Ch 14: More About Classes

CS 2308
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14.1 Instance and Static Members

- instance variable: a member variable in a class. Each object (instance) has its own copy.
- static variable: one variable shared among all objects of a class
- static member function:
  - can be used to access static member variable;
    - normal functions can access static member variables, too
  - but it cannot access instance variables
  - can be called like a standalone function

Tree class declaration

```
// Tree class
class Tree  {
  private:
    static int objectCount;
    int numOfLeaves;
  public:
    Tree(int);
    int getObjectCount();
    int getNumOfLeaves();
};

// Definition of the static member variable, written
// outside the class.
int Tree::objectCount = 0;

// Member functions defined
Tree::Tree(int lvs) {
   objectCount++;
   numOfLeaves = lvs;
}

int Tree::getObjectCount() { return objectCount;}
int Tree::getNumOfLeaves() { return numOfLeaves;}
```

Static member variable **declared** here

Static member variable **defined** here (required)

Static variable is incremented each time Tree is constructed.

Program demo of static variable

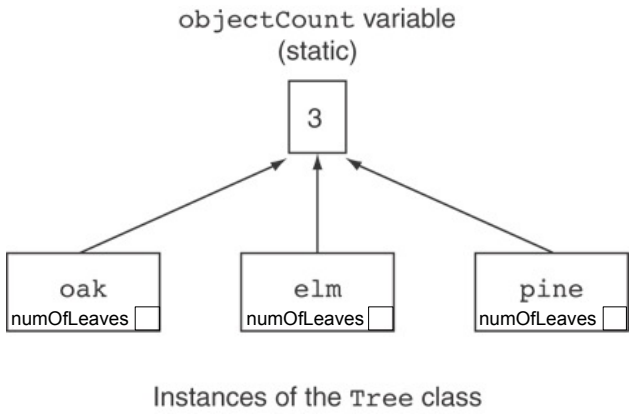
```
#include <iostream>
using namespace std;
#include "Tree.h"

int main() {
   Tree oak(305);
   Tree elm(1045);
   Tree pine(999);

   cout << "We have " << pine.getObjectCount()
        << "Trees in our program.\n";
   cout << "The pine tree has " << pine.getNumOfLeaves()
        << "leaves.\n";
}
```

What will be the output?

Three instances of the Tree class, but only one objectCount variable



Instances of the `Tree` class

static member function

- Declared with `static` before return type:

```
static int getObjectCount();
```

Put in the class declaration

- Static member functions can access static member data **only**

```
int Tree::getObjectCount() {
   return objectCount;
}
```

Don't need static keyword here.

- Can be called independently of objects (use class name):

```
cout << "We have " << Tree::getObjectCount()
     << "Trees in our program.\n";
```


14.3 Member-wise Assignment

- Can use "=" to
  - **assign** (copy) one object to another, or
  - **initialize** an object with another object's data
- Copies member to member. e.g., Just like = for structs

```
instance2 = instance1;  //Note: assignment
```

means: copy all member values from instance1 and assign to the corresponding member variables of instance2

- Also used at initialization: `Time t2 = t1;`

Member-wise assignment: demo

```
Time t1(10, 20);
Time t2(12, 40);

cout << "t1: " << t1.display() << endl;
cout << "t2: " << t2.display() << endl;

t2 = t1;

cout << "t1: " << t1.display() << endl;
cout << "t2: " << t2.display() << endl;
```

```
t2 = t1; //equivalent to:
t2.hour = t1.hour;
t2.minute = t1.minute;
```

```
Output:
t1: 10:20
t2: 12:40
t1: 10:20
t2: 10:20
```

14.4 Copy Constructors

- Special constructor used when a newly created object is **initialized** using another object of the **same class**.

```
Time t1;
Time t2 (t1);
Time t3 = t1;
```

Both of the last two use the copy constructor

  - [used implicitly when passing arguments by value]
- The **default** copy constructor copies field-to-field (member-wise assignment).
- Default copy constructor works fine in many cases

IntCell declaration

- Problem: what if the object contains a pointer?

```
class IntCell
{
   private:
      int *storedValue;   //ptr to int

   public:
      IntCell (int initialValue);
      ~IntCell();
      int read () const;
      void write (int x);
};
```


IntCell Implementation

```
#include "IntCell.h"

IntCell::IntCell (int initialValue) {
  storedValue = new int;
  *storedValue = initialValue;
}

IntCell::~IntCell() {
  delete storedValue;
}

int IntCell::read () const {
  return *storedValue;
}

void IntCell::write (int x) {
  *storedValue = x;
}
```


Problem with member-wise assignment

- What we get from member-wise assignment in objects containing dynamic memory (ptrs):

```
IntCell object1(5);
IntCell object2 = object1; // calls copy constructor

  //object2.storedValue=object1.storedValue

object2.write(13);
cout << object1.read() << endl;
cout << object2.read() << endl;
```

What is output?

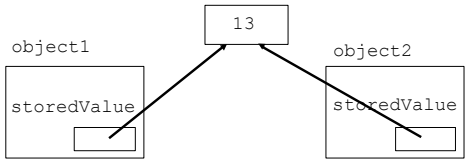
```
5
13
```

or

```
13
13
```

Problem with member-wise assignment

- Why are they both changed to 13?
- Member-wise assignment does a shallow copy. It copies the pointer's address instead of allocating new memory and copying the value.
- As a result, both objects point to the same location in memory



Programmer-Defined Copy Constructor

- Prototype and definition of copy constructor:

```
IntCell(const IntCell &obj);
```

Add to class declaration

```
IntCell::IntCell(const IntCell &obj) {
   storedValue = new int;
   *storedValue = obj.read();  //or *(obj.storedValue)
   //or even: write(obj.read);
}
```

- Copy constructor takes a **reference** parameter to an object of the class
  - otherwise, pass-by-value would use the copy constructor to initialize the obj parameter, which would call the copy constructor: this is an infinite loop

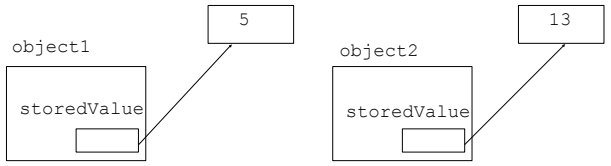
Programmer-Defined Copy Constructor

Each object now points to separate dynamic memory:

```
IntCell object1(5);
IntCell object2 = object1;  //now calls MY copy constr

object2.write(13);
cout << object1.read() << endl;
cout << object2.read() << endl;
```

Output:
5
13



Copy Constructor: limitations

- Copy constructor is called ONLY during initialization of an object, NOT during assignment.
- If you use assignment with IntCell, you will **still** end up with member-wise assignment and a shared value:

```
IntCell object1(5);
IntCell object2(0);
object2 = object1;
// object2.storedValue = object1.storedValue

object2.write(13);
cout << object1.read() << endl;
cout << object2.read() << endl;
```

Output:
13
13

14.5 Operator Overloading

- Operators such as =, +, <, … can be defined to work for objects of a programmer-defined class
- The name of the function defining the over-loaded operator is `operator` followed by the operator symbol:
  `operator+` to define the + operator, and
  `operator=` to define the = operator
- Just like a regular member function:
  - Prototype goes in the class declaration
  - Function definition goes in implementation file

Operator Overloading

- Prototype in Time class declaration:

```
int operator- (Time right);
```

t1 - t2 will return the total number of minutes between t1 and t2

- `operator-` is the function name
- The operator function is defined from the per-spective of the object on the left side of the minus
  - inside the operator- function definition, `hour` and `minute` will be from the left hand side (t1)
- `Time right` is the parameter for the right hand side of operator (t2).
  - inside the operator- function definition, `right.hour` and `right.minute` will be from the right hand side (t2)

Calling an Overloaded Operator

- The operator function is called on the object on the left side of the operator
- It can be called like a normal member function:

```
int minutes = object1.operator-(object2);
```

- It can also be called using the more conventional operator syntax:

```
int minutes = object1 - object2;
```

This is the main reason to overload operators, so you can use this syntax for objects of your class

- Both call the same `operator-` function, from the perspective of object1

Example: minus for Time objects

Subtraction

```
class Time {
   private:
     int hour, minute;
   public:
     int operator- (Time right);
};

int Time::operator- (Time right) {     //Note: 12%12 = 0
   return (hour%12)*60 + minute -
          ((right.hour%12)*60 + right.minute);
}

int main() {
  Time time1(12,20), time2(4,40);
  int minutesDiff = time2 - time1;
  cout << minutesDiff << endl;
}
```

Output: 260

Overloading == and < for Time

```
class Time
{
      private:
      int hour;
      int minute;
      void addHour();

    public:
      Time();
      Time(int);
      Time(int,int);
      void addMinute();    //adds one minute
      void addMinute(int); //adds n minutes
      int getHour();
      int getMinute();

      int operator- (Time right);
      bool operator== (Time right);
      bool operator< (Time right);

      void setHour(int);
      void setMinute(int);

      string display();
};
```


Overloading == and < for Time

```
bool Time::operator== (Time right) {
   if (hour == right.hour && minute == right.minute)
      return true;
   else
      return false;
}

bool Time::operator< (Time right) {
   if (hour == right.hour)
      return (minute < right.minute);
   return (hour%12) < (right.hour%12);
}

int main() {
  Time time1(12,20), time2(12,21);
  if (time1<time2) cout << "correct" << endl;
  time1.addMinute();
  if (time1==time2) cout << "correct again"<< endl;
}
```


Overloading + for Time

```
class Time {
  private:
    int hour, minute;
  public:
    Time operator+ (Time right);
};
Time Time::operator+ (Time right) { //Note: 12%12 = 0
  int totalMin = (hour%12)*60 + minute +
           (right.hour%12)*60 + right.minute;
  int h = totalMin / 60;  //integer division, total hours
  h = h%12;               //keep it between 0 and 11
  if (h==0) h = 12;       //convert 0:xx to 12:xx
  Time result(h, totalMin % 60);  //create new Time obj
  return result;
}
int main() {
  Time t1(12,5);
  Time t2(2,50);
  Time t3 = t1+t2;
  cout << t3.display() << endl;
}
```

Output: 2:55

Overload = for IntCell

```
class IntCell {
   private:
      int *storedValue;
   public:
      IntCell(const IntCell &obj);
      IntCell(int);
      ~IntCell();
      int read() const;
      void write(int);
      void operator= (IntCell);
};

void IntCell::operator= (IntCell rhs) {
   write(rhs.read());
}

//in a driver:
IntCell object1(5), object2(0);
object2 = object1;
object2.write(13);
cout << object1.read() << endl;   //object1 is unchanged
```

Now = for IntCell will **not** use member-wise assignment

Output: 5