Inheritance

- Property of object-oriented programming that allows one class, known as a *derived class*, to share the structure and behavior of another class, known as the *base class*
- Allows newly created members to inherit members (attributes and methods) from existing classes
- Derived (or child) classes include their own members and members inherited from the base (or parent) class
- A collection of classes with common inherited members is viewed as a *family* of classes

Why use inheritance?

- Allows you to reuse the code from a previous programming project
  - You can enhance an existing class by adding new attributes and methods
  - Extremely practical approach in an environment with multiple programmers, working on the code written by others long ago
    - You do not have to get inside each method of an existing class to modify the data and code
- Allows you to build a *hierarchy* among classes
  - A general bank account is used to define attributes such as an account number and account balance, and member functions such as deposit that are common to all bank accounts
  - Classes that define checking account and savings accounts can be derived from the base class bank account
  - We could even derive another class called super-now account from the class checking account, leading to a grandchild class of bank account
  - Such a family of classes is referred to as a *class hierarchy*
- *IS-A relationship*
  - Important link between a derived class and its base class
  - Must exist for proper use of inheritance
  - A checking account *IS-A* bank account

Derived classes

- A derived class is declared using the following format:

```
class <derived class> : public <base class>
{
    <derived class member data>
    <derived class member functions>
};
```

- The class for bank accounts

```
class bank_account
{
    protected:
        int     account_no;
        float   balance;

    public:
        void deposit ( float );          // Add deposit
        int  account_num ( void );       // Return account number
        float curr_bal ( void );         // Return current balance
};
```

  - There is no constructor function to initialize the attributes of the class because we are going to leave that for the derived classes
  - The way things are structured, we will not be creating any objects for the base class
  - When no objects are to be created for a class, the class is known as an *abstract class*
  - The attributes of the class have been declared to be `protected`

- `protected` member
  - A member that is accessible to both the base class and any derived classes of the base class in which it is declared
  - A `protected` member in a base class is accessible to any class within the class family but not accessible from outside the class family
  - If a member is declared to be `private` to a base class, it is *not* accessible to a derived class
- Implementation of methods in the base class

```
void bank_account::deposit ( float amount )
{
    balance += amount;
}

int bank_account::account_num ( void )
{
    return ( account_no );
}

float bank_account::curr_bal ( void )
{
    return ( balance );
}
```

- Derived class for checking account

```
class checking : public bank_account
{
    protected:
        float minimum;        // Minimum balance to avoid check charge
        float charge;         // Per check-charge

    public:
        // Constructor functions
        checking ( void );
```

```
        checking ( int, float, float, float );
        void  cash_check ( float );     // Cash a check
};
```

- The keyword `public` prior to the base class name makes the class `bank_account` a public base class to the derived class `checking`
- A `public` base class allows all `public` members of the base class to be `public` in the derived class
- The inherited members of the `public` base class (both attributes and methods) maintain their access level in the derived class
- Without the use of the keyword `public`, the `public` functions of the base class would *not* be accessible to any code using an object of the class `checking`, and the following will lead to a compile-time error

  ```
  checking ca;
  float bal = ca.curr_bal();
  ```

- `minimum` and `charge` are defined to be `protected` members because they will be inherited by the class `super_now`
- Because of inheritance, `checking` has four attributes – two of its own and two inherited from `bank_account`

- Implementation of the methods in the derived class `checking`

```
checking::checking ( void )      // Default constructor
{
    account_no = 0;
    balance = 0.0;
    minimum = 0.0;
    charge = 0.50;
}

checking::checking ( int acct_no = 0, float bal = 0.0, float min = 1000, \
                     float chg = 0.50 )
{
    account_no = acct_no;
    balance = bal;
    minimum = min;
    charge = chg;
}

void checking::cash_check ( float amt )      // Cash a check
{
    if ( amt > balance )             // Test for overdraft
        cerr << "Cannot cash check, account will be overdrawn." << endl;
    else                             // Cash check
        balance -= ( balance < minimum ) ? ( amt + charge ) : amt;
}
```

- The derived class `super_now`

```
class super_now : public checking
{
    float int_rate;                 // Annual rate of interest

    public:
        super_now ( void );         // Constructor functions
```

```
        super_now ( int, float, float, float, float );
        void add_interest ( void ); // Add interest to balance
};
```

  - The super_now class has only one attribute, and inherits four attributes from its parent and grandparent

- Implementation of the methods in the derived class super_now

```
super_now::super_now ( void )       // Default constructor
{
    account_no = 0;
    balance = 0.0;
    minimum = 0.0;
    charge = 0.50;
    int_rate = 2.0;
}

super_now::super_now ( int acct_no = 0, float bal = 0.0, float min = 0.0, \
                       float chg = 0.5, float rate = 2.0 )
: checking ( acct_no, bal, min, chg )
{
    int_rate = rate;
}

void super_now::add_interest ( void )  // Add interest to balance
{
    float interest;

    if ( balance >= minimum )
    {
        interest = balance * ( int_rate * 0.01 / 12 );
        balance += interest;
    }
}
```

- The derived class savings

```
class savings : public bank_account
{
    float int_rate;         // Annual rate of interest

    public:
        savings ( void );   // Default constructor
        savings ( int, float, float );
        void add_interest ( void );    // Add interest to balance
        void withdraw ( float );       // Make a withdrawal
};
```

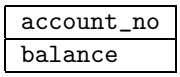
  - Two attributes are inherited from the base class bank_account

- Implementation of the methods in the derived class savings

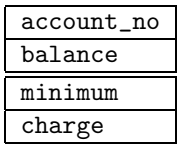
```
savings::savings ( void )               // Default constructor
{
    account_no = 0;
```

```
    balance = 0.0;
    int_rate = 4.0;
}

savings::savings ( int acct_no = 0, float bal = 0.0, float rate = 4.0 )
{
    account_no = acct_no;
    balance = bal;
    int_rate = rate;
}

void savings::withdraw ( float amt )      // Make a withdrawal
{
    balance -= amt;
}

void savings::add_interest ( void )       // Add interest
{
    float interest;

    interest = balance * ( int_rate * 0.01 / 12 );
    balance += interest;
}
```

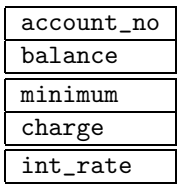
- Structure of the base class `bank_account`



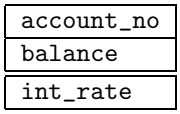
- Structure of the derived class `checking`



- Structure of the derived class `super_now`



- Structure of the derived class `savings`



  - In each of the above classes, a pointer to the derived classes is also a pointer to the base class
  - Consider the following case:

```
bank_account * b = new checking;
```

This will allocate space for an object of the class `checking` but ignore the attributes that are not visible in `bank_account`

- Difference between inheritance and using a base class as a subclass in the derived class
  - Both the cases have the same memory layout with the following differences:
  - A pointer to the derived class is not automatically a pointer to the base class
  - A public member function of the base class cannot be applied to the derived class (you will have to specify `derived.base.foo()`)

Virtual functions

- Dynamic v. Static binding
  - Static binding
    - Static binding occurs when a polymorphic function is defined for several classes in a family and the code for the function is attached, or bound, at compile time
    - Overloaded functions are statically bound
  - Dynamic binding
    - Dynamic (or late) binding occurs when a polymorphic function is defined for several classes in a family but the actual code for the function is not attached, or bound, until execution time
    - A polymorphic function that is dynamically bound is called a virtual function.
- A pointer to a derived class automatically points to a base class
  - We can put pointers to a derived class objects and to base class objects in an array
  - We cannot put actual objects of the base class and derived classes in an array because of different memory size requirements
  - Imagine printing the bank statement for all checking accounts:

    ```
    for ( accts.reset(); !accts.at_end(); accts.advance() )
        accts.print_statement();
    ```

  - Because of differing memory requirements, there is no way of telling whether the account is a plain checking account or a super-now account and certainly, the print function for both the cases will have to be handled differently
  - We can add a type field to specify the type of account and use it to pick up the correct print function:

    ```
    switch ( acct->type )
    {
    case 0: acct->print_statement(); break;
    case 1: ( ( super_now * ) acct ) -> print_statement(); break;
    }
    ```

- A virtual function allows us to avoid writing such code and solves the problem by making the `print_statement` function virtual in base class `checking`

```
class checking : public bank_account
{
    // ...
    virtual void print_statement();
};
```

- A virtual function alerts the compiler automatically to make a type field that distinguishes a plain checking account and all its derived classes, and to translate each call

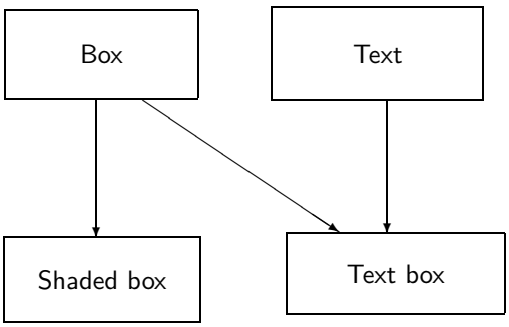
```
acct->print_statement();
```

into run-time selection of the correct method

- This is also known as *run-time overloading* of the function
- Only member functions can be virtual

Multiple inheritance

- Look at the following inheritance hierarchy:



  - The inheritance is no longer a tree-shaped hierarchy
  - Text box inherits from two classes: Box and Text
  - It was possible to define the class `Text_Box` as

```
class Text_box : public Box
{
    Text t;
    public:
        // ...
};
```

    but then, it will not inherit from the class `Text`

- Solution: Multiple inheritance
- The declaration looks like:

```
class Text_Box : public Box, public Text
{
    // ...
};
```

- Notice that there are two separate keywords `public` in front of each class from where the derived class inherits
- The constructor function for such a class looks like

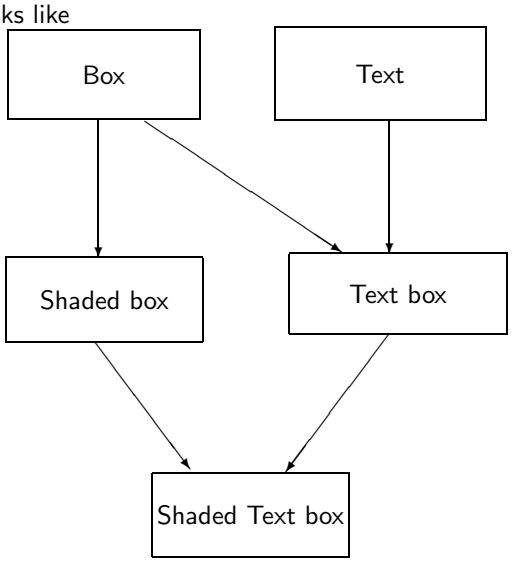
```
Text_Box :: Text_Box ( int x1, int y1, int x2, int y2, const char t[] )
: Box ( x1, y1, x2, y2 ), Text ( t )
{}
```

- With multiple inheritance, a pointer to a derived class no longer automatically points to the base class because the order of inclusion of the two classes is not guaranteed

- However, whenever a pointer to a derived class is converted to a pointer to any of the base classes, an appropriate offset is added by the compiler
- What if we now want to have a class called `Shaded_Text_Box`
  - It is natural to combine the two classes: `Shaded_Box` and `Text_Box` as

    ```
    class Shaded_Text_Box : public Shaded_Box, public Text_Box
    {
        // ...
    };
    ```

  - The inheritance looks like

  - There is a serious problem: The class `Box` is inherited via both `Shaded_Box` and `Text_Box`
  - If any of the attributes in the class `Box` is referred to, is the reference to be resolved through `Shaded_Box` or `Text_Box`
  - Wasting the space for both `Box`es is certainly undesirable
- Solution: virtual base classes
  - The classes `Shaded_Box` and `Text_Box` can both declare the base class `Box` to be virtual

    ```
    class Text_Box : virtual public Box { ... };
    class Shaded_Box : public virtual Box { ... };
    ```

    The order of `public` and `virtual` does not matter
  - A class inheriting from both these classes will get only one instance of `Box`
  - If there are multiple virtual classes, the common ones are coalesced to a single copy
- Restriction on base class construction
  - A virtual base class may be initialized only from the most derived class or with a constructor that requires no arguments
    - In the above example, the most derived class is `Shaded_Text_Box`