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Resource Management

Memory, auto_ptr<> and RAII

- The most commonly used resource in C++ programs is memory
  - there are also file handles, mutexes, database connections, etc.
- It is important to release a resource after that it has been used

An example

```
class Vehicle { ... }; // root class of a hierarchy

Vehicle* createVehicle(); /* return a pointer to root
class but may create any other object in the hierarchy.
The caller MUST delete the returned object */

void f() {
  Vehicle* pV = createVehicle();
  //... use pV
  delete pV;
}
```

An example

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void f() {
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  //... use pV
  delete pV;
}
```

If there's a premature return or an exception we may never reach the delete !

A solution

- Put the resource returned by `createVehicle` inside an object whose destructor automatically release the resource when control leaves `f()`.
  - destructor calls are automatic
- With these objects that manage resources:
  - resources are acquired and immediately turned over to resource-managing objects (RAII)
  - these objects use their destructors to ensure that resources are released

RAII

Resource Acquisition Is Initialiazation

What is RAII

- This technique was invented by Stroustrup to deal with resource deallocation in C++ and to write exception-safe code: the only code that can be guaranteed to be executed after an exception is thrown are the destructors of objects residing on the stack.
- This technique allows to release resources before permitting exceptions to propagate (in order to avoid resource leaks)

What is RAII - cont.

- Resources are tied to the lifespan of suitable objects.
  They are acquired during initialization, when there is no chance of them being used before they are available.
  They are released with the destruction of the same objects, which is guaranteed to take place even in case of errors.

RAII example

```
#include <cstdio>
#include <stdexcept> // std::runtime_error

class file {
public:
    file (const char* filename) : file_(std::fopen(filename, "w+")) {
        if (!file_) {
            throw std::runtime_error("file open failure");
        }
    }
    ~file() {
        if (std::fclose(file_)) {
           // failed to flush latest changes.
           // handle it
        }
    }
    void write (const char* str) {
        if (EOF == std::fputs(str, file_)) {
            throw std::runtime_error("file write failure");
        }
    }
private:
    std::FILE* file_;
    // prevent copying and assignment; not implemented
    file (const file &);
    file & operator= (const file &);
};
```

RAII example

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#include <stdexcept> // std::runtime_error

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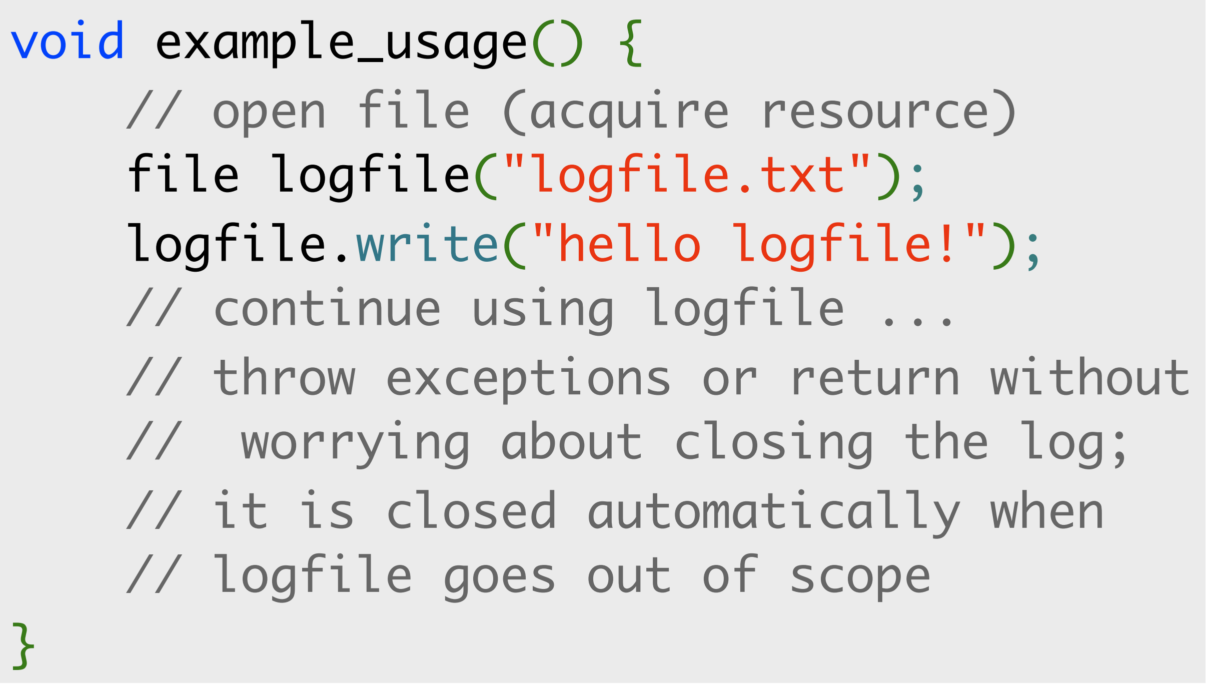

```
void example_usage() {
    // open file (acquire resource)
    file logfile("logfile.txt");
    logfile.write("hello logfile!");
    // continue using logfile ...
    // throw exceptions or return without
    //  worrying about closing the log;
    // it is closed automatically when
    // logfile goes out of scope
}
```

auto_ptr

auto_ptr

- auto_ptr is a pointer-like object (a *smart pointer*) whose destructor automatically calls delete on what it points to
    - it's in the C++ standard library: #include <memory>
    - other smart pointers exist (e.g. Boost)

auto_ptr: an example

- Reconsider the f() function using auto_ptr:

```
void f() {
   std::auto_ptr<Vehicle> pV(createVehicle());
   // use pV as before...
} /* the magic happens here: automatically
deletes pV via the destructor of auto_ptr,
called because it’s going out of scope */
```

auto_ptr: another example

- In general here’s how to rewrite unsafe code in safe code:

```
// Original code
void f() {
  T* pt( new T );
  /*...more code...*/
  delete pt;
}
```

```
//Safe code, with auto_ptr
void f() {
  auto_ptr<T> pt( new T );
  /*...more code...*/
} /* pt's destructor is called
as it goes out of scope, and
the object is deleted
automatically */
```

auto_ptr characteristics

- Since auto_ptr automatically deletes what it points to when it is destroyed, there should not be two auto_ptr pointing to an object
    - or the object may be deleted twice: it's an undefined behaviour, if we are lucky the program just crashes
- To avoid this auto_ptr have a special feature: copying them (e.g. copy constructor or assignment operator) sets them to null and copying pointer assumes the ownership of the object

auto_ptr characteristics: example

```
// pV1 points to the created object
std::auto_ptr<Vehicle> pV1(createVehicle());

std::auto_ptr<Vehicle> pV2( pV1 );
/* now pV2 points to the object and pV1 is
null !  */

pV1 = pV2;
/* now pV1 points to the object and pV2 is
null !  */
```

auto_ptr characteristics - cont.

- If the target auto_ptr holds some object, it is freed
- This copy behaviour means that you can’t create an STL container of auto_ptr !
  - Remind: STL containers want objects with normal copy behaviours
  - Modern compilers (with modern STL) issue compile errors

auto_ptr characteristics - cont.

- If you do not want to loose ownership use the const auto_ptr idiom:

```
const auto_ptr<T> pt1( new T );
        // making pt1 const guarantees that pt1 can
        // never be copied to another auto_ptr, and
        // so is guaranteed to never lose ownership

    auto_ptr<T> pt2( pt1 ); // illegal
    auto_ptr<T> pt3;
    pt3 = pt1;              // illegal
    pt1.release();          // illegal
    pt1.reset( new T );     // illegal
```

- it just allows dereferencing

auto_ptr characteristics - cont.

- auto_ptr use delete in its destructor so do NOT use it with dynamically allocated arrays:

  ```
  std::auto_ptr<std::string>
  aPS(new std::string[10]);
  ```

- use a vector instead of an array

auto_ptr methods

- use get() to get a pointer to the object managed by auto_ptr, or get 0 if it’s pointing to nothing
- use release() to set the auto_ptr internal pointer to null pointer (which indicates it points to no object) without destructing the object currently pointed by the auto_ptr.
- use reset() to deallocate the object pointed and set a new value (it’s like creating a new auto_ptr)

auto_ptr methods

```
auto_ptr<int> p (new int);
*p.get() = 100;
cout << "p points to " << *p.get() << endl;
```

- use release() to set the auto_ptr internal pointer to null pointer (which indicates it points to no object) without destructing the object currently pointed by the auto_ptr.
- use reset() to deallocate the object pointed and set a new value (it’s like creating a new auto_ptr)

auto_ptr methods

```
auto_ptr<int> auto_pointer (new int);
int * manual_pointer;
*auto_pointer=10;
manual_pointer = auto_pointer.release();
cout << "manual_pointer points to " <<
*manual_pointer << "\n";
// (auto_pointer is now null-pointer auto_ptr)
delete manual_pointer;
```

- use reset() to deallocate the object pointed and set a new value (it’s like creating a new auto_ptr)

auto_ptr methods

```
auto_ptr<int> p;
p.reset (new int);
*p=5;
cout << *p << endl;

p.reset (new int);
*p=10;
cout << *p << endl;
```

- use reset() to deallocate the object pointed and set a new value (it’s like creating a new auto_ptr)

auto_ptr methods - cont.

- operator*() and operator->() have been overloaded and return the element pointed by the auto_ptr object in order to access one of its members.

```
auto_ptr<Car> c(new Car);
c->startEngine();
(*c).getOwner();
```

Scope guard

- Sometime we don't want to release resources if no exception is thrown but we do want to release them if exception is thrown. The “Scope guard” is a variation of RAII

-
  ```
  Foo* createAndInit() {
    Foo* f = new Foo;
    auto_ptr<Foo> p(f);
    init(f); // may throw
             // exception
    p.release();
    return f;
  }
  ```

-
  ```
  int run () {
    try {
      Foo *d = createAndInit();
      return 0;
    } catch (...) {
      return 1;
    }
  }
  ```

Scope guard

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   Foo* f = new Foo;
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   init(f); // may throw
            // exception
   p.release();
   return f;
}
```

Use auto_ptr to guarantee that an exception does not leak

When we are safe release the auto_ptr and return the pointer

Credits

- These slides are (heavily) based on the material of:
    - Scott Meyers, "Effective C++, 3rd ed."
    - Wikipedia
    - Herb Sutter, "Exceptional C++"