C/C++ Programming Language

CS205 Spring

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Week 15

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Content

- Review
- Friends
- Nested Classes
- Exceptions (object)
- Runtime Type Identification (object)
- Type Cast Operators

Brief Review

Review

- Classes with Object Members
- Private Inheritance
- Multiple Inheritance
- Class Templates

Friends

Friend Classes

- Friend functions?
  - The extended interface for a class
  - A common kind of Friend: overloading the << operator (left operand)
- Friends (neither is-a nor has-a)
  - 1. **Any** method of the friend class can access private and protected members of the original class
  - 2. Designate particular member functions of a class to be friends to another class
  - Cannot be imposed from the outside
- An example
  - A television and a remote control
    - ✓ *is-a* relationship of public inheritance doesn't apply
    - ✓ *has-a* relationship of containment or of private or protected inheritance doesn't apply

Friend Declaration

- Run tv.h, tv.cpp, use_tv.cpp
  - The Remote methods are implemented by using the public interface for the Tv class
  - Provide the class with methods for altering the settings
  - A remote control should **duplicate** the controls built in to the television
- Friend declaration
  - A friend declaration can appear in a public, private, or protected section
  - The location makes no difference for as a friend but is different for the devised class or for the outside

```
friend class Remote;
```

Friend Member Functions

- A problem?
  - The only Remote method that accesses a private Tv member directly is Remote::set_chan(), so that's the only method that needs to be a friend
- A second solution
  - Make Remote::set_chan() a friend to the Tv class
  - Declare it as a friend in the Tv class declaration

```
class Tv
{
    friend void Remote::set_chan(Tv & t, int c);
    ...
};
```

- A new problem of circular dependence?
  - If Tv defined in front, compiler needs to see the Remote definition
  - But the fact that Remote methods mention Tv objects
- The third solution: forward declaration

```
class Tv;   // forward declaration
class Remote { ... };
class Tv { ... };
```

Could you use the following arrangement instead?

```
class Remote;          // forward declaration
class Tv { ... };
class Remote { ... };
```

No

Friend Member Functions

- Another difficulty remains

Remote → `void onoff(Tv & t) { t.onoff(); }`

  - Compiler needs to have seen the Tv class declaration at this point
  - But the declaration necessarily follows the Remote declaration.
- The fourth solution
  - Restrict Remote to method declarations and to place the actual definitions after the Tv class.

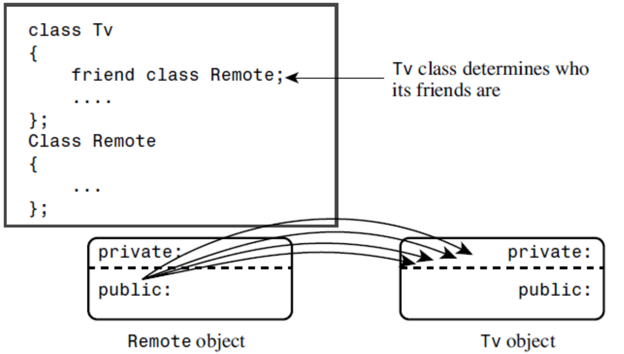
```
class Tv;                    // forward declaration
class Remote { ... };        // Tv-using methods as prototypes only
class Tv { ... };
// put Remote method definitions here
```

The Remote prototypes look like this:

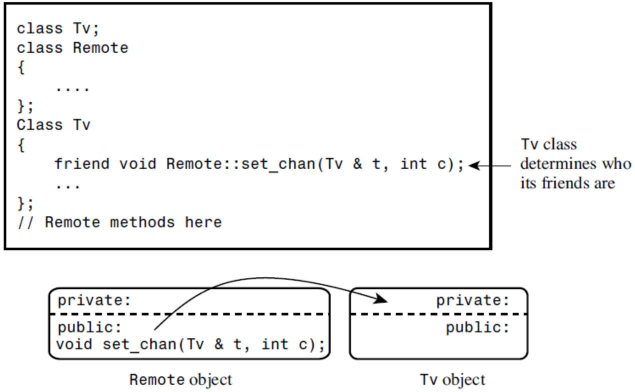
```
void onoff(Tv & t);
```

Comparison

- Class friends versus class member friends



All Remote methods can affect private Tv members.



Just Remote::set_chan() can affect private Tv members.

Other Friendly Relationships

- 1. Interactive controls
  - Make the classes friends to each other
  - Eg.: the television might activate a **buzzer** in your remote control if your response is wrong
  - Tv::buzz() method has to be defined outside the Tv declaration so that the definition can follow the Remote declaration
  - If you don't want buzz() to be inline, you need to define it in a separate method definitions file

```
class Tv
{
friend class Remote;
public:
    void buzz(Remote & r);
    ...
};
class Remote
{
friend class Tv;
public:
    void Bool volup(Tv & t) { t.volup(); }
    ...
};
inline void Tv::buzz(Remote & r)
{
   ...
}
```

A problem

One point to keep in mind is that a `Tv` method that uses a `Remote` object can be **prototyped** *before* the `Remote` class declaration but must be defined *after* the declaration so that the compiler will have enough information to compile the method.

Other Friendly Relationships

- A problem
  - A function needs to access private data in two separate classes while it is impossible to be a member function of each class
  - It could be a member of one class and a friend to the other
- 2. Shared friends (better solution)
  - Eg.: Probe class represents some sort of programmable measuring device and an Analyzer class represents some sort of programmable analyzing device. Each has an internal clock, and you would like to be able to synchronize the two clocks

```
class Analyzer;  // forward declaration
class Probe
{
    friend void sync(Analyzer & a, const Probe & p);  // sync a to p
    friend void sync(Probe & p, const Analyzer & a);  // sync p to a
};
class Analyzer
{
    friend void sync(Analyzer & a, const Probe & p);  // sync a to p
    friend void sync(Probe & p, const Analyzer & a);  // sync p to a
    ...
};
```

```
// define the friend functions
inline void sync(Analyzer & a, const Probe & p)
{
    ...
}
inline void sync(Probe & p, const Analyzer & a)
{
    ...
}
```

Nested Classes

Nested Classes

- What is the nested class?
  - Place a class declaration inside another class
    - ✓ Member functions of the class containing the declaration can create and use objects of the nested class
    - ✓ The outside world can use the nested class only if the declaration is in the public section
  - Why? Assist in the implementation of other class and to avoid name conflicts
    - ✓ Why not a containment?
- Nesting classes is not the same as containment
    - ✓ Containment: have a class object as a member
    - ✓ Nesting class: define a type locally to the class
    - ✓ What is the difference?

```
class Queue
{
// class scope definitions
    // Node is a nested class definition local to this class
    class Node
    {
    public:
        Item item;
        Node * next;
        Node(const Item & i) : item(i), next(0) { }
    };
    ...
};
```

Nested Classes and Access

- Two kinds of access
  - Where a nested class is declared controls the scope of the nested class
  - The public, protected, and private sections of a nested class provide access control to class members
- Scope
  - In a private section, it is known only to that containing class
  - In a protected section, it is visible to containing class but invisible to the outside world. While, a derived class would know about it
  - In a public section, it is available to the containing class, to derived classes, and to the outside world

Where Declared in Nesting Class	Available to Nesting Class	Available to Classes Derived from the Nesting Class	Available to the Outside World
Private section	Yes	No	No
Protected section	Yes	Yes	No
Public section	Yes	Yes	Yes, with class qualifier

Access Control

- The same rules that govern access to a regular class govern access to a nested class
  - A containing class object can access only the public members of a nested class object explicitly
  - The location of a class declaration determines the scope or visibility of a class
  - The usual access control rules (public, protected, private, friend) determine the access a program has to members of the nested class
- Nesting in a template

```
template <class Item>
class QueueTP
{
private:
    enum {Q_SIZE = 10};
    // Node is a nested class definition
    class Node
    {
    public:
        Item item;
        Node * next;
        Node(const Item & i):item(i), next(0){ }
    };
    Node * front;       // pointer to front of Queue
    Node * rear;        // pointer to rear of Queue

};
```

Nesting in a Template

- Remember class template (template argument)?
  - Templates are a good choice for implementing container classes such as the Queue class

```
// queuetp.h -- queue template with a nested class
#ifndef QUEUETP_H_
#define QUEUETP_H_

template <class Item>
class QueueTP
{
private:
    enum {Q_SIZE = 10};
    // Node is a nested class definition
    class Node
    {
    public:
        Item item;
        Node * next;
        Node(const Item & i):item(i), next(0){ }
    };
    Node * front;        // pointer to front of Queue
    Node * rear;         // pointer to rear of Queue
    int items;           // current number of items in Queue
    const int qsize;     // maximum number of items in Queue
    QueueTP(const QueueTP & q) : qsize(0) {}
    QueueTP & operator=(const QueueTP & q) { return *this; }
public:
    QueueTP(int qs = Q_SIZE);
    ~QueueTP();
    bool isempty() const
    {
        return items == 0;
    }
    bool isfull() const
    {
        return items == qsize;
    }
    int queuecount() const
    {
        return items;
    }
    bool enqueue(const Item &item); // add item to end
    bool dequeue(Item &item);       // remove item from front
};
```

How to define the method?

```
Queue::Node::Node(const Item & i) : item(i), next(0) { }
```

Exceptions

Rudimentary Options

- An example: harmonic mean of two numbers

$$2.0 \times x \times y \;/\; (x + y)$$

- Calling abort(): run error1.cpp
  - Send a message such as "abnormal program termination" to the standard error stream and terminate the program
  - Return an implementation-dependent value that indicates failure to the operating system
- Returning an error code: run error2.cpp
  - Return values to indicate a problem
  - We have used it in the previous examples

Throw-Catch Mechanism

- An exceptional circumstance arises while a program is running
- Exception mechanism provide a way to transfer control from one part of a program to another
  - ➢ Throwing an exception
    - ✓ throw keyword indicates the throwing of an exception
    - ✓ A throw statement, in essence, is a jump (other jump operators??)
  - ➢ Catching an exception with a handler
    - ✓ catch keyword indicates the catching of an exception
    - ✓ Followed by a **type** declaration that indicates the type of exception
  - ➢ Using a try block
    - ✓ A try block identifies a block of code for which particular exceptions will be activated
    - ✓ Followed by one or more catch blocks
- Run error3.cpp

Throw-Catch Mechanism

- Can we use more complex types? YES!
- Using objects as exceptions
  - Advantage: use different exception types to distinguish among different functions and situations that produce exceptions
  - An object can carry information with it, and you can use this information to help identify the conditions that caused the exception to be thrown
  - A catch block could use that information to decide which course of action to pursue
- Run exc_mean.h, error4.cpp
  - Geometric and harmonic means

More Exception Features of Throw-Catch Mechanism

- Differences to the normal function
  - One difference
    - ✓ A return statement: transfer execution to the calling function
    - ✓ A throw: transfer execution to the first function having a try-catch
  - Second difference
    - ✓ The compiler always creates a copy when throwing an exception

```
class problem {...};
...
void super() throw (problem)
{
    ...
    if (oh_no)
    {
        problem oops;    // construct object
        throw oops;      // throw it
    ...
}
...
try {
    super();
}
catch(problem & p)
{
// statements
}
```

- The exception class
  - Define an exception class that C++ uses as a base class
  - One **virtual** member function is named what(), and it returns a string

```
#include <exception>
class bad_hmean : public std::exception
{
public:
    const char * what() { return "bad arguments to hmean()"; }
...
};
```

More Exception Features

- The stdexcept exception classes
  - The stdexcept header file defines several more exception classes
  - logic_error and runtime_error classes
    - ✓ logic_error family: domain_error, invalid_argument, length_error, out_of_bounds
    - ✓ runtime_error family: range_error, overflow_error, underflow_error

```
class logic_error : public exception {
public:
explicit logic_error(const string& what_arg);
...
};

class domain_error : public logic_error {
public:
explicit domain_error(const string& what_arg);
...
};
```

- The bad_alloc exception and new
  - Have new throw a bad_alloc exception
  - new returned a null pointer when it couldn't allocate the memory

```
int * pi = new (std::nothrow) int;
int * pa = new (std::nowthrow) int[500];
```

- Run newexcp.cpp

Runtime Type Identification

What Is RTTI For?

- Runtime type identification (RTTI)
  - One of the more recent additions to C++
  - Isn't supported by many older implementations
- Why RTTI?
  - Provide a standard way to determine the type of object during runtime
  - Allow future libraries to be compatible with each other
- How Does RTTI Work?
  - The dynamic_cast operator generates a pointer of a base type from a pointer of a derived type. Otherwise, it returns the null pointer.
  - The typeid operator returns a value identifying the type of an object.
  - A type_info structure holds information about a particular type.

RTTI

- The dynamic_cast operator
  - Safely assign the address of an object to a pointer of a particular type
    - ✓ Invoke the correct version of a class method
    - ✓ Keep track of which kinds of objects were generated

```
class Grand { // has virtual methods};
class Superb : public Grand { ... };
class Magnificent : public Superb { ... };

Grand * pg = new Grand;
Grand * ps = new Superb;
Grand * pm = new Magnificent;
Magnificent * p1 = (Magnificent *) pm;        // #1
Magnificent * p2 = (Magnificent *) pg;        // #2
Superb * p3 = (Magnificent *) pm;             // #3
```

safe
not safe
safe

```
Superb * pm = dynamic_cast<Superb *>(pg);
```

NULL

RTTI

- The typeid operator
  - Let you determine whether two objects are the same type
  - Accept two kinds of arguments
    - ✓ The name of a class
    - ✓ An expression that evaluates to an object
  - The typeid operator returns a reference to a type_info **object**
- The type_info class
  - Defined in the typeinfo header file
  - Overload the == and != operators so that you can use these operators to compare types

```
typeid(Magnificent) == typeid(*pg)
```

Type Cast Operators

Type Cast Operators

- Select an operator that is suited to a particular purpose
- Examples
  - None of them make much sense
  - In C, all of them are allowed
- Four type cast operators
  - dynamic_cast
    - ✓ Allow upcasts within a class hierarchy
    - ✓ *is-a* relationship
    - ✓ Disallow other casts
  - const_cast
    - ✓ Type cast for const or volatile value
    - ✓ An error if any other aspect of the type is altered
- Run constcast.cpp

```
struct Data
{
    double data[200];
};

struct Junk
{
    int junk[100];
};
Data d = {2.5e33, 3.5e-19, 20.2e32};
char * pch = (char *) (&d);    // type cast #1 - convert to string
char ch = char (&d);           // type cast #2 - convert address to a char
Junk * pj = (Junk *) (&d);     // type cast #3 - convert to Junk pointer
```

```
dynamic_cast < type-name > (expression)
```

```
const_cast < type-name > (expression)
```

It removes the const label

```
High bar;
const High * pbar = &bar;
    ...
High * pb = const_cast<High *> (pbar);    // valid
const Low * pl = const_cast<const Low *> (pbar);    // invalid
```

Type Cast Operators

- static_cast
  - ✓ It's valid only if type_name can be converted implicitly to the same type that expression has, or vice versa
  - ✓ Otherwise, the type cast is an error
- reinterpret_cast
  - ✓ Do implementation-dependent things
  - ✓ Cast a pointer type to an integer type that's large enough to hold the pointer representation
  - ✓ Can't cast a pointer to a smaller integer type or to a floating point type
  - ✓ Can't cast a function pointer to a data pointer or vice versa

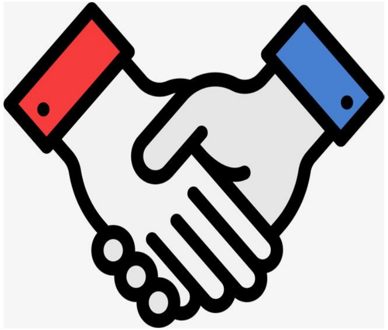
```
static_cast < type-name > (expression)
```

`High` is a base class to `Low` and that `Pond` is an unrelated class

```
High bar;
Low blow;
...
High * pb = static_cast<High *> (&blow);     // valid upcast
Low * pl = static_cast<Low *> (&bar);        // valid downcast
Pond * pmer = static_cast<Pond *> (&blow);   // invalid, Pond unrelated
```

```
reinterpret_cast < type-name > (expression)
```

```
struct dat {short a; short b;};
long value = 0xA224B118;
dat * pd = reinterpret_cast< dat *> (&value);
cout << hex << pd->a;   // display first 2 bytes of value
```



Thanks

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