COMP 2012H Honors Object-Oriented Programming and Data Structures

Topic 15: Static Data Members and Member Functions

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Part I

Static Variables with File/Function Scope

Static Variables with a File/Function Scope

- Static variables are global variables which
  - are created only once in a program.
  - reside on the static data region of the loaded program.
  - have a lifetime across the entire run of a program.
  - still may have limited scope: file, function, class.
- Static variables in a function
  - are initialized only once regardless how many times the function is called.
  - retain their values across the function calls.
  - can be accessed only inside the function.

Example: Static Variable with a File Scope

```
#include <iostream> /* afile.cpp */
using namespace std;

int a;
int func();

int main() {
  a = 10;
  cout << a << " " << func() << endl;
  return 0;
}
```

```
int a; /* bfile.cpp */
int func() {
  a = 20;
  return a;
}
```

Question: What would happen if we compile the program using the following command?

```
g++ -o output afile.cpp bfile.cpp
```

Example: Static Variable with a File Scope

```
#include <iostream> /* afile-static.cpp */
using namespace std;

static int a;
int func();

int main() {
  a = 10;
  cout << a << " " << func() << endl;
  return 0;
}
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
int a; /* bfile.cpp */
int func() {
  a = 20;
  return a;
}
```

Question: What is the output of the program compiled using the following command?

```
g++ -o output afile-static.cpp bfile.cpp
```


Example: Static Variables with a Function Scope

```
#include <iostream>     /* File: static-var-function.cpp */
using namespace std;

int fibonacci(int n, int& calls)
{
    static int num_calls = 0; // Initialized only once
    calls = ++num_calls;

    if (n <= 0)
        return 0;
    else if (n == 1 || n == 2)
        return 1;
    else
        return fibonacci(n-2, calls) + fibonacci(n-1, calls);
}
int main()
{
    int n; int n_calls;
    cout << "Enter n: "; cin >> n;
    cout << "\nfibonacci(" << n << ") = " << fibonacci(n, n_calls);
    cout << "\nnumber of fibonacci calls = " << n_calls << endl;
    return 0;
}
```

Question: What is the output?

Part II

Static Class Data Members

Example: Students Study for an Exam By Memorizing

```
#include <iostream>     /* File: student-non-static.h */
#include <string>
// vector is a template class in C++ Standard Template Lib (STL).
// vectors are smart arrays that automatically expand if necessary.
#include <vector>
using namespace std;

class Student
{
  private:
    string name;            // Student's name
    vector<string> memory;  // Each student has his own memory

  public:
    Student(string s) : name(s) { }

    // push_back() is vector's member function that does insertion
    void memorize(string txt) { memory.push_back(txt); }
    void do_exam();
};
```

How Do Students Take an Exam

```cpp
#include "student-non-static.h" /* File: student-non-static.cpp */

void Student::do_exam()
{
    // empty() is vector's member function to check if it is empty
    if (memory.empty())
        cout << name << ": "<< "Huh???" << endl;
    else
    {
        // Like a (generalized) const pointer to vector's elements
        vector<string>::const_iterator p;

        // begin() returns the pointer to the vector's beginning
        // end() returns the pointer to the cell beyond vector's end
        for (p = memory.begin(); p != memory.end(); ++p)
            cout << name << ": " << *p << endl;
    }

    cout << endl;
}
```


Exam Takes Place Now

```cpp
#include "student-non-static.h" /* File: exam-non-static.cpp */

int main()
{
    Student Jim("Jim");
    Jim.memorize("Data consistency is important");
    Jim.memorize("Copy constructor != operator=");

    Student Steve("Steve");
    Steve.memorize("Overloading is convenient");
    Steve.memorize("Make data members private");
    Steve.memorize("Default constructors have no arguments");

    Student Alan("Alan");

    Jim.do_exam();
    Steve.do_exam();
    Alan.do_exam();
    return 0;
} // Compile: g++ student-non-static.cpp exam-non-static.cpp
```


Result of an Exam

```
Jim: Data consistency is important
Jim: Copy constructor != operator=

Steve: Overloading is convenient
Steve: Make data members private
Steve: Default constructors have no arguments

Alan: Huh???
```

Students Try to Cheat by "Collective Wisdom"

```cpp
#include <iostream>     /* File: student-static.h */
#include <vector>
#include <string>
using namespace std;

class Student
{
  private:
    string name;
    static vector<string> memory; // Students share memory!

  public:
    Student(string s) : name(s) { }
    void memorize(string txt) { memory.push_back(txt); }
    void do_exam();
};
```

Students Cheat by Collective Memory

```
#include"student-static.h"      /* File: student-static.cpp */

// Globally define class static data; here, it is
// initialized by calling vector's default constructor
vector<string> Student::memory;

void Student::do_exam()
{
    if (memory.empty())
        cout << name << ": "<< "Huh???" << endl;
    else
    {
        vector< string >::const_iterator p;

        for (p = memory.begin(); p != memory.end(); ++p)
            cout << name << ": " << *p << endl;
    }

    cout << endl;
}
```


Unfair Exam

```
#include "student-static.h" /* File: exam-static.cpp */

int main()
{
    Student Jim("Jim");
    Jim.memorize("Data consistency is important");
    Jim.memorize("Copy constructor != operator=");

    Student Steve("Steve");
    Steve.memorize("Overloading is convenient");
    Steve.memorize("Make data members private");
    Steve.memorize("Default constructors have no arguments");

    Student Alan("Alan");

    Jim.do_exam();
    Steve.do_exam();
    Alan.do_exam();
    return 0;
} // Compile: g++ student-static.cpp exam-static.cpp
```


Result of Cheating

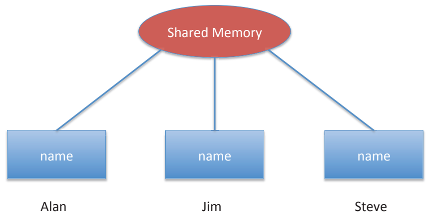
Here, all students share their memories. So even though Alan didn't memorize anything, he can access all the knowledge memorized by Jim and Steve.

```
Jim: Data consistency is important
Jim: Copy constructor != operator=
Jim: Overloading is convenient
Jim: Make data members private
Jim: Default constructors have no arguments

Steve: Data consistency is important
Steve: Copy constructor != operator=
Steve: Overloading is convenient
Steve: Make data members private
Steve: Default constructors have no arguments

Alan: Data consistency is important
Alan: Copy constructor != operator=
Alan: Overloading is convenient
Alan: Make data members private
Alan: Default constructors have no arguments
```

Static Class Data: Summary



- Static class data members are actually global variables specified by the keyword static under the scope of a class.
- There is only one single copy of a static variable in a class, which are shared among all objects of the class.
- Static variables of a class exist even when there are no objects of the class; they do not take up space inside an object.
- Static variables cannot be initialized in the class definition (except for const int/enum static data).
- Static variables must be defined outside the class definition, usually in the class implementation (.cpp) file.
- One still has to observe their access and const qualifier.

Part III

Static Class Member Functions/Methods

Named Constructors

- C++ constructors have the name of the class.
- Different constructors can only be distinguished if they have different argument types — function overloading.
- E.g., Can't have 2 Clock constructors with an `int` argument, interpreted as either in HHMM format or # minutes after midnight.

```
class Clock {             /* File: incorrect-clock.h */
  public:
    Clock() : hour(0), minute(0) { }
    Clock(int mins) : hour(mins/60), minute(mins%60) { }
    Clock(int hhmm) : hour(hhmm/100), minute(hhmm%100) { }
    void tick();
  private:
    int hour, minute;
};

Clock c1;         // 0:00
Clock c2(120);    // 1:20
Clock c3(180);    // 3:00
```


One Solution: Global Constructor-like Functions

```
class Clock              /* File: clock-w-global-fcn.cpp */
{
  public:
    Clock(int h = 0, int m = 0) : hour(h), minute(m) { }
    void tick();

  private:
    int hour, minute;
};

Clock make_clock_hhmm(int hhmm)
    { return Clock( hhmm/100, hhmm%100 ); }

Clock make_clock_minutes(int min)
    { return Clock( min/60, min%60 ); }
```


Disadvantages of Global Constructor-like Functions

1. Global functions all live in the same (global) namespace, so the names of the "constructor-like functions" have to be long.
2. It is not clear that the functions belong to the class. When the class is modified, it might be easy to forget to look at the "constructor-like functions."
3. Global constructor-like functions cannot access private data members of the class. (Though this may be solved by friend functions.)

Example: Class Clock With Static Methods

```
class Clock                /* File: clock-w-static-fcn.h */
{
    friend ostream& operator<<(ostream& os, const Clock& c)
      { return os << c.hour << " hr. " << c.minute << " min. "; }

  public:
    Clock() : hour(0), minute(0) { }

    static Clock HHMM(int hhmm)
        { return Clock(hhmm/100, hhmm%100); }

    static Clock minutes(int m)
        { return Clock(m/60, m%60); }

  private:
    int hour, minute;
    Clock(int h, int m) : hour(h), minute(m) { }
};
```


Class Clock With Static Methods — clock-test.cpp

```
#include <iostream>      /* File: test-clock.cpp */
using namespace std;
#include "clock-w-static-fcn.h"

int main()
{
    Clock c1;                           // 0:00
    Clock c2 = Clock::HHMM(123);        // 1:23
    Clock c3 = Clock::minutes(123);     // 2:03

    cout << c1 << endl;
    cout << c2 << endl;
    cout << c3 << endl;

    return 0;
}
```

Static Member Function / Class Method

- Classes may also have static member functions or methods.
- Static data member (member functions) are also called class data (methods).
- Static member variables (methods) are actually global variables (functions) but with a class scope and are subject to the access control specified by the class developer.
- Static member functions can be called in 2 ways:
  1. like a global function by using the class scope operator::.
  2. like a member function of the class using the . operator.
- Still have to observe their access control: static data member/member functions may still be public|protected|private.

Static Member Function / Class Method ..

Static member functions belong to a class, not to a particular object of the class. Therefore, static methods of a class

1. do not have the implicit this pointer like regular non-static member functions.
2. may be used even when there are no objects of the class!
3. can only make use of static data members of the class.
4. cannot be const nor virtual functions.
5. cannot be overloaded with a non-static member function of the same prototype.

Example: Class Car — car.h

```
#include <iostream>     /* File: car.h */
using namespace std;

class Car
{
  public:
    Car()  { ++num_cars; }
    ~Car() { --num_cars; }

    void drive(int km) { total_km += km; }
    static int cars_still_running() { return num_cars; }

  private:
    static int num_cars;
    int total_km = 0;
};
```


Example: Class Car — car.cpp

```
#include "car.h" /* File: test-car.cpp */
int Car::num_cars = 0; // Define + initialize static class member

int main()
{
    cout << Car::cars_still_running() << endl;
    Car vw;  vw.drive(1000);
    Car bmw; bmw.drive(10);
    cout << Car::cars_still_running() << endl;

    Car *cp = new Car[100];
    cout << Car::cars_still_running() << endl;

    {
        Car kia; kia.drive(400);
        cout << Car::cars_still_running() << endl;
    }
    cout << Car::cars_still_running() << endl;
    delete [] cp;
    cout << Car::cars_still_running() << endl; return 0;
}
```


Static Data Members and Member Function / Method

Compare a class **Car** with a factory:

- The **Car** objects are the products made by the factory.
- Data members are data on the products, and methods are services provided by the objects.
- Static class data/methods are data/services provided by the `factory`.
- Even if no object of this type has been created, we can access the static class data/methods.
- A regular member function of **Car**, such as

  ```
  void drive(int km) { total_km += km; }
  ```

  after compilation becomes:

  ```
  void Car::drive(Car* this, int km) { this->total_km+=km; }
  ```
- On the other hand, a static method of **Car** such as

  ```
  static int cars_still_running() { return num_cars; }
  ```

  after compilation becomes:

  ```
  int Car::cars_still_running() { return Car::num_cars; }
  ```


That's all!

Any questions?