I/O streams

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Acknowledgement: Lecture slides based on those created by Bjarne Stroustrup for use with his textbook

Overview

- Introduction
- Input & output
- The stream model
  - ostream
  - istream
  - Reading and writing
    - Reading from character streams
- The I/O classes
  - Relationship among I/O types
- File I/O
  - General model
  - General process
  - File streams
  - Using file stream objects
    - Opening a file for reading
    - Opening a file for writing (discard contents)
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    - For most programs, limiting I/O to the console window is insufficient
- The `standard library` provides different kinds of I/O types to support different kinds of I/O processing

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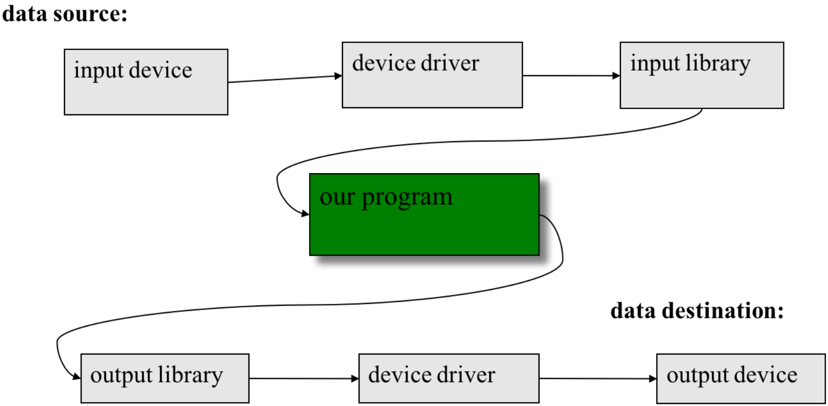
Input & output



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  - You may have heard of buffered I/O; a `stream buffer` houses a fixed amount of extracted stream data

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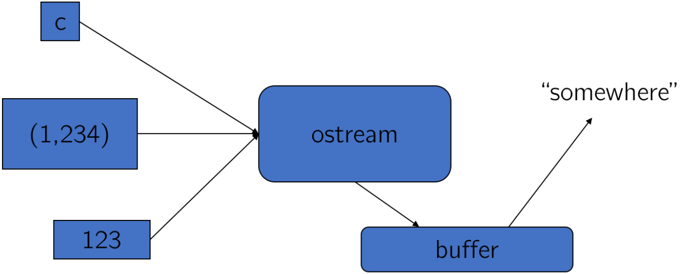
ostreams



- An `ostream` turns values of various types into character sequences
- sends those characters somewhere
- `std::cout` is an `ostream` typed object that provides characters sequences to standard output

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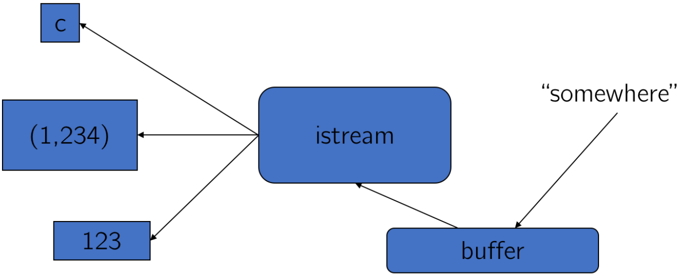
istreams



- An istream turns character sequences into values of various types
- gets those characters from somewhere
- std::cin is an istream typed object that consumes character sequences from standard input

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Reading and writing

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  - Typically stored (entered, printed, etc.) as text
    - But not necessarily (e.g., binary streams)

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- We would specify how we would like to consume these five characters using an `istream` in our program
    - We could read the input into an `std::string`
    - We could read the number `3`, followed by the character `*`, etc.
- It is completely up to us what type we would like to convert the characters into

  (as long as the character sequence is valid for the desired type)

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The I/O classes

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iostream	istream reads from a stream
iostream	ostream writes to a stream
iostream	iostream reads and writes a stream
fstream	ifstream reads from a file
fstream	ofstream writes a file
fstream	fstream reads and writes a file
sstream	istringstream reads from a string
sstream	ostringstream writes a string
sstream	stringstream reads and writes a string

- The above classes are provided to us by the standard library and allow for different kinds of I/O processing
  - To support languages that use wide characters, the library also provides a set of types and objects for wchar_t data

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  - We can use >> to read data irrespective of whether we re reading from the console window, a disk file, or a string
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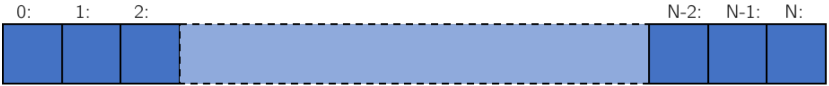
- We can read/write a file if we know its name and format

A file



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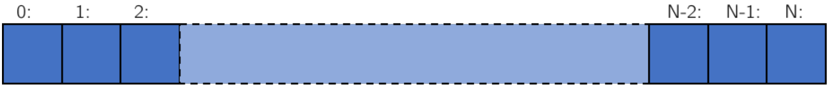

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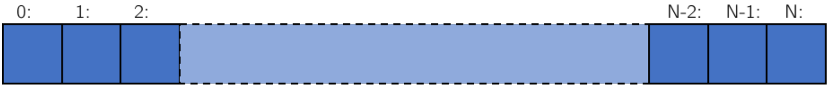

- At the fundamental level, a file is a sequence of bytes numbered from 0 upwards
- Other notions can be supplied by programs that interpret a “file format”
  - For example, the 6 bytes (characters) “123.45” might be interpreted as the floating-point number 123.45

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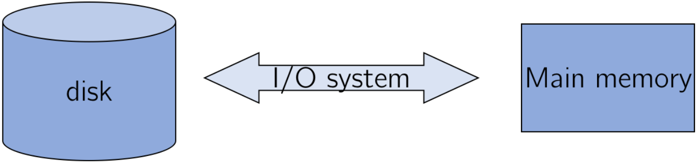

disk

I/O system

Main memory

iostreams

Files
(sequences of bytes)

Objects
(of various types)

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File streams

Header	Type
`fstream`	`ifstream` reads from a `file`
`fstream`	`ofstream` writes a `file`
`fstream`	`fstream` reads and writes a `file`

- These types provide the same operations as those we have used on with `std::cin` and `std::cout`

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  - When we initialize the `fstream` object with a file name, that file is opened implicitly
    - When an `fstream` object is created, open is called automatically
  - `// construct an ifstream and open ifile`
    `ifstream in{ifile};`
  - `// construct an ofstream and open ofile`
    `ofstream out{ofile};`
  - When the `fstream` object s lifetime ends, the `fstream` will implicitly close the file
    - When an `fstream` object is destroyed, close is called automatically

Opening a file for reading

```
// ...

cout << "Please␣enter␣input␣file␣name:␣";
string iname;
cin >> iname;

ifstream ist {iname};
// ifstream is “aninput stream from a ”file
// defining an ifstream with a name string
// opens the file of that name for reading

if (!ist) throw runtime_error("'cant␣open␣input␣file");

// ...
```

Opening a file for writing (discard contents)

```
// ...

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
// the contents of the file are discarded

if (!ofs) throw runtime_error("'cant␣open␣output␣file");

// ...
```

Opening a file for writing (append to existing contents)

```
// ...

cout << "Please␣enter␣name␣of␣output␣file:␣";
string oname;
cin >> oname;

ofstream ofs {oname, ofstream::app};
// ofstream is an “output stream from a ”file
// defining an ofstream with a name string
// opens the file with that name for writing
// the contents of the file are preserved

if (!ofs) throw runtime_error("'cant␣open␣output␣file");

// ...
```

Reading 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 in the range

  $$0, \ldots, 23$$

- No further format is assumed
- Termination
  - Reaching the end of file terminates the read
  - Anything unexpected in the file terminates the read

Reading a file

```
vector<int> hours;
vector<double> temps;

std::string iname = "temperatures.dat"
ifstream ist {iname};
if (!ist) throw runtime_error("'cant␣open␣input␣file");

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

Overview

- Introduction
- Input & output
- The stream model
  - ostream
  - istream
  - Reading and writing
    - Reading from character streams
- The I/O classes
  - Relationship among I/O types
- File I/O
  - General model
  - General process
  - File streams
  - Using file stream objects
    - Opening a file for reading
    - Opening a file for writing (discard contents)
    - Opening a file for writing (append to existing contents)
    - Reading a file
- I/O error handling
  - Stream state flags
  - Stream state functions
  - Validating input with stream state
- References

I/O error handling

- Sources of errors:

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- Sources of errors:
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- The I/O stream types define flags and functions that allow us to interrogate and manipulate the condition state of a stream
  - We can use a stream as a condition, e.x., `if (cin)`, to ask whether that stream is valid
  - If the condition evaluates `false`, we know we have a situation, but we re not sure why the stream is invalid (just yet)

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- Input & output
- The stream model
  - ostream
  - istream
  - Reading and writing
    - Reading from character streams
- The I/O classes
  - Relationship among I/O types
- File I/O
  - General model
  - General process
  - File streams
  - Using file stream objects
    - Opening a file for reading
    - Opening a file for writing (discard contents)
    - Opening a file for writing (append to existing contents)
    - Reading a file
- I/O error handling
  - Stream state flags
  - Stream state functions
  - Validating input with stream state
- References

Stream state flags

- The I/O stream types each provide a collection of bits (typed `iostate`) that are used to convey information about the state of a stream; different bit pattern are used to express different kinds of I/O conditions

Flag	**Meaning**
`goodbit`	Set when the stream is not in an error state
`badbit`	Set when an unrecoverable failure has occurred
`failbit`	Set when a recoverable error has occurred
`eofbit`	Set when the stream has hit end-of-file

Stream state flags

- Each I/O stream type has an `rdstate` function that returns an `iostate` value corresponding to the current state of a stream

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if ((cin.rdstate() & std::ios::failbit ) != 0)
   /* failbit set, do something to recover */
```

Stream state flags

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- We could check whether the failbit is set for cin by writing:

  ```
  if ((cin.rdstate() & std::ios::failbit ) != 0)
     /* failbit set, do something to recover */
  ```

- Similarly, we could check whether the failbit is set for an ifstream named ifs by writing:

  ```
  if ((ifs.rdstate() & std::ifstream::failbit ) != 0)
     /* failbit set, do something to recover */
  ```

Stream state flags

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- We could check whether the `failbit` is set for `cin` by writing:

```
if ((cin.rdstate() & std::ios::failbit ) != 0)
   /* failbit set, do something to recover */
```

- Similarly, we could check whether the `failbit` is set for an `ifstream` named `ifs` by writing:

```
if ((ifs.rdstate() & std::ifstream::failbit ) != 0)
   /* failbit set, do something to recover */
```

- Lucky for us, there is an easier way to check the current state of a respective stream

Overview

- Introduction
- Input & output
- The stream model
  - ostream
  - istream
  - Reading and writing
    - Reading from character streams
- The I/O classes
  - Relationship among I/O types
- File I/O
  - General model
  - General process
  - File streams
  - Using file stream objects
    - Opening a file for reading
    - Opening a file for writing (discard contents)
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    - Reading a file
- I/O error handling
  - Stream state flags
  - Stream state functions
  - Validating input with stream state
- References

Stream state functions

- The I/O stream types have functions that can be used to interrogate the state of a stream

	Flag			
Function	`goodbit`	`badbit`	`failbit`	`eofbit`
`good()`	✓			
`bad()`		✓		
`fail()`		✓	✓	
`eof()`				✓

Overview

- Introduction
- Input & output
- The stream model
    - ostream
    - istream
    - Reading and writing
        - Reading from character streams
- The I/O classes
    - Relationship among I/O types
- File I/O
    - General model
    - General process
    - File streams
    - Using file stream objects
        - Opening a file for reading
        - Opening a file for writing (discard contents)
        - Opening a file for writing (append to existing contents)
        - Reading a file
- I/O error handling
    - Stream state flags
    - Stream state functions
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Validating input with stream state

```
string prompt = "Enter␣an␣integer:␣";
cout << prompt;

int i;
cin >> i;

while (!cin.good())    // goodbit NOT set
{
    if (cin.bad()) { // badbit set
        /* do something */
    } else if (cin.eof()) { // eofbit set
        /* do something else */
    } else { // failbit set
        cout << "Invalid␣input!" << endl;
        cin.clear();
        cin.ignore(numeric_limits<streamsize>::max(), '\n');
        cout << prompt;
        cin >> i;
    }
}
/* do something with valid input */
```

Validating input with stream state

- `cin.clear();`
  - Resets all conditional values of `cin` to valid state
  - Does not affect the `buffered input`
- `cin.ignore(numeric_limits<streamsize>::max(), '\n');`
  - Ignore contents in the buffer
    - First argument is the max number of characters to ignore
    - Second argument is a character that, when observed in the stream, tells us to stop ignoring characters

Overview

- Introduction
- Input & output
- The stream model
  - ostream
  - istream
  - Reading and writing
    - Reading from character streams
- The I/O classes
  - Relationship among I/O types
- File I/O
  - General model
  - General process
  - File streams
  - Using file stream objects
    - Opening a file for reading
    - Opening a file for writing (discard contents)
    - Opening a file for writing (append to existing contents)
    - Reading a file
- I/O error handling
  - Stream state flags
  - Stream state functions
  - Validating input with stream state
- **References**

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