5 Standard Library – Using I/O streams

Introduction

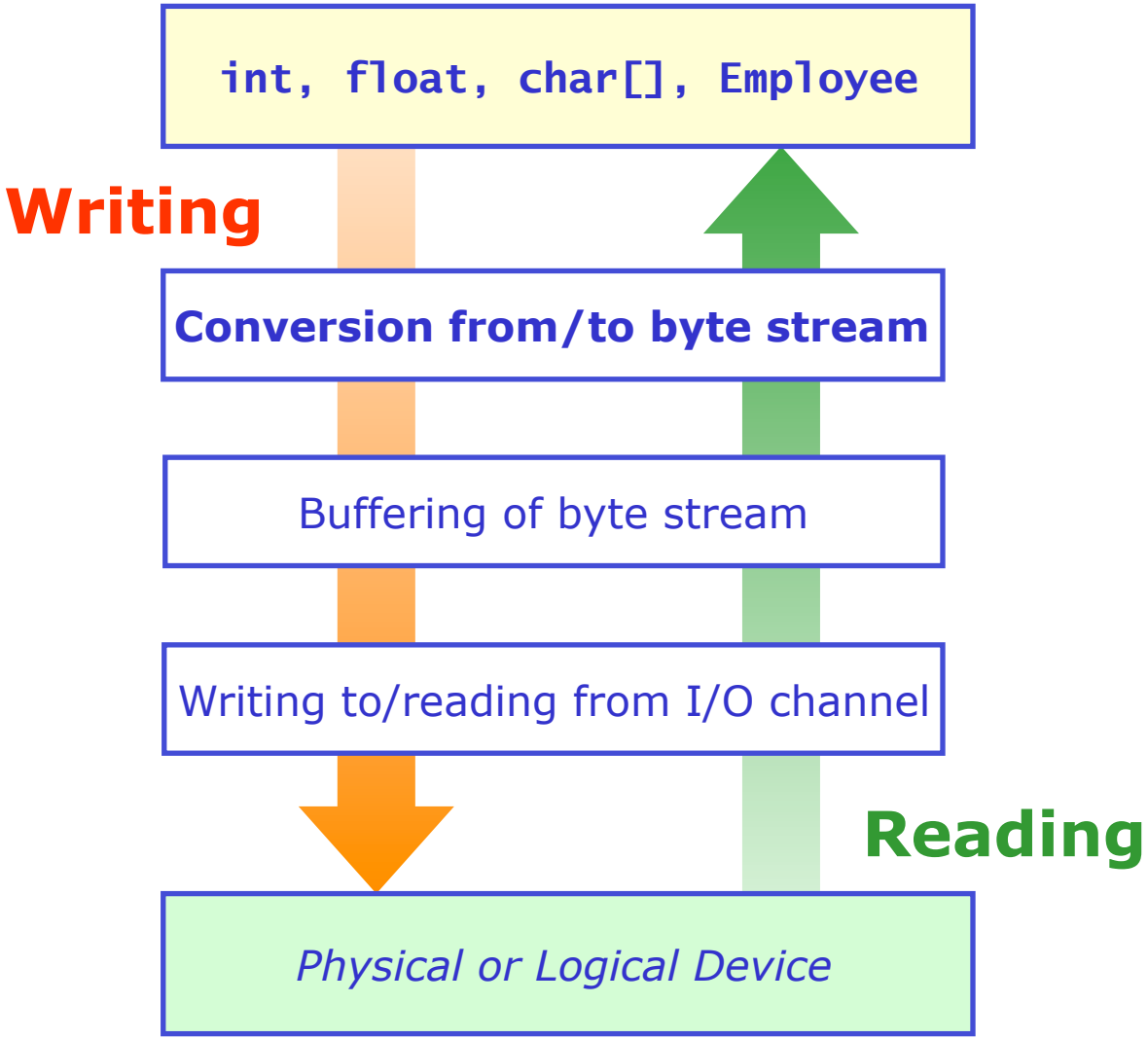
- The Standard Library organizes all kinds of I/O operations through a standard class '**iostream**'
- We've already used class `iostream` several types through the objects `cin` and `cout`

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

int main() {
  double x;

  // Read x from standard input
  cin >> x ;

  // Write x to standard output
  cout << "x = " << x << endl ;

  return 0 ;
}
```

- We will now take a better look at how streams work

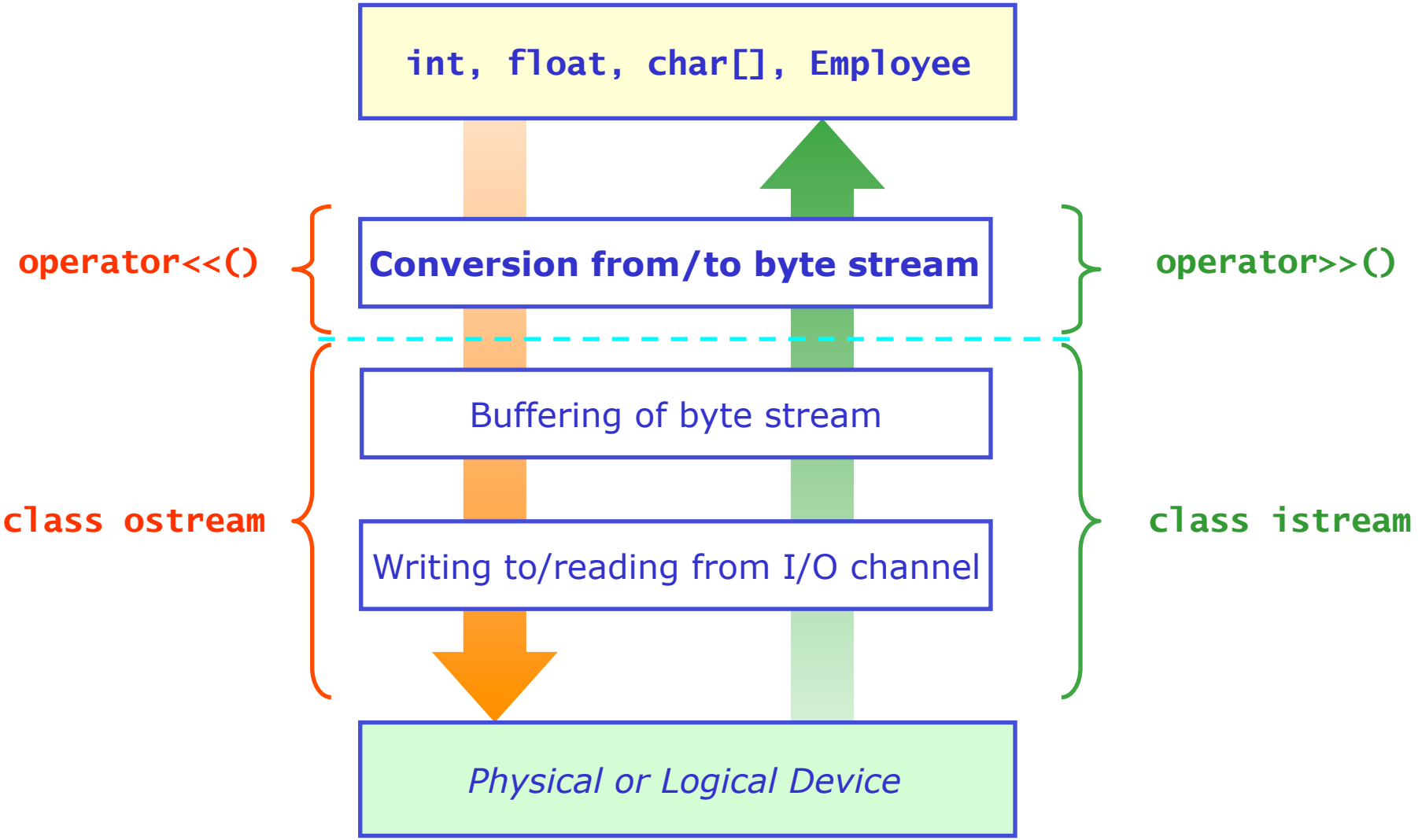
A look behind the scenes

- I/O in C++ involves three distinct steps



I/O classes and operators in C++

- Operators<<(), >>() do step 1, classes `istream`, `ostream` do step 2



Stream object in the Standard Library

- Stream classes in Standard Library

Include file	*Logical or physical device*	*Direction of byte stream*		
		Input	Output	Both
<iostream>	Generic (e.g.terminal)	**istream**	**ostream**	**iostream**
<fstream>	File	**ifstream**	**ofstream**	**fstream**
<sstream>	std::string	**istringstream**	**ostringstream**	**stringstream**

- Standard Library stream classes also implement all operators to convert built-in types to byte streams
  - Implemented as member operators of stream class
  - Example: `ostream::operator<<(int) ;`

- Standard Library also provides three global stream objects for 'standard I/O'
  - `istream` object `cin` for 'standard input'
  - `ostream` objects `cout`,`cerr` for 'standard output','standard error'

Using streams without operators >>(),<<()

- Streams provide several basic functions to read and write bytes
  - Block operations

```
char buf[100] ;
int count(99) ;

// read ‘count’ bytes from input stream
cin.read(buf, count) ;

// write ‘count’ bytes to output stream
cout.write(buf, count) ;
```

Using streams without operators >>(),<<()

- Streams provide several basic functions to read and write bytes
  - Line oriented operations

```
// read line from stdin up to and including the newline char
cin.get(buf,100) ;

// read line from std up to newline char
cin.getline(buf,100) ;

// read line up to and including ':'
cin.get(buf,100,':') ;

// read single character
cin.get(c) ;

// write buffer up to terminating null byte
cout.write(buf,strlen(buf)) ;

// write single character
cout.put(c) ;
```

How is the stream doing?

- Member functions give insight into the *state* of the stream

Function	Meaning
`bool good()`	Next operation *might* succeed
`bool eof()`	End of input seen
`bool fail()`	Next operation will fail
`bool bad()`	Stream is corrupted

- Example – reading lines from a file till the end of the file

```
ifstream ifs("file.txt") ;
char buf[100] ;

// Loop as long as stream is OK
while(!ifs.fail()) {
   ifs.getline(buf,100) ;

   // Stop here if we have reached end of file
   if (ifs.eof()) break ;

   cout << "just read '" << buf << "'" << endl ;
}
```

Some handy abbreviations

- Streams overload operator `void*()` to return `!fail()`
  - Can shorten preceding example to

```
while(ifs) { // expanded to while(ifs.operator void*())
   ifs.getline(buf,100) ;
   if (ifs.eof()) break ;
   cout << "just read '" << buf << "'" << endl ;
}
```

- Also return value of `getline()` provides similar information
  - Returns true if stream is good() and stream is not at eof() after operation

```
while(ifs.getline(buf,100)) {
  cout << "just read '" << buf << "'" << endl ;
}
```

Using stream operators

- The next step is to use the streaming operators instead of the 'raw' IO routines
  - Encapsulation, abstraction → let objects deal with their own streaming
- Solution: use `operator>>()` instead of `getline()`

shoesize.txt

```
Bjarne 42
Leif 47
Thor 52
```

```
ifstream ifs("shoesize.txt") ;
string name ;
int size ;

while(ifs >> name >> size) {
  cout << name << " has shoe size " << size << endl ;
}
```

Using stream operators

- Remember: syntax of stream operators is like that of any other operator

```
string name ;
int size ;
cin >> name >> size ;
```

```
string name ;
int size ;
cin.operator>>(   cin.operator>>(name),   size) ;
```

- For all built-in types
  - `operator<<(ostream,TYPE)` and `operator>>(istream,TYPE)` are implemented as member functions of the streams
  - Special case: `operator<<(const char*)` and `operator>>(char*)` read and write `char[]` strings

Parsing input – some fine points

- Delimiters
  - How does the text line

    ```
    Bjarne Stroustrup 42
    ```

    map on to the statement

    ```
    cin >> firstName >> lastName >> shoeSize ;
    ```

  - Because each `operator>>()` stops reading when it encounters 'white space'
  - White space is 'space','tab','vertical tab','form feed' and 'newline'
  - White space between tokens is automatically 'eaten' by the stream

- Reading string tokens
  - Be careful using `char[]` to read in strings: `operator>>(const char*)` does not know your buffer size and it can overrun!
  - Better to use `class string`

Formatting output of built-in types

- For built-in types streams have several functions that control formatting
  - Example: manipulating the base of integer output

```
cout.setf(ios_base::oct,ios_base::basefield) ; // set octal
cout << 1234 << endl ; // shows '2322'

cout.setf(ios_base::hex,ios_base::basefield) ; // set hex
cout << 1234 << endl ; // shows '4d2'
```

  - But it is often inconvenient to use this as calling formatting function interrupt chained output commands
- To accomplish formatting more conveniently streams have 'manipulators'
  - Manipulators are 'pseudo-objects' that change the state of the stream on the fly:

```
cout << oct << 1234 << endl << hex << 1234 << endl ;
// shows '2322' '4d2'
```

Overview of manipulators

- So manipulators are the easiest way to modify the formatting of built-in types
- What manipulators exist?
  - Integer formatting

Manipulator	Stream type	Description
`dec`	iostream	decimal base for integer
`hex`	iostream	hexadecimal base for integer
`oct`	iostream	octal base for integer
`[no]showpos`	iostream	show '+' for positive integers
`setbase(int n)`	iostream	base n for integer

  - Floating point formatting

Manipulator	Stream type	Description
`setprecision(int n)`	iostream	show n places after decimal point
`[no]showpoint`	iostream	[don't]show trailing decimal point
`scientific`	iostream	scientific format `x.xxexx`
`uppercase`	iostream	print `0XFF`, `nnExx`
`fixed`	iostream	format `xxxx.xx`

Manipulators – continued

- Alignment & general formatting

Manipulator	Stream type	Description
`left`	iostream	align left
`right`	iostream	align right
`internal`	iostream	use internal alignment for each type
`setw(int n)`	iostream	next field width is n positions
`setfill(char c)`	iostream	set field fill character to c

- Miscellaneous

Manipulator	Stream type	Description
`endl`	ostream	put '\n' and flush
`ends`	ostream	put '\0' and flush
`flush`	ostream	flush stream buffers
`ws`	istream	eat white space
`setfill(char c)`	iostream	set field fill character to c

- Include `<iomanip>` for most manipulator definitions

Formatting output with manipulators

- Very clever, but how do manipulators work?
  - A manipulator is a 'pseudo-object' that modifies the state of the stream
  - More precisely: a manipulator is a *static member function* of the stream that takes a stream as argument, for example

```
class ostream {
  static ostream& oct(ostream& os) {
    os.setf(ios::oct,ios::basefield) ;
  }
} ;
```

  - The manipulator applies its namesake modification to the stream argument
  - You put manipulators in your print statement because class `ostream` also defines

```
operator<<(ostream&(*f)(ostream&)) {
  return f(*this) ;
}
```

    This operator processes any function that takes a single `ostream&` as argument and returns an `ostream`. The operator calls the function with itself as argument, which then causes the wanted operation to be executed on itself

Random access streams

- Streams tied to files and to strings also allow random access
  - Can move 'current' position for reading and writing to arbitrary location in file or string

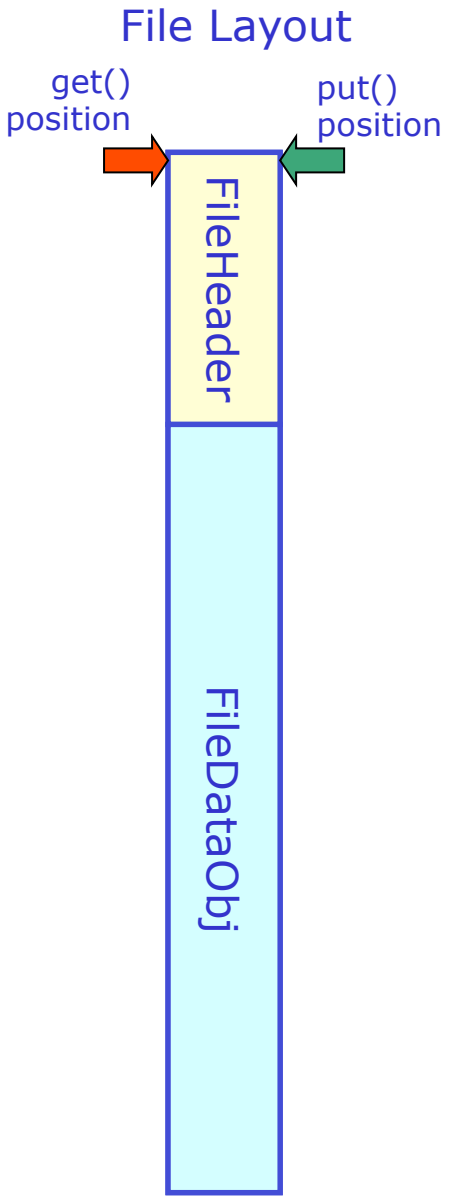
member function	stream	Description
`streampos tellg()`	input	return current location of 'get()' position
`seekg(streampos)`	input	set location of 'get()' position
`streampos tellp()`	output	return current location of 'put()' position
`seekp(streampos)`	output	set location of 'put()' position

  - Streams open for both input and output (`fstream`, `stringstream`) have all four methods, where `put()` and `get()` pointer can be in different positions

Random access streams

- Example use of `tell()`,`seek()`

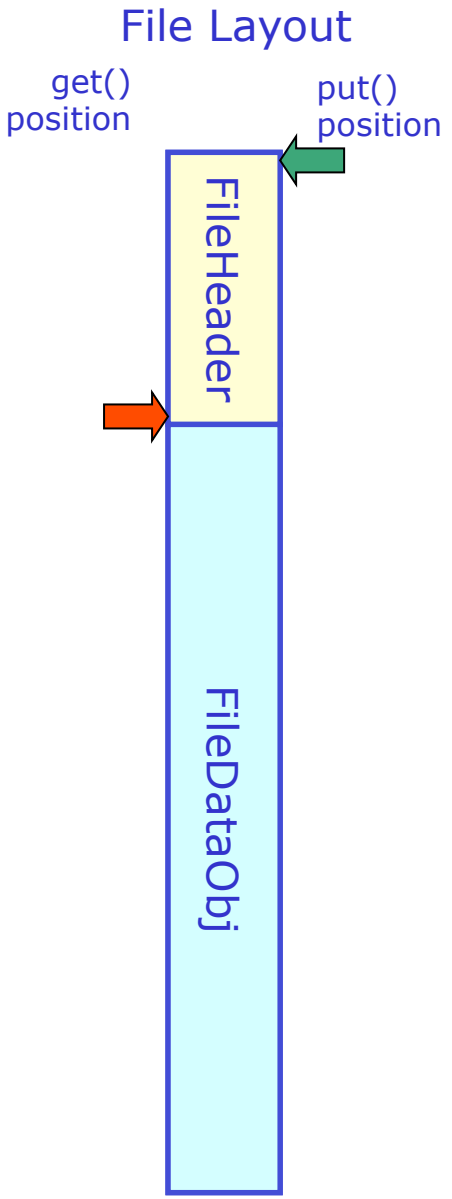
```
#include <fstream>

// Open file for reading and writing
fstream iofile("file.dat",ios::in|ios::out) ;
```



Random access streams

- Example use of `tell()`,`seek()`

```
#include <fstream>

// Open file for reading and writing
fstream iofile("file.dat",ios::in|ios::out) ;

// Read in (fictitious) file header
FileHeader hdr ;
iofile  >> hdr ;
```



Random access streams

- Example use of `tell()`,`seek()`

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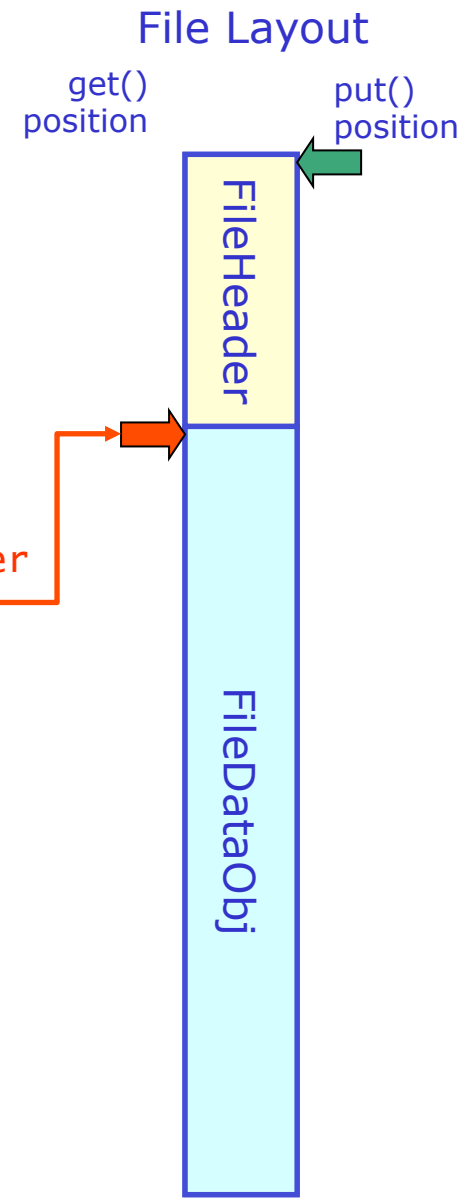
// Open file for reading and writing
fstream iofile("file.dat",ios::in|ios::out) ;

// Read in (fictitious) file header
FileHeader hdr ;
iofile  >> hdr ;

// Store current location of stream 'get()' pointer
streampos marker = ifs.tellg() ;
```



Random access streams

- Example use of `tell()`,`seek()`

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// Open file for reading and writing
fstream iofile("file.dat",ios::in|ios::out) ;

// Read in (fictitious) file header
FileHeader hdr ;
iofile  >> hdr ;

// Store current location of stream 'get()' pointer
streampos marker = ifs.tellg() ;

// Read (fictitious) file data object
FileDataObj fdo ;
iofile >> fdo ;
```
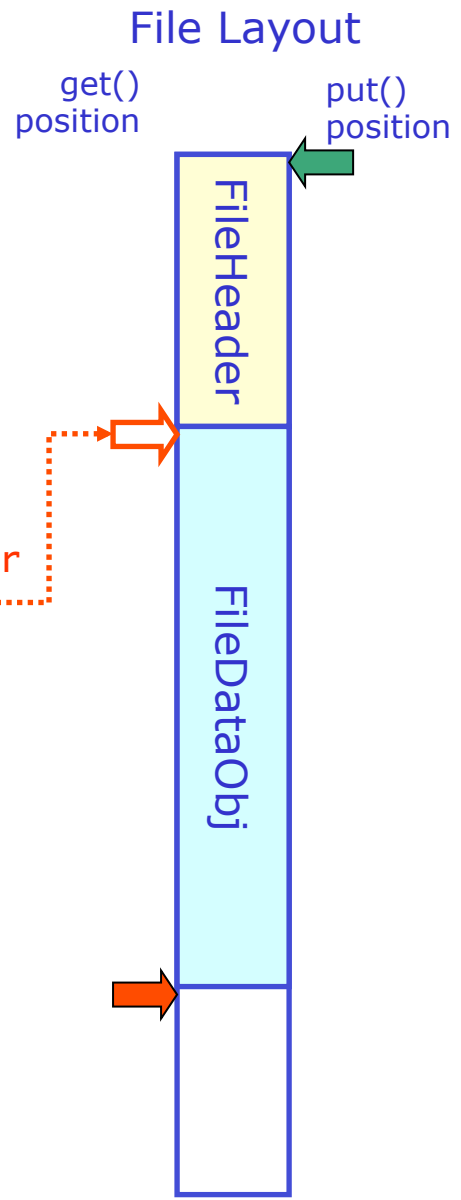
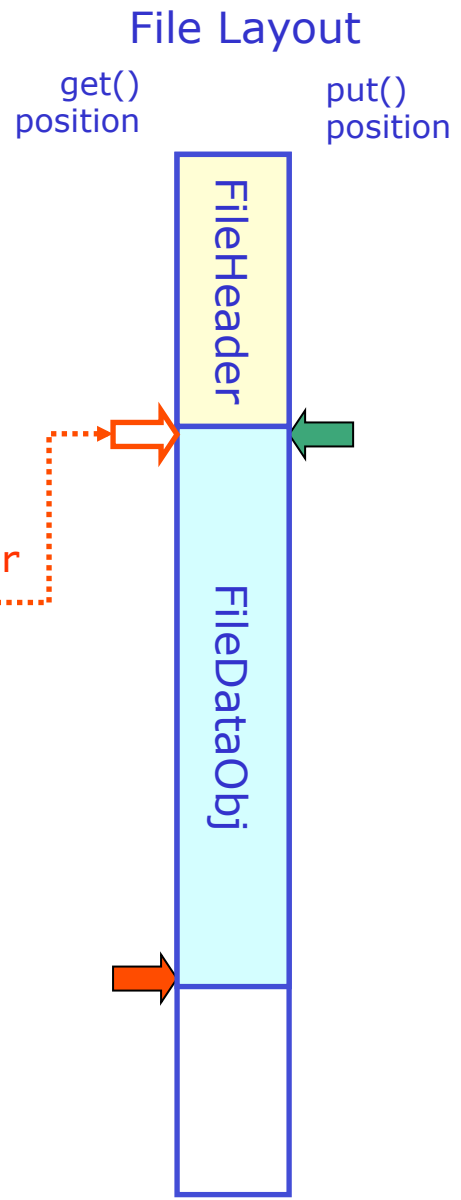



Random access streams

- Example use of `tell()`,`seek()`

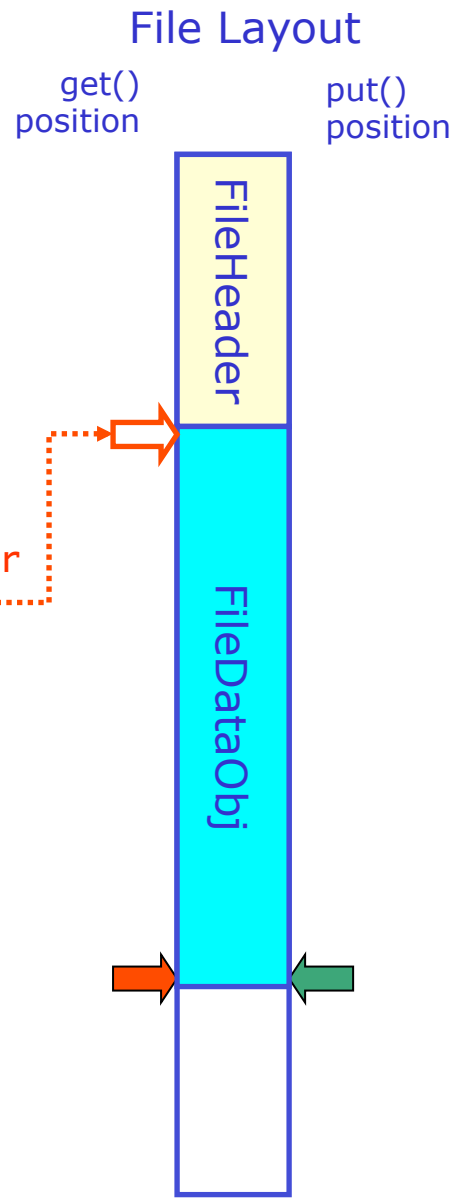
```
#include <fstream>

// Open file for reading and writing
fstream iofile("file.dat",ios::in|ios::out) ;

// Read in (fictitious) file header
FileHeader hdr ;
iofile  >> hdr ;

// Store current location of stream 'get()' pointer
streampos marker = ifs.tellg() ;

// Read (fictitious) file data object
FileDataObj fdo ;
iofile >> fdo ;

// modify file data object

// Move current' location of stream
// 'put '()' pointer to marked position
ifs.tellp(marker) ;
```



Random access streams

- Example use of `tell()`,`seek()`

```
#include <fstream>

// Open file for reading and writing
fstream iofile("file.dat",ios::in|ios::out) ;

// Read in (fictitious) file header
FileHeader hdr ;
iofile  >> hdr ;

// Store current location of stream 'get()' pointer
streampos marker = ifs.tellg() ;

// Read (fictitious) file data object
FileDataObj fdo ;
iofile >> fdo ;

// modify file data object

// Move current' location of stream
// 'put '()' pointer to marked position
ifs.tellp(marker) ;

// Write modified object over old location in file
iofile << fdo ;
```



Streaming custom classes

- You can stream custom classes by defining your matching `operator<<()`,`operator>>()` for those classes
  - Standard Library stream classes implement operators <<, >> as member functions for streaming of all basic types basic types
  - This is not an option for you as you can't modify the Standard Library classes
  - But in general, binary operators can be
    1. member of class `ostream(cout)`,
    2. member of your class, or
    3. be a global function.
  - Option 1) already ruled out
  - Option 2) doesn't work because class being read/written needs to be *right*most argument of operator, while as a member function it is by construction the *left* argument of the operator
  - Option 3) works: implement `operator<<` as global operator

Streaming custom classes

- For types that can be printed on a single line, overloading the operator<<, operator>> is sensible
  - Class string obvious example

```
String s(“Hello”) ;
cout << string << “ World” ;
```

```
String s(“Hello”) ;
cout.operator<<(operator<<(cout,string),”World”) ;
```

- For classes that read/write multi-line output, consider a separate function
  - operator>>,<< syntax for such cases potentially confusing: processing white space etc traditionally handled by stream not by operator
  - Example names: `readFromStream()`,`writeToStream()`

Implementing your own <<,>> operators

- Important: operators <<,>> need to return a reference to the input `ostream`, `istream` respectively
  - Essential for ability to chain << operations

```
cin >> a >> b ;
cout << a << b << c ;
```

- Example implementation for class string

```
ostream& operator<<(ostream& os, const String& s) {
   os << s._s ;
   return os ;
}

istream& operator>>(istream& is, String& s) {
   const int bufmax = 256 ;
   static char buf[256] ;
   is >> buf ;
   s = buf ;
   return is ;
}
```

Note: no const here as String is modified