FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

Lecture 11

Inheritance

C++ object model

Object: Region of storage.

Created by definition, new-expression, implementation.

It can have a name.

Further it has a storage duration which influences its lifetime, and a type.

Some objects are polymorphic.

Objects can contain other objects, called subobjects.

Object-oriented Programming (OOP)

object-oriented programming: Term used to describe programs that use data abstraction, inheritance, and dynamic binding.

Polymorphism: A term derived from a Greek word that means "many forms."

Polymorphism refers to the ability to obtain type-specific behavior based on the dynamic type of a reference or pointer.

dynamic binding: Delaying until run time the selection of which function to run.

In C++, dynamic binding refers to the run-time choice of which virtual function to run based on the underlying type of the object to which a reference or pointer is bound.

Inheritance

Inheritance: Types related by inheritance share a common interface.

A derived class inherits properties from its base class.

base class: A class that is the parent of another class.

The base class defines the interface that a derived class inherits.

derived class: A derived class is one that shares an interface with its parent class.

Derived classes I

- A derived class can redefine the members of its base and can define new members.
- A derived-class scope is nested in the scope of its base class(es), so the derived class can access members of the base class directly.
- Members defined in the derived with the same name as members in the base hide those base members; in particular, member functions in the derived do not overload members from the base.
- A hidden member in the base can be accessed using the scope operator.

Derived classes II

- **protected access label**: Members defined after a protected label may be accessed by class members and friends and by the members (but not friends) of a derived class.
  - protected members are not accessible to ordinary users of the class.
- **class derivation list**: Used by a class definition to indicate that the class is a derived class.
  - A derivation list includes an optional access level and names the base class.
  - If no access label is specified, the type of inheritance depends on the keyword used to define the derived class.
  - By default, if the derived class is defined with the struct keyword, then the base class is inherited publicly.
  - If the class is defined using the class keyword, then the base class is inherited privately.

Derived classes III

- Derived objects contain their base classes as subobjects
- However, there is no requirement that the compiler lays out the base and derived parts of an object contiguously
- A class must be defined to be used as a base class
- Forward declarations must not include the derivation list
- **immediate (direct) base class**: A base class from which a derived class inherits directly.
  - The immediate base is the class named in the derivation list.
  - Only an immediate base class may be initialized in the derivation list
  - The immediate base may itself be a derived class.
- Example
  - Class Base {}; class D1 : public Base {};
  - Class d1 : public Base; // error!

Types of inheritance

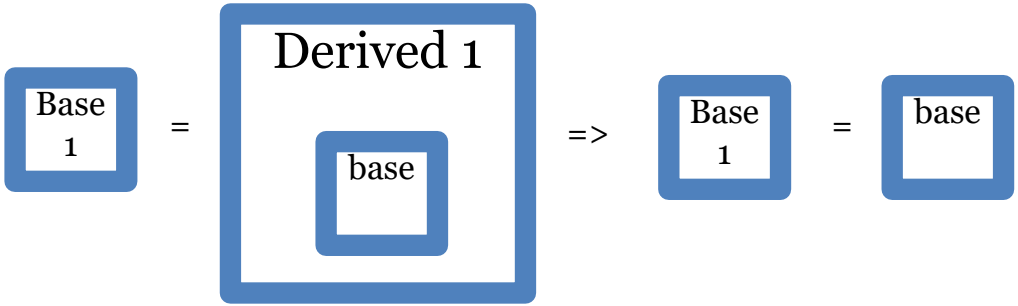
public inheritance: The public interface of the base class is part of the public interface of the derived class.

private inheritance: A form of implementation inheritance in which the public and protected members of a private base class are private in the derived.

protected inheritance: In protected inheritance the protected and public members of the base class are protected in the derived class.

Conversions from Derived to Base I

- Assignment Base = Derived



- The derived portion of the object is "sliced down," leaving only the base portion, which is assigned to the base.

Conversions from Derived to Base

- When we call a BaseClass copy constructor or assignment operator on an object of type DerivedClass:
  1. The DerivedClass object is converted to a reference to BaseClass, which means only that a BaseClass reference is bound to the DerivedClass object
  2. That reference is passed as an argument to the copy constructor or assignment operator
  3. Those operators use the BaseClass part of DerivedClass to initialize (or assign) the members of the BaseClass on which the constructor or assignment was called
  4. Once the operator completes, the object is a BaseClass. It contains a copy of the BaseClass part of the DerivedClass from which it was initialized or assigned, but the DerivedClass parts of the argument are ignored

Copy Control and Inheritance

- If a derived class explicitly defines its own copy constructor or assignment operator, that definition completely overrides the defaults
- Therefore, copy constructor and assignment operator for inherited classes are responsible for copying and assigning also their base-class members
- The copy constructor cannot, and the assignment operator should not be defined as virtual

Virtual functions I

- **virtual function**: Member function that defines type-specific behavior.
  - Calls to a virtual made through a reference or pointer are resolved at run time, based on the type of the object to which the reference or pointer is bound.
  - Once a function is declared as virtual in a base class it remains virtual in all derived classes

Virtual functions II

- **dynamic type**: Type at run time.
  - Pointers and references to base-class types can be bound to objects of derived type.
  - In such cases the static type is reference (or pointer) to base, but the dynamic type is reference (or pointer) to derived.
- **static type**: Compile-time type.
  - Static type of an object is the same as its dynamic type.
  - The dynamic type of an object to which a reference or pointer refers may differ from the static type of the reference or pointer.

Pure virtual functions

- **pure virtual**: A virtual function declared in the class header using = 0 at the end of the function's parameter list.
  - A pure virtual is one that need not be defined by the class.
  - A class with a pure virtual is an abstract class.
  - If a derived class does not define its own version of an inherited pure virtual, it is abstract as well.
- **abstract base class**: Class that has or inherits one or more pure virtual functions.
  - It is not possible to create objects of an abstract base-class type.
  - Abstract base classes exist to define an interface.
  - Derived classes will complete the type by defining type-specific implementations for the pure virtuals defined in the base.

Virtual destructors

- A derived class destructor automatically invokes the base class destructor
- The root class of an inheritance hierarchy should define a virtual destructor
  - In order to assure proper deleting of pointer members
- If a virtual is called from inside a constructor or destructor, it runs the version defined for the type of the constructor or destructor itself

Class scope under Inheritance

- A derived-class member with the same name as a member of the base class hides direct access to the base-class member
- If the derived class redefines any of the overloaded members, then only the ones redefined in the derived class are accessible through the derived type
- This is the reason why virtuals must have the same prototype on base and derived classes

Name Lookup and Inheritance

- Name lookup happens at compile time and follows the steps:

1. Determine the static type of the object, reference, or pointer through which the function is called
2. Look for the function in that class.
   - If it is not found, look in the immediate base class and continue up the chain of classes until either the function is found or the last class is searched.
   - If the name is not found in the class or its enclosing base classes, then the call is an error
3. Once the name is found, do normal type-checking to see if this call is legal given the definition that was found
4. Assuming the call is legal, the compiler generates code.
   - If the function is virtual and the call is through a reference or pointer, then the compiler generates code to determine which version is run based on the dynamic type of the object.
   - Otherwise, the compiler generates code to call the function directly

Multiple and Virtual Inheritance I

- **multiple inheritance**: Inheritance in which a class has more than one immediate base class.
  - The derived class inherits the members of all its base classes.
  - Multiple base classes are defined by naming more than one base class in the class derivation list.
  - A separate access label is required for each base class.
- **virtual inheritance**: Form of multiple inheritance in which derived classes share a single copy of a base that is included in the hierarchy more than once.

Multiple and Virtual Inheritance II

- **virtual base class**: A base class that was inherited using the virtual keyword.
  - A virtual base part occurs only once in a derived object even if the same class appears as a virtual base more than once in the hierarchy.
  - In nonvirtual inheritance a constructor may only initialize its immediate base class(es).
  - When a class is inherited virtually, that class is initialized by the most derived class, which therefore should include an initializer for all of its virtual parent(s).

Multiple and Virtual Inheritance III

- **constructor order**: Ordinarily, base classes are constructed in the order in which they are named in the class derivation list.
  - A derived constructor should explicitly initialize each base class through the constructor initializer list.
  - The order in which base classes are named in the constructor initializer list does not affect the order in which the base classes are constructed.
  - In a virtual inheritance, the virtual base class(es) are constructed before any other bases.
  - They are constructed in the order in which they appear (directly or indirectly) in the derivation list of the derived type.
  - Only the most derived type may initialize a virtual base; constructor initializers for that base that appear in the intermediate base classes are ignored.

Multiple and Virtual Inheritance IV

- **destructor order**: Derived objects are destroyed in the reverse order from which they were constructed
  - the derived part is destroyed first, then the classes named in the class derivation list are destroyed, starting with the last base class.
  - Classes that serve as base classes in a multiple-inheritance hierarchy ordinarily should define their destructors to be virtual.

Runtime type information (RTTI)

- **run-time type identification**: Term used to describe the language and library facilities that allow the dynamic type of a reference or pointer to be obtained at run time.
  - The RTTI operators, typeid and dynamic_cast, provide the dynamic type only for references or pointers to class types with virtual functions.
  - When applied to other types, the type returned is the static type of the reference or pointer.

typeid keyword

- **typeid**: Unary operator that takes an expression and returns a reference to an object of the library type named type_info that describes the type of the expression.
  - When the expression is an object of a type that has virtual functions, then the dynamic type of the expression is returned.
  - If the type is a reference, pointer, or other type that does not define virtual functions, then the type returned is the static type of the reference, pointer, or object.
- **type_info:** Library type that describes a type.
  - The type_info class is inherently machine-dependent, but any library must define type_info with members like name()
  - type_info objects may not be copied.

Dynamic Cast

- dynamic_cast: Operator that performs a checked cast from a base type to a derived type.
  - The base type must define at least one virtual function.
  - The operator checks the dynamic type of the object to which the reference or pointer is bound.
  - If the object type is the same as the type of the cast (or a type derived from that type), then the cast is done.
  - Otherwise, a zero pointer is returned for a pointer cast, or an exception is thrown for a cast of a reference.

Pointer to Members

- **pointer to member**: Pointer that encapsulates the class type as well as the member type to which the pointer points.
  - The definition of a pointer to member must specify the class name as well as the type of the member(s) to which the pointer may point:
  - T C::*pmem = &C::member;
  - This statement defines pmem as a pointer that can point to members of the class named C that have type T and initializes it to point to the member in C named member.
  - When the pointer is dereferenced, it must be bound to an object of or pointer to type C:
    classobj.*pmem; classptr->*pmem;
    fetches member from object classobj of object pointed to by classptr.