Special Topics

RAII, smart pointers, building projects, and more!

CS106L - Winter 23

Announcements!

- **This is our last real class!** Thursday's class will be an overview of what we've covered as well as extra office hours!

- Late days for assignments **are automatic** – no need to let us know if you're using them!

- For assignments, the general guideline for if it counts as completed is **if it runs**. Build errors result in no completion.

Special Topics

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CONTENTS

01. **RAII**

A coding standard and practice

02. **Smart Pointers**

Putting SMFs to good use

03. **Building C++ Projects**

`./build_and_run.sh` … what?

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`./build_and_run.sh` … what?

Identifying code paths

How many code paths exist in this function?

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string get_name_and_print_sweet_tooth(Person p) {
  if (p.favorite_food() == "chocolate" ||
      p.favorite_drink() == "milkshake") {
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  }
  return p.first() + " " + p.last();
}
```

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Identifying code paths

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Code path: A single
run-through of the code that
the computer would see

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Let's consider each possibility!

Case 1: p doesn't like chocolate or milkshakes

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And now we're done!

TOTAL: 3

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...are we?

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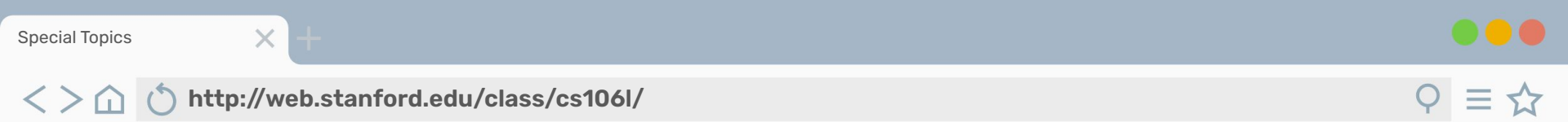
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Now entering: exceptions!

When a function has an error, it can crash the program.

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However, we can write code to handle these to let us continue!

- This is "catching" the exception!

```
try {
      // code that we check for exceptions
}
catch([exception type] e1) { // "if"
      // behavior when we encounter an error
}
catch([other exception type] e2) { // "else if"
      // ...
}
catch { // the "else" statement
      // catch-all (haha)
}
```

Now, how many code paths do we see?

TOTAL: 3

What happens when a function throws an exception?

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TOTAL: ~~3~~ 23!

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Hidden Code Paths

There are (at least) 23 code paths in the code before!

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- (10) operators may be user-overloaded, thus may throw
- (1) copy constructor of string for return value may throw
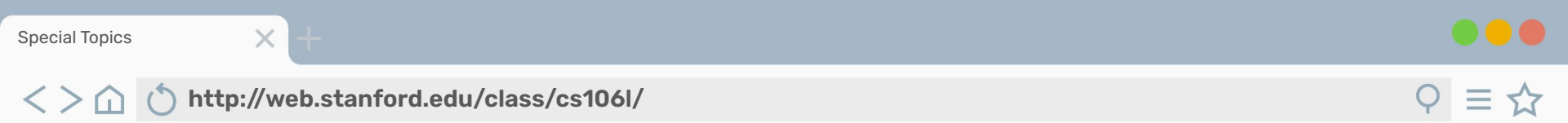
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Takeaway

There are often more code paths than meet the eye!

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- Make sure to cover all possible paths in test cases for production code.

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There are often more code paths than meet the eye!

- Make sure to cover all possible paths in test cases for production code.
- Or, catch any errors that could create other potential paths!

What else could go wrong?

Beyond exceptions, keep an eye out for anything else that could potentially go awry.

Do you see anything suspicious about this code?

```cpp
string get_name_and_print_sweet_tooth(int id_number) {
  Person* p = new Person(id_number); // assume the constructor fills in variables
  if (p->favorite_food() == "chocolate" ||
      p->favorite_drink() == "milkshake") {
    cout << p->first() << " "
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  auto result = p->first() + " " + p->last();
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What else could go wrong?

What happens if an exception is thrown?

Can we guarantee that we won't leak memory?

```cpp
string get_name_and_print_sweet_tooth(int id_number) {
  Person* p = new Person(id_number);  // assume the constructor fills in variables
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```

This problem isn't unique to pointers!

There are many resources that need to be returned after use:

	Acquire	Release
Heap memory	new	delete
Files	open	close
Locks	try_lock	unlock
Sockets	socket	close

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This problem isn't unique to pointers!

There are many resources that need to be returned after use:

How do we guarantee resources are returned even in the event of exceptions?

|	Acquire	Release
Heap memory	`new`	`delete`
Files	`open`	`close`
Locks	`try_lock`	`unlock`
Sockets	`socket`	`close`

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RAII: Resource Acquisition is Initialization

RAII is a concept developed by our good friend Bjarne and a
driving philosophy behind C++, Java, and other languages.

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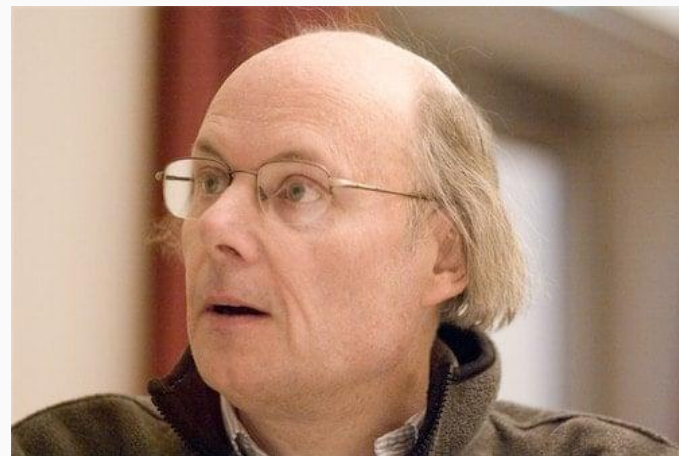
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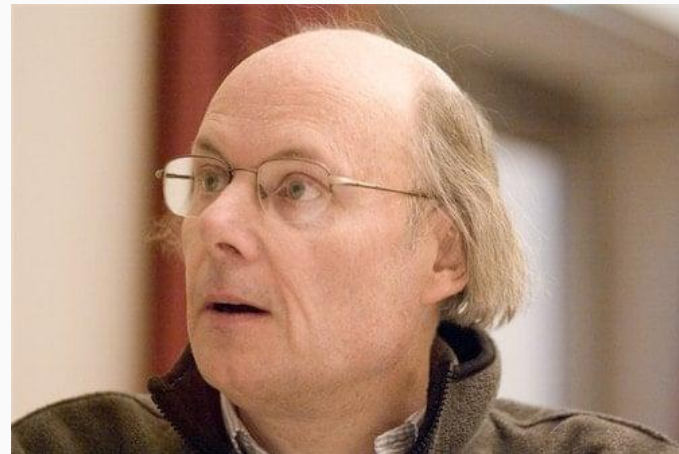
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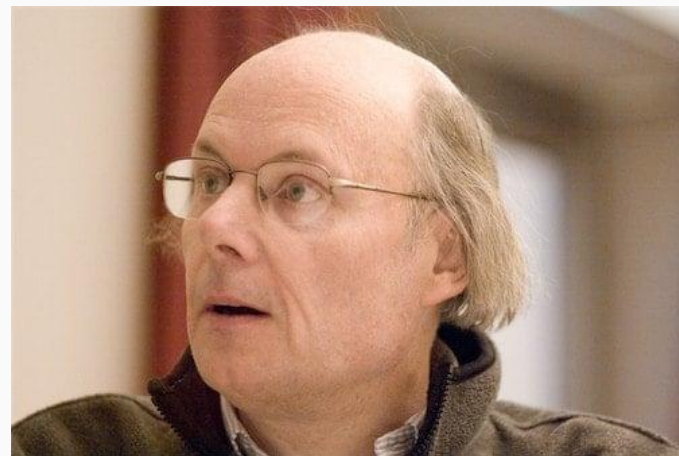
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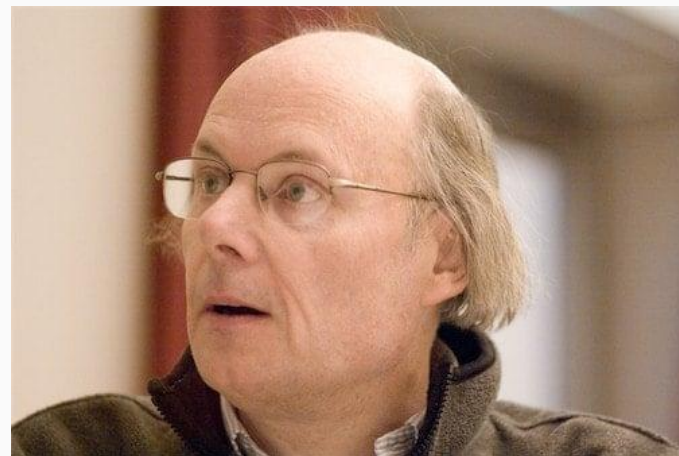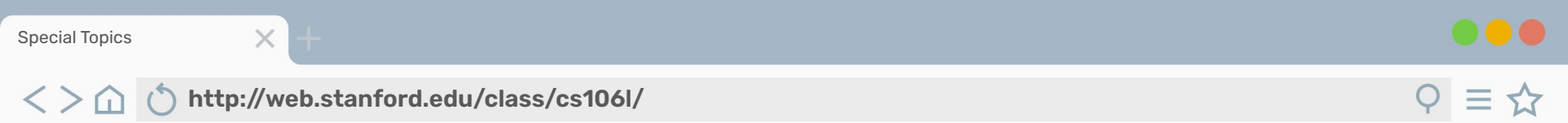- All resources used by a class should be acquired in the constructor
- All resources used by a class should be released in the destructor

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Why RAII?

Why care about this?

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Why RAII?

Why care about this?

- Objects should be usable immediately after creation.

- There should never be a "half-valid" state of an object, where it exists in memory but is not accessible to/used by the program.

- The destructor is always called (when the object goes out of scope), so the resource is always freed!

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Is this RAII-compliant?

You've seen this in 106B!

```cpp
void printFile() {
  ifstream input;
  input.open("hamlet.txt");

  string line;
  while (getline(input, line)) { // might throw exception
    cout << line << endl;
  }

  input.close();
}
```

No!

The ifstream is not opened and closed in the constructor and destructor.

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void printFile() {
  ifstream input;
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Neither is a naked mutex!

Check out CS111 for more on what this is!

```cpp
void cleanDatabase (mutex& databaseLock,
                    map<int, int>& database) {
  databaseLock.lock();

  // other threads will not modify database
  // modify the database
  // if exception thrown, mutex never unlocked!

  databaseLock.unlock();
}
```

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How do we fix it?

Let's implement a class whose entire job is to acquire the lock in the constructor and release it in the destructor.

```cpp
void cleanDatabase (mutex& databaseLock,
                    map<int, int>& database) {
  lock_guard<mutex> lg(databaseLock);

  // other threads will not modify database
  // modify the database
  // if exception thrown, mutex is unlocked!

  // no need to unlock at end, as it's handle by the lock_guard
}
```

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What about RAII for memory?

R.11: Avoid calling `new` and `delete` explicitly

Reason

The pointer returned by `new` should belong to a resource handle (that can call `delete`). If the pointer returned by `new` is assigned to a plain/naked pointer, the object can be leaked.

Note

In a large program, a naked `delete` (that is a `delete` in application code, rather than part of code devoted to resource management) is a likely bug: if you have N `delete`s, how can you be certain that you don't need N+1 or N-1? The bug may be latent: it may emerge only during maintenance. If you have a naked `new`, you probably need a naked `delete` somewhere, so you probably have a bug.

Enforcement

(Simple) Warn on any explicit use of `new` and `delete`. Suggest using `make_unique` instead.

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The same fix works!

We fixed mutexes by creating a new object that acquires the resource in the constructor and releases it in the destructor.

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We can do the same thing for memory!

- These wrapper pointers are called "smart pointers."

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- `std::shared_ptr`
  - Can make copies, destructed when underlying memory goes out of scope

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- `std::unique_ptr`
  - Uniquely owns its resource, can't be copied
- `std::shared_ptr`
  - Can make copies, destructed when underlying memory goes out of scope
- `std::weak_ptr`
  - Models temporary ownership: when an object only needs to be accessed if it exists (convert to shared_ptr to access)

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In practice

From this...

```cpp
void rawPtrFn() {
  Node* n = new Node;
  // do things with n
  delete n;
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```cpp
void rawPtrFn() {
  Node* n = new Node;
  // do things with n
  delete n;
}
```

…to this!

```cpp
void rawPtrFn() {
  std::unique_ptr<Node> n(new Node);
  // do things with n
  // automatically freed!
}
```

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Why can't we copy unique_ptr?

When a unique_ptr goes out of scope, it frees the memory associated with it.

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shared_ptr gets around this for us by only deallocating memory when all of the shared_ptrs have gone out of scope.

Creating smart pointers...

```
std::unique_ptr<T> up{new T};


std::shared_ptr<T> sp{new T};


std::weak_ptr<T> wp = sp;
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This is still explicitly calling new!

We can fix it!

```cpp
std::unique_ptr<T> up{new T};
std::unique_ptr<T> up = std::make_unique<T>();

std::shared_ptr<T> sp{new T};
std::shared_ptr<T> sp = std::make_shared<T>();

std::weak_ptr<T> wp = sp;
// can only be copy/move constructed (or empty)!
```

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Which is better?

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Which is better?

Always use std::make_unique<T> and std::make_shared<T>!

- If we don't use make_shared, then we're allocating memory twice (once for sp, and once for new T)!
- We should be consistent across smart pointers – if we use make_shared, also use make_unique!

CONTENTS

What do `make` and `Makefiles` do?

- `make` is a "build system"

- Uses g++ as its main engine

- Several stages to the compiler system

- Can be utilized through a `Makefile`!

- Let's take a look at a simple makefile to get some practice!

http://web.stanford.edu/class/cs106l/

CS111 Example

```
TARGET = sh111

CXXBASE = g++
CXX = $(CXXBASE) -std=c++17
CXXFLAGS = -ggdb -O -Wall -Werror

CPPFLAGS =
LIBS =

OBJS = sh111.o
HEADERS =

all: $(TARGET)

$(OBJS): $(HEADERS)

$(TARGET): $(OBJS)
	$(CXX) -o $@ $(OBJS) $(LIBS)


clean:
	rm -f $(TARGET) $(LIB) $(OBJS) $(LIBOBJS) *~ .*~ _test_data*

.PHONY: all clean starter
```

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If we have `Makefiles` already, why use `cmake`?

- `cmake` is a cross-platform `make`!
- `make` is a build system, and `cmake` creates entire build systems!
  - Another level of abstraction that takes in an even higher-level config file, ties in external libraries, and outputs a `Makefile`, which is then run.

Example cmake file

```
cmake_minimum_required(VERSION 3.0)
project(wikiracer)

set(CMAKE_CXX_STANDARD 17)
set(CMAKE_CXX_STANDARD_REQUIRED True)

find_package(cpr CONFIG REQUIRED)

# adding all files
add_executable(main main.cpp wikiscraper.cpp.o error.cpp)

target_link_libraries(main PRIVATE cpr)
```

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Example cmake file (ours!)

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Looks closer to a coding language as we know it!

Thanks!

Next up: final class review! :(