You’ve already seen inheritance:

- `std::istream` is a PARENT of `std::ifstream`

Base (parent) classes are more general
Derived (child) classes are more specific
C++: Inheritance

• Distinguish between “has a” and “is a” relationships

• Example:
  – A Honda HAS A motor
  – A Honda IS A car

• Now: make this into a data model
C++: Inheritance

• Example: StudentRecord

• From your homework, you looked at StudentRecord.

• StudentRecord HAS A first name
• StudentRecord HAS A last name
• StudentRecord HAS A score

```cpp
class StudentRecord {
  ...
  std::string firstname_;  // First name
  std::string lastname_;    // Last name
  double score_;           // Score
};
```
C++: Inheritance

• Now try to make this into an interface with SPECIALIZED attributes

• Suppose we have a special StudentRecord, i.e. a record with a student’s score in a specific class (say, Physics).

• How do we generalize?
  – Make a BASE CLASS out of StudentRecord
  – Make DERIVED CLASSES to implement the specifics
• Syntax:

```cpp
class StudentRecord {
    // ...
};
```

Inherits PUBLICLY from StudentRecord
(can have private but don’t worry about it)
C++: Inheritance

• What’s the use?
  – Generalization!

• Suppose you have a base class, “Car”, and two derived classes “Honda” and “Chevy”. You want to write code to have a robot fill up the gas tank.

• The logic is really about Cars, not Hondas or Chevies.
  – So something like:

```cpp
class Car {
    bool fill(Gas const & gas);
};
class Chevy : public Car {???};
class Honda : public Car {???};
```
C++: Inheritance

• Syntax is to make the function VIRTUAL in the base class:

```cpp
class Car {
    virtual bool fill(Gas const & gas);
};
```

• Then OVERRIDE them in the derived classes and fill in relevant details:

```cpp
class Chevy : public Car {
    virtual bool fill(Gas const & gas){
        fillLeftSide(gas);
    }
};

class Honda : public Car {
    virtual bool fill(Gas const & gas){
        fillRightSide(gas);
    }
};
```
C++: Inheritance

- In C++:
  - Use "virtual" keyword
    ```cpp
class Chevy : public Car {
    virtual bool fill(Gas const & gas) {
      fillLeftSide(gas);
    }
};
```

- In C++11 and later: can use "override" keyword:
  ```cpp
class Chevy : public Car {
    bool fill(Gas const & gas) override {
      fillLeftSide(gas);
    }
};
```

This is a bit stricter, requires that the function be exactly the same as a virtual function in the base class.
Now we understand “public”, “protected”, and “private”:

• Public: available to all code
• Protected: available to “this” class and any derived classes
• Private: available only to “this” class
With inheritance, you can use polymorphism:

– Call code from the DERIVED class by accessing through the BASE class

```cpp
std::vector< Car * > cars;
Chevy malibu;
Honda accord;
cars.push_back( &malibu );
cars.push_back( &accord );

for ( Car * pcar : cars ) {
    pcar->Fill(gas);
}
```

Can make BASE CLASS POINTERS to the derived class objects

Then treat them the same way in code without having to know specific details!
C++: Inheritance

• This works through the VIRTUAL TABLE (vtable)
  – Pointer to code that is defined at RUN TIME
    • “Dynamic binding” or “late binding”
    • To call derived classes, need to DEREFERENCE the pointer in the vtable
      – This can sometimes lead to poorer performance… more later
  – Depending on run-time value of objects, looks at a different class

• Example:

```cpp
std::vector< Car * > cars;
Car * pcar_1 = get_car_from_user();
Car * pcar_2 = get_car_from_user();
cars.push_back( pcar_1 );
cars.push_back( pcar_2 );

for ( Car * pcar : cars ) {
    pcar->Fill(gas);
}
```
If your base class doesn’t actually refer to a real type, it is a PURE INTERFACE

Also known as an “abstract base class”

In our “Car” example, there is no such model of “Car” that is just “Car”. You need to have a Honda or a BMW or a Toyota or a Chevy or a Ford.

Therefore Car should be abstract!

Syntax: provide virtual DECLARATION of a function, with no DEFINITION, set it equal to zero:

```cpp
class Car {
    virtual bool fill(Gas const & gas) = 0;
};
```
Example of generalizing StudentRecord:

Suppose we have a specialized cases of StudentRecord:
- StudentRecordPhysics: inputs TWO scores
- StudentRecordLiterature: inputs THREE scores

To make generic: make “base” class have a vector<double> to represent scores
C++: Friend Classes

• Data access:
  – Protected : derived classes

• What about OTHER classes or functions you want to be able to access?
  – Friends!

  – Yes, really.

• One common use : operator<< and operator>>
C++: Friend classes

- Syntax is pretty simple: in your class definition, just like the Mines of Moria:

```cpp
class A{
public:
    friend class B;
};
```

- speak friend, and enter

B now has access to all of A’s private and protected data
C++: Friend Classes

• Often use for operator<< and operator>>:

• In header (.h) file:

```cpp
class StudentRecord {
    public:
        ...

    friend std::ostream & operator<<( std::ostream & out, StudentRecord const & );
    friend std::istream & operator>>( std::istream & in , StudentRecord const & );
}
```

• In source (.cc) file:

```cpp
std::ostream & operator<<( std::ostream & out, StudentRecord const &right )
{ right.print(out); return out; }

std::istream & operator>>( std::istream & in, StudentRecord &right )
{ right.input(in); return in; }
```
Hands on

• Folder “InheritanceExample”

• Type “make” and you get the executable
• We’ve been using templates since last week:
• Operates on ANY class
• `std::vector<int>`, `std::vector<double>`, `std::vector<StudentRecordPhysics>`, etc

• Now let’s look a bit deeper
C++: Class Templates

```cpp
template< class T>
class Storage

Storage<int> s(2);
```
C++: Class Templates

• Similar to function templates, declare with “template <class T>”

• Then the code you write has a PLACEHOLDER value called “T”. “T” is not a class. It is a dummy. It does not exist.

• This defines an INTERFACE to operate on the class object
So std::vector<T> is a template

It doesn’t matter if “T” is a float or an int (or a StudentRecord), the operations of “std::vector” are unchanged!

Class template std::vector<T>, then make classes like std::vector<int>, std::vector<StudentRecordPhysics>, etc.
C++: Class Templates

- If you do not correctly set up your templates, you will get sixty-seven pages of compiler warnings

- It issues the warnings for EVERY instance of the class template

- Usually the first one is the one you care about, and it is actually usually descriptive, so READ THEM!
• Can also have MULTIPLE template parameters
• Example: Associative container “std::map”
  – Like a vector, but has an abstract KEY and can be sorted in any way you like “Compare”

```cpp
template<
  class Key,
  class T,
  class Compare = std::less<Key>,
  class Allocator = std::allocator<std::pair<const Key, T>>
>
> class map;
```

• Example: “Maps”