Advanced C++ Programming

Keyword Safari

Preliminaries

Overview & Goals

- **Goal**: We want to be fluent in advanced C++
  - This also includes reading code from any source
- There are a number of concepts which are important to understand in order to achieve this goal, but that we cannot dedicate an entire lecture to
  - Gathered in this lecture

Storage Class Specifiers

Background

- Objects (e.g. variables) in C++ feature ***storage*** and have a type of ***linkage***

Storage Duration	
Automatic storage duration Allocated at the beginning of a *block*, deallocated at the end; e.g. local variables	**Thread** storage duration Allocated when a *thread* begins, deallocated when it ends
Static storage duration Allocated at the start of the *program*, deallocated at the end; e.g. global variables	**Dynamic** storage duration Explicitly allocated and deallocated by the programmer using dynamic memory allocation functions

Background

- Objects (e.g. variables) in C++ feature ***storage*** and have a type of ***linkage***

Linkage	
No linkage Names with no linkage always generate a unique object instance. E.g. local variables	
Internal linkage If a name has internal linkage, it can be referred to within the current translation unit	**External linkage** Names with external linkage can be referred to from other translation units. E.g. normal (unqualified) functions

Storage Class Specifiers

- **`static`**
  Forces *static* or *thread* storage duration and *internal* linkage
- **`extern`**
  Forces *static* or *thread* storage duration and *external* linkage
- **`thread_local`**
  Forces *thread* storage duration

05_01_storage_classes.cpp

Local Static Initialization

- Local "static" variables are initialized the first time control flow passes through their declaration
  - On subsequent passes, the initialization is skipped
  - Destructors are called at program exit
- This is demonstrated in 05_02_static_initialization.cpp
- ***Note***: local statics introduce unexpected state
  → Carefully consider their usage!

CV Type Qualifiers

CV Qualifier Basics

- For any type T which is not a function or reference type, there are three more distinct types in the C++ type system:
  - `const T`
    A T which cannot be modified.
  - `volatile T`
    A T which might be modified externally (accesses are side-effects for the purpose of optimization).
  - `const volatile T`
    A T which cannot be modified in this context, but might be changed externally.

CV Ordering and Implicit Conversion

Ordering   **(“<“ = “less qualified”)**
unqualified < const
unqualified < volatile
unqualified < const volatile
const < const volatile
volatile < const volatile

Implicit conversion occurs to ***more qualified*** CV types.

E.g.
unqualified → const
const → const volatile

05_03_cv_qualification.cpp

Additional Class Member Options

Overview

- We already discussed *virtual*, *override*, and *final*, as well as *const*
- The keyword “`static`” has a different meaning for class members
- Constructors can be designated “`explicit`”
- In addition to *const* qualifiers, member functions can be *lvalue and rvalue reference qualified*
- Class data members may be designated “`mutable`“

Static Class Members

- In class definitions, “static” declares
  members not bound to any class instance
- It can be applied to both data members and member functions
- Simple examples are shown in 05_04_static_members.cpp
- *For most practical purposes, static data members act like global variables, and static member functions act like freestanding functions*

Explicit Constructors

- Single-argument constructors are, by default, *implicitly used for conversion operations*
- This concept is demonstrated in 05_05_explicit_constructors.cpp
- The keyword “explicit” prevents this from occurring
- Guidelines
  1. By default, declare all single-argument constructors explicit, unless you really want implicit conversion to occur (e.g. building a “Complex” number from a double)
  2. Prefer named conversion functions over constructor conversion

Member Function Reference Qualifiers

- As we discussed previously, member functions may be “const” qualified
  - This affects the const-ness of the `this` object
- In the same fashion, they can be l- or r-value reference qualified
  - This affects the *value* categories for `this` that they bind to
- The example in 05_06_member_ref_qualifiers.cpp illustrates this
  - Also shows an important use case which can significantly increase the safety of a library

Mutable Data Members

- Data members may be `mutable`-qualified to allow modifying them in `const`-qualified member functions
- This should only be used for members *which do not change the externally visible state of the class*
- Example use cases: caching, lazy evaluation
  Basic idea in 05_07_mutable_data_members.cpp
- *Beware*:
  These types of caching can easily lead to race conditions in parallel execution

Constexpr

Constexpr Basics

- `constexpr` is a specifier that can be applied to functions and variables and indicates that *it is possible to evaluate their value at compile time*
- Let's look at an example in 05_08_constexpr.cpp
- The idea is to make a *declaration of **intent***,
  and codify this requirement as part of an interface
- There are a number of constraints on what can be declared constexpr

Constexpr Constraints

Constexpr functions

- Must not be virtual
- Return and parameter types must be literal types
- May not contain some kinds of statements

http://en.cppreference.com/w/cpp/concept/LiteralType

Prohibited Statements
`asm` declarations
`goto`
`labels` (other than `case` and `default`)
`try` blocks
variable definitions • of Non-literal type; or • with static or thread storage; or • with no initialization

Conclusion

Summary

- Understand variable and object storage, linkage, and CV qualification
- For classes
  - Distinguish static and non-static members
  - Correctly use const, mutable, and reference qualification
  - Understand the reasoning for explicit single-argument constructors
- Use constexpr for compile-time computation