Object-Oriented Programming and Data Structures

COMP2012: Static Data Members and Member Functions

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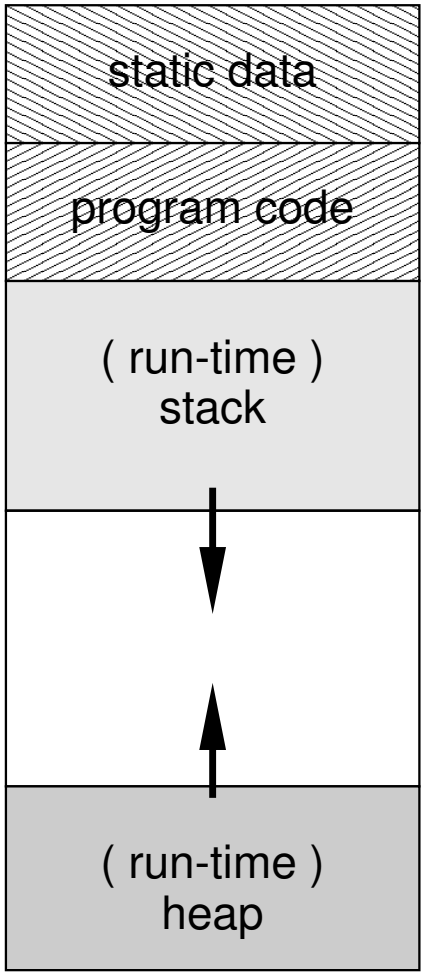
Static Variables with a File/Function Scope

- 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 controlled by its scope: file, function, class.
  - if not explicitly initialized, will be zero-initialized for basic types (and their arrays) and default-initialized for objects.
- Static variables in a function
  - are initialized only once regardless how many times the function is called.
  - retain their values across function calls.
  - can be accessed only inside the function.



Example: Static Variable with a File Scope

```
1   #include <iostream>      /* File: static-var-file.cpp */
2   using namespace std;
3
4   // Global but static variables can be only used
5   // in the current file; no external linkage
6   static int x = 5;
7
8   int f() { return ++x; }
9
10  int main()
11  {
12      cout << x << endl;
13      cout << f() << endl;
14      cout << f() << endl;
15
16      return 0;
17  }
```

Question: What is the output?

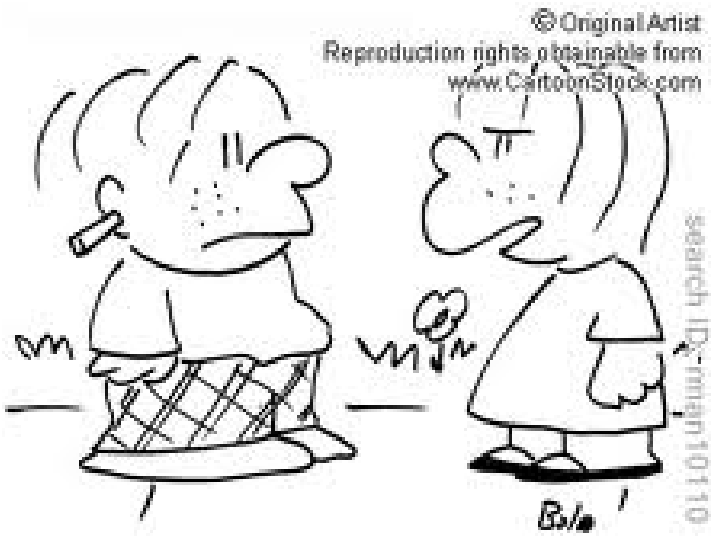
Example: Static Variables with a Function Scope

```
1  #include <iostream>     /* File: static-var-function.cpp */
2  using namespace std;
3
4  int fibonacci(int n, int& calls)
5  {
6      static int num_calls = 0; // Initialized only once
7      calls = ++num_calls;
8
9      if (n <= 0)
10         return 0;
11     else if (n == 1 || n == 2)
12         return 1;
13     else
14         return fibonacci(n-2, calls) + fibonacci(n-1, calls);
15 }
16 int main()
17 {
18     int n; int n_calls;
19     cout << "Enter n: "; cin >> n;
20     cout << "\nfibonacci(" << n << ") = " << fibonacci(n, n_calls);
21     cout << "\nnumber of fibonacci calls = " << n_calls << endl;
22     return 0;
23 }
```

Question: What is the output?

Part I

Static Class Data Members



Example: Students Study for an Exam By Memorizing

```
1   #include <iostream>     /* File: student-non-static.h */
2   #include <string>
3   using namespace std;
4   const int MAX_MEM {100};
5
6   class Student
7   {
8     private:
9       string name;              // Student's name
10      string memory[MAX_MEM]; // Each student has his own memory
11      int amount_of_memory = 0;
12
13    public:
14      Student(string s) : name(s) { }
15      void do_exam();
16
17      void memorize(string txt)
18      {
19          if (amount_of_memory >= MAX_MEM)
20              cerr << name << " can't memorize anything anymore!\n" << endl;
21          else
22              memory[amount_of_memory++] = txt;
23      }
24  };
```

How Do Students Take an Exam

```
1  #include "student-non-static.h" /* File: student-non-static.cpp */
2
3  void Student::do_exam()
4  {
5      if (amount_of_memory == 0)  // Haven't studied anything!
6          cout << name << ": "<< "Huh???" << endl;
7      else
8      {
9          for (int k = 0; k < amount_of_memory; ++k)
10             cout << name << ": " << memory[k] << endl;
11     }
12
13     cout << endl;
14 }
```

Exam Takes Place Now

```
1  #include "student-non-static.h" /* File: exam-non-static.cpp */
2
3  int main()
4  {
5      Student Jim("Jim");
6      Jim.memorize("Data consistency is important");
7      Jim.memorize("Copy constructor != operator=");
8
9      Student Steve("Steve");
10     Steve.memorize("Overloading is convenient");
11     Steve.memorize("Make data members private");
12     Steve.memorize("Default constructors have no arguments");
13
14     Student Alan("Alan");
15
16     Jim.do_exam();
17     Steve.do_exam();
18     Alan.do_exam();
19     return 0;
20 } // 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"

```
1   #include <iostream>     /* File: student-static.h */
2   #include <string>
3   using namespace std;
4   const int MAX_MEM {100};
5
6   class Student
7   {
8     private:
9       string name;                        // Student's name
10      static string memory[MAX_MEM]; // Students share their memories
11      static int amount_of_memory;
12
13    public:
14      Student(string s) : name(s) { }
15      void do_exam();
16
17      void memorize(string txt)
18      {
19          if (amount_of_memory >= MAX_MEM)
20              cerr << name << " can't memorize anything anymore!\n" << endl;
21          else
22              memory[amount_of_memory++] = txt;
23      }
24  };
```

Students Cheat by Collective Memory

```
1   #include "student-static.h" /* File: student-static.cpp */
2
3   // Define AND initialize static data globally
4   string Student::memory[MAX_MEM] { };
5   int Student::amount_of_memory {0};
6
7   void Student::do_exam()
8   {
9       if (amount_of_memory == 0)  // Haven't studied anything!
10          cout << name << ": "<< "Huh???" << endl;
11      else
12      {
13          for (int k = 0; k < amount_of_memory; ++k)
14              cout << name << ": " << memory[k] << endl;
15      }
16
17      cout << endl;
18  }
```

Unfair Exam

```
1  #include "student-static.h" /* File: exam-static.cpp */
2
3  int main()
4  {
5      Student Jim("Jim");
6      Jim.memorize("Data consistency is important");
7      Jim.memorize("Copy constructor != operator=");
8
9      Student Steve("Steve");
10     Steve.memorize("Overloading is convenient");
11     Steve.memorize("Make data members private");
12     Steve.memorize("Default constructors have no arguments");
13
14     Student Alan("Alan");
15
16     Jim.do_exam();
17     Steve.do_exam();
18     Alan.do_exam();
19     return 0;
20 } // Compile: g++ student-static.cpp exam-static.cpp
```

Result of Cheating

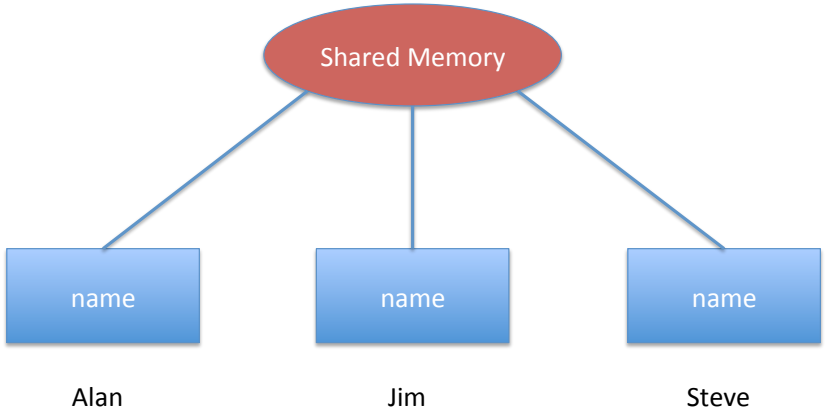
Here, all students share their memories. So even though Alan didn't memorize anything, he can access all the knowledge memorized by Jim and Steve.

```
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 II

Static Class Member Functions/Methods

Example: Class Clock With Static Methods

```
1   class Clock                  /* File: clock-w-static-fcn.h */
2   {
3       friend ostream& operator<<(ostream& os, const Clock& c)
4         { return os << c.hour << " hr. " << c.minute << " min. "; }
5
6     public:
7       Clock() : hour(0), minute(0) { }
8
9       static Clock HHMM(int hhmm)
10          { return Clock(hhmm/100, hhmm%100); }
11
12      static Clock minutes(int m)
13          { return Clock(m/60, m%60); }
14
15    private:
16      int hour, minute;
17      Clock(int h, int m) : hour(h), minute(m) { }
18  };
```

Class Clock With Static Methods — clock-test.cpp

```
1  #include <iostream>      /* File: test-clock.cpp */
2  using namespace std;
3  #include "clock-w-static-fcn.h"
4
5  int main()
6  {
7      Clock c1;                          // 0:00
8      Clock c2 = Clock::HHMM(123);       // 1:23
9      Clock c3 = Clock::minutes(123); // 2:03
10
11     cout << c1 << endl;
12     cout << c2 << endl;
13     cout << c3 << endl;
14
15     return 0;
16 }
```

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

```
1   #include <iostream>      /* File: car.h */
2   using namespace std;
3
4   class Car
5   {
6     public:
7       Car()  { ++num_cars; }
8       ~Car() { --num_cars; }
9
10      void drive(int km) { total_km += km; }
11      static int cars_still_running() { return num_cars; }
12
13    private:
14      static int num_cars;
15      int total_km = 0;
16  };
```

Example: Class Car — car.cpp

```
1  #include "car.h" /* File: test-car.cpp */
2  int Car::num_cars = 0; // Define + initialize static class member
3
4  int main()
5  {
6      cout << Car::cars_still_running() << endl;
7      Car vw;  vw.drive(1000);
8      Car bmw; bmw.drive(10);
9      cout << Car::cars_still_running() << endl;
10
11     Car *cp = new Car[100];
12     cout << Car::cars_still_running() << endl;
13
14     {
15         Car kia; kia.drive(400);
16         cout << Car::cars_still_running() << endl;
17     }
18     cout << Car::cars_still_running() << endl;
19     delete [] cp;
20     cout << Car::cars_still_running() << endl; return 0;
21 }
```

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

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

  after compilation becomes:

```
1  void Car::drive(Car* this, int km) { this->total_km+=km; }
```

- On the other hand, a static method of **Car** such as

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

  after compilation becomes:

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