High Level Programming

The IO Library

Stefano Quer
Dipartimento di Automatica e Informatica
Politecnico di Torino

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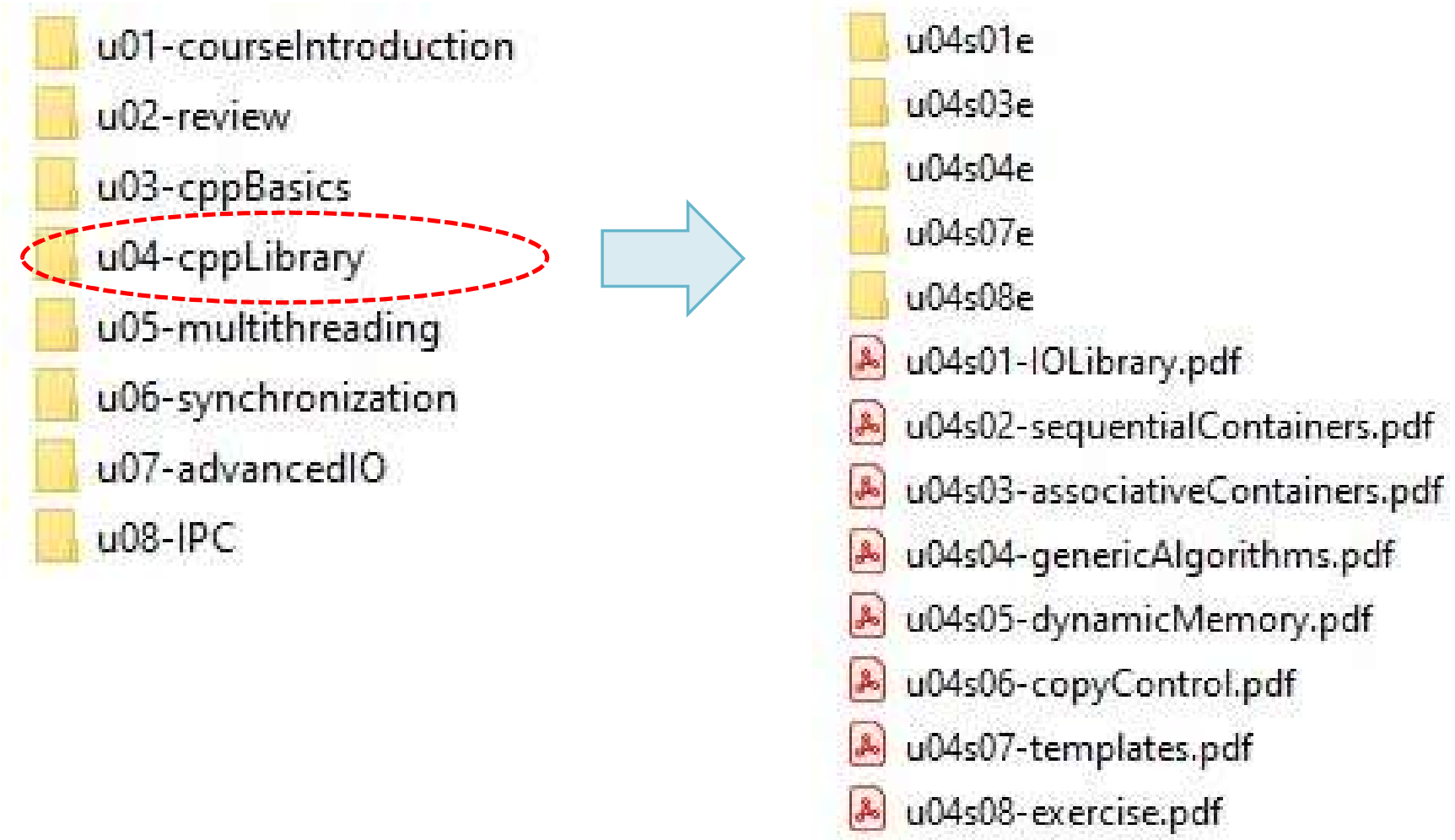
Premises

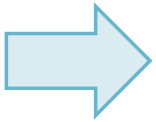
- Where are we?



Condition states

- When we perform IO, an error can occur
  - Some errors are recoverable, others are not
  - Once an error has occurred, subsequent IO operations will fail
    - The code should always check for errors in IO streams
    - The easiest way to check the state of a stream object is to use a condition

```
cin >> s;
```



```
if (cin >> s) { ... Success ... }

while (cin >> s) { ... Success ... }
```

IO Library

- The header fstream defines the types used to read and write named files
  - These types provide the same operations as those we have used on the objects **cin** and **cout**
    - Thanks to inheritance, we can use the standard IO operators on them
      - **<<**, **>>**, and **getline**

Type	Meaning
ifstream	To read from a given file.
ofstream	To write to given file.
fstream	To read or write a given file.

IO Library

- To support languages that use wide characters, the library defines a set of objects manipulating wchart_t
  - These objects' names start with
    - Ifstream→wifstream, etc.
    - cin→wcin, cout→wcout, cerr→wcerr
- Noticel that IO objects cannot be assigned

```
ofstream fo1, fo2;
...
fo2 = fo1;              // Error: cannot assign strems
```

Condition states

- The IO classes also define functions and flags that we can check to understand the status of the stream
  - If **s** is a stream we can interrogate its status

Attention:
while (!s.eof()) { … }
is buggy !!!

Type	Meaning
s.eof()	True if the stream hits EOF.
s.fail()	True if the IO operation failed.
s.bad()	True if the stream is corrupted.
s.good()	True if the stream is in a valid state.
s.clear()	Reset all condition values to a valid state. Return void.
etc.	

IO Library

- We can also use specific members to manage the file associated with the stream

fs: Stream
f: File name

fstream or ifstream or ofstream

Type	Meaning
fstream fs;	Creates an unbound file stream.
fstream fs(f);	Creates an fstream fs and open file f. The object f must be a string or a C-like pointer to a string.
fstream fs(f,mode);	Like the previous one but open the file in the given mode.
fs.open(f)	Open the file f and bound it to fs.
fs.open(f,mode)	Like the previous one, but open the file in the given mode. Please see the next page.
fs.close()	Close the file to which fs is bound. Return void.
fs.is_open()	Return a bool to indicate whether the file associated with fs is open.

IO Library

- Each stream has an associated file mode
  - The mode can be changed when the file is opened
  - In output mode, the previous content is lost (if we do not append)

Type	Meaning
in	Open for input.
out	Open for output.
app	Append: Seek to the end before every write. All writes are at the end of the file.
ate	Seek to the end immediately after open. Then, it is possible to move around (seek). Combine it with other types.
trunc	Truncate the file. In output, the default it truncate the file (rewrite it) even if trunc is not specified.
binary	Perform IO operation in binary mode. Combine it wioth other types.

Examples

Opening a file in different mode

```
// Out and trunc are implicit
ofstream out("myfile");

// Trunc is implicit
ofstream out("myfile", ofstream::out);

ofstream out("myfile", ofstream::out | ofstream::trunc);

ofstream out("myfile", ofstream::out | ofstream::app);

// Out is implicit
ofstream out("myfile", ofstream::app);
```

Examples

```
#include <iostream>
#include <fstream>
#include <string>

typedef struct my_s {
  string title;
  int x, y;
} my_t;

my_t test;
test.title = ""; test.x = test.y = 0;
ofstream file;

file.open ("example.txt", ofstream::out);
file << test.title;
file << "\t" << test.x;
file << "\t" << test.y << std::endl;

file.close();
```

Write some file content

endl: writes a newline and flushes the buffer
flush: flushes the buffer
ends: writes a NULL and flushes the buffer

Examples

```
#include <iostream>
#include <fstream>

using std::cout; using std::cerr;
using std::endl; using std::string;
using std::ifstream;

int main() {
  string filename("input.txt");
  int number;

  ifstream infile(filename);
  if (!infile.is_open()) {
    cerr << "Error: " << filename << endl;
    return EXIT_FAILURE;
  }
  ...
  infile.close();

  return EXIT_SUCCESS;
}
```

Opening a file in reading mode

Main reading cycle ... see ahead

Examples

All writes are flushed immediately
setbuf(stdout,0); → cout << unitbuf;
Opposite operation:
cout << nounitbuf;

```
int number;

cout << unitbuf;

while (infile >> number) {
  cout << number << "; ";
}
cout << endl;
```

Read integer values

```
while (infile.get(c)) {
  cout << c << "; ";
}
cout << endl;
```

Read single characters

Examples

Does not read (and print) newlines

```
string s;
while (getline(infile,s)) {
  cout << s << "; ";
}
cout << endl;
```

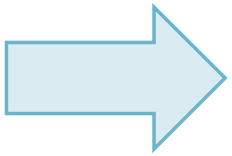
Read entire file lines

```
string s;
while (infile >> s) {
  cout << s << "; ";
}
cout << endl;
```

Read single strings

Exercise: IO in C, UNIX, and C++

- An IO library comparison
  - Write a segment of C code that writes and then reads a sequence of N integer values
  - Use the ASCII and binary forms
    - C library
    - UNIX library
    - C++ library
  - Compare file size and runtimes



```
#include <iostream>
#include <fstream>
#include <cstdlib>

#include <stdio.h>
#include <string.h>
#include <stdlib.h>

#include <unistd.h>
#include <fcntl.h>

using std::cout;
using std::endl;
using std::fstream;
using std::ofstream;
using std::ifstream
```

Solution

Time library

Computing times

```
#include <chrono>

long long microseconds;

auto start = std::chrono::high_resolution_clock::now();

write();
OR
read();

auto elapsed = std::chrono::high_resolution_clock::
  now() - start;
microseconds = std::chrono::duration_cast<std::chrono::
  microseconds>(elapsed).count();
cout << "  C    Write Time: " << microseconds << endl;
```

Either write or read the file

Solution

The C library is buffered

```
                          setbuf(fp,0);
fp = fopen ("...", "w");
for (i=0; i<n; i++) {
  val = rand();
  fprintf (fp, "%d\n", val);
}
fclose (fp);
```

C Buffered

Force a buffer size equal to zero

```
fp = fopen ("...", "r");
while (fscanf (fp, "%d", &val) != EOF) {
  i++;
}
fclose (fp);
```

Solution

UNIX

```
fd = open ("...", O_WRONLY | O_CREAT | ...);
for (i=0; i<n; i++) {
   val = rand();
   write (fd, &val, sizeof (int));
}
close (fd);
```

```
fd = open ("...", O_RDONLY);
while (read (fd, &val, sizeof (int)) != 0) {
  i++;
}
close (fd);
```

Solution

Trade-off Time-Memory

UNIX +

```
v = (int *) malloc (n * sizeof (int));
fd = open ("...", O_WRONLY | O_CREAT | ...);
for (i=0; i<n; i++) {
  v[i] = rand();
}
write (fd, v, n*sizeof (int));
close (fd);
```

```
fd = open ("...", O_RDONLY);
read (fd, v, n*sizeof (int));
close (fd);
```

Solution

C++

```
s.open ("...", ofstream::out);
for (i=0; i<n; i++) {
  val = rand();
  s << val << endl;
}
s.close();
```

Force an fflush
Unbuffered

```
s.open ("...", ifstream::in);
while (s >> val) {
  i++;
}
s.close();
```

Solution

C++ Binary

```
s.open ("...",
  ofstream::out | ofstream::binary);
for (i=0; i<n; i++) {
  val = rand();
  s.write ((char *) &val, sizeof (int));
}
s.close();
```

```
s.open ("...", ifstream::in | ifstream::binary);
while (s.read((char *) &val, sizeof (int))) {
  i++;
}
s.close();
```

Solution

Variable (due to the size of random integers)

$n = 2 \cdot 10^6$

- File Size [MBytes]

Library	ASCII	Binary
C, UNIX, C++	20.965	8.00

Fixed

- CPU Time [seconds]

Library	Write	Read
C (ASCII, buffered)	0.172	0.125
UNIX (binary)	1.513	0.411
C++ (ASCII, unbuffered)	1.762	0.102

Solution

Variable (due to the size of random integers)

$n = 2 \cdot 10^6$

File Size [MBytes]

Library	ASCII	Binary
C, UNIX, C++	20.965	8.00

Fixed

CPU Time [seconds]

Library	Write	Read
C (ASCII, buffered)	0.172	0.125
C (ASCII, unbuffered)	1.806	0.139
UNIX (binary)	1.513	0.411
UNIX (binary, array)	0.028	0.001
C++ (ASCII, unbuffered)	1.762	0.102
C++ (binary)	0.046	0.022