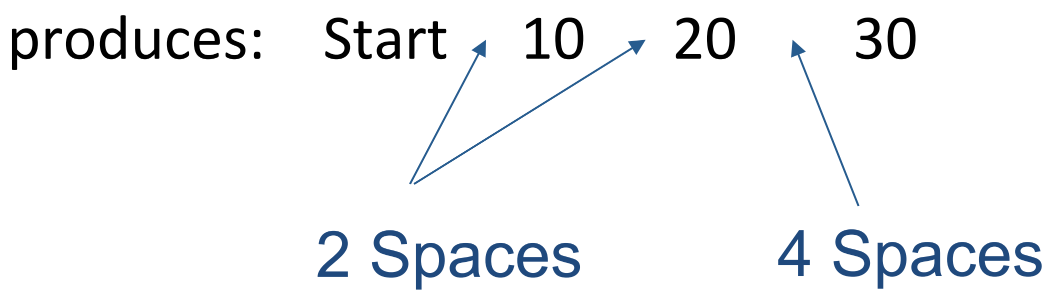
- Used after the insertion operator (**<<**) as if the manipulator function call is an output item

The **setw** Manipulator

- **setw** does the same task as member function **width**
  - **setw** calls the width function to set spaces for output
  - Found in the library **<iomanip>**

- Example:

```
cout << "Start" << setw(4) << 10
     << setw(4) << 20 << setw(6) << 30;
```



produces: Start 10 20 30

2 Spaces

4 Spaces

- *The 1st setw(4) ensures 4 spaces between “Start" and 10, INCLUSIVE of the spaces taken up by 10.*
- *The 2nd setw(4) ensures 4 spaces between 10 and 20, INCLUSIVE of the spaces taken up by 20.*
- *The 3rd setw(6) ensures 6 spaces between 20 and 30, INCLUSIVE of the space taken up by 30.*

The **setprecision** Manipulator

- **setprecision** does the same task as member function **precision**
  - Found in the library **<iomanip>**

- Example:

```
cout.setf(ios::fixed);
cout.setf(ios::showpoint);
cout << "$" << setprecision(2)
     << 10.3  << endl
     << "$" << 20.5 << endl;
```

produces:

```
$10.30
$20.50
```

- setprecision setting stays in effect until changed

Appending Data to Output Files

- Output examples we've given so far *create new files*
  - If the output file already contained data, that data is now lost

- To ***append*** new output to the end an existing file use the constant **ios::app** defined in the **iostream** library:

```
outStream.open("important.txt", ios::app);
```

- If the file does not exist, a new file will be created

- Other member functions include those that return where in the output file (or input file) the next data will be
  - Helps with customizing read and writing files
  - To be used carefully!

Entering File Names for I/O Files

- Users can also enter the name of a file to be read/written
  - As an input read by **cin**

- You can use regular C++ strings for the filenames, but **ONLY** if you ensure that you are compiling with C++ version 11 (or later).

- OTHERWISE, you'll have to use C-strings
  - **WARNING!!!! PAY ATTENTION TO THIS!!!**

- Textbook has details on how to use C-strings for filenames

Note on Compiles using C++ ver. 11

- To make sure you compile using an updated version of C++ (ver. 11), do this (in Linux):

Actually, C++ ver. 14 exists, but we won't use that here…

```
$ g++ prog.cpp -o prog -std=c++11
```

- If you want your compiler to give you warnings (as well as error msgs of course), do this (in Linux):

```
$ g++ prog.cpp -o prog -std=c++11 -Wall
```

These Compile Statements are Getting Loooong!

- Wait until you have to compile these long statements over and over again for a multitude of C++ files!

- **Makefiles** to the rescue!
  - Next week, we'll discuss how to use this valuable Linux tool

In-Class DEMO!

Program does the following:

- Reads inputs from an input file
  - User will enter filename for the program
- Does some computations with the read inputs
- Writes the results as outputs to an output file
  - User will enter filename for the program

To Dos

- Homework #10

- THU: More on I/O formatting & Strings in C++
  - Read rest of **Chapter 6** in textbook

- TUE: Arrays
  - Read **Chapter 7** in textbook

</LECTURE>