C/C++ Programming Language

CS205 Spring

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Lecture 11

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Content

- Review
- An example of string class: problems
- Compiler automatically generates functions
  - Default constructors
  - Copy constructors
  - Assignment operators
- Improved string class
  - Comparison, accessing characters
- Pointers to objects

Brief Review

Review

- Operator Overloading
  - Operator function
  - Friends
  - Example: overloading the << operator
- Automatic Conversions and Type Casts for Classes (=)
  - Type cast from single augment to an object (constructor)
    - ✓Implicit constructor
    - ✓Explicit constructor
  - Conversion function (operator)

Dynamic Memory and Classes

The Reasons for Dynamic Memory

- Problems: some things were not confirmed during programming
  - What would you like for breakfast, lunch, and dinner for the next month?
  - How many ounces of milk for dinner on the 3rd day?
  - How many raisins in your cereal for breakfast on the 15th day?
- Letting the program decide about memory during runtime rather than during compile time
  - Memory use can depend on the needs of a program instead of on a rigid set of storage-class rules
  - C++ utilizes the new and delete operators
    - ✓ Destructors can become necessary
    - ✓ Have to overload an assignment operator to get a program to behave properly

A Review Example and Static Class Members

- Run vegnews.cpp, strbad.h, strbad.cpp
- Problems
  - Passing an object as a function argument somehow causes the destructor to be called
  - Although passing by value is supposed to protect the original argument from change, the function messes up the original string beyond recognition, and some nonstandard characters get displayed
  - The number of constructor calls does not equal the number of destructor calls
- Compiler automatically generates the constructor

```
StringBad sailor = sports;

StringBad sailor = StringBad(sports); //constructor using sports
```

Special Member Functions

- C++ automatically provides the following member functions
  - A default constructor if you define no constructors
  - A copy constructor if you don't define one
  - An assignment operator if you don't define one
  - A default destructor if you don't define one
  - An address operator if you don't define one

Default Constructors

- C++ provides you with a default constructor, if you fail to provide any constructors at all

```
Klunk::Klunk() { }  // implicit default constructor
```

- Define a default constructor explicitly
  - No arguments
  - Or all its arguments have default values
- Can have only one default constructor

```
Klunk() { klunk_ct = 0 }              // constructor #1
Klunk(int n = 0) { klunk_ct = n; }    // ambiguous constructor #2
```

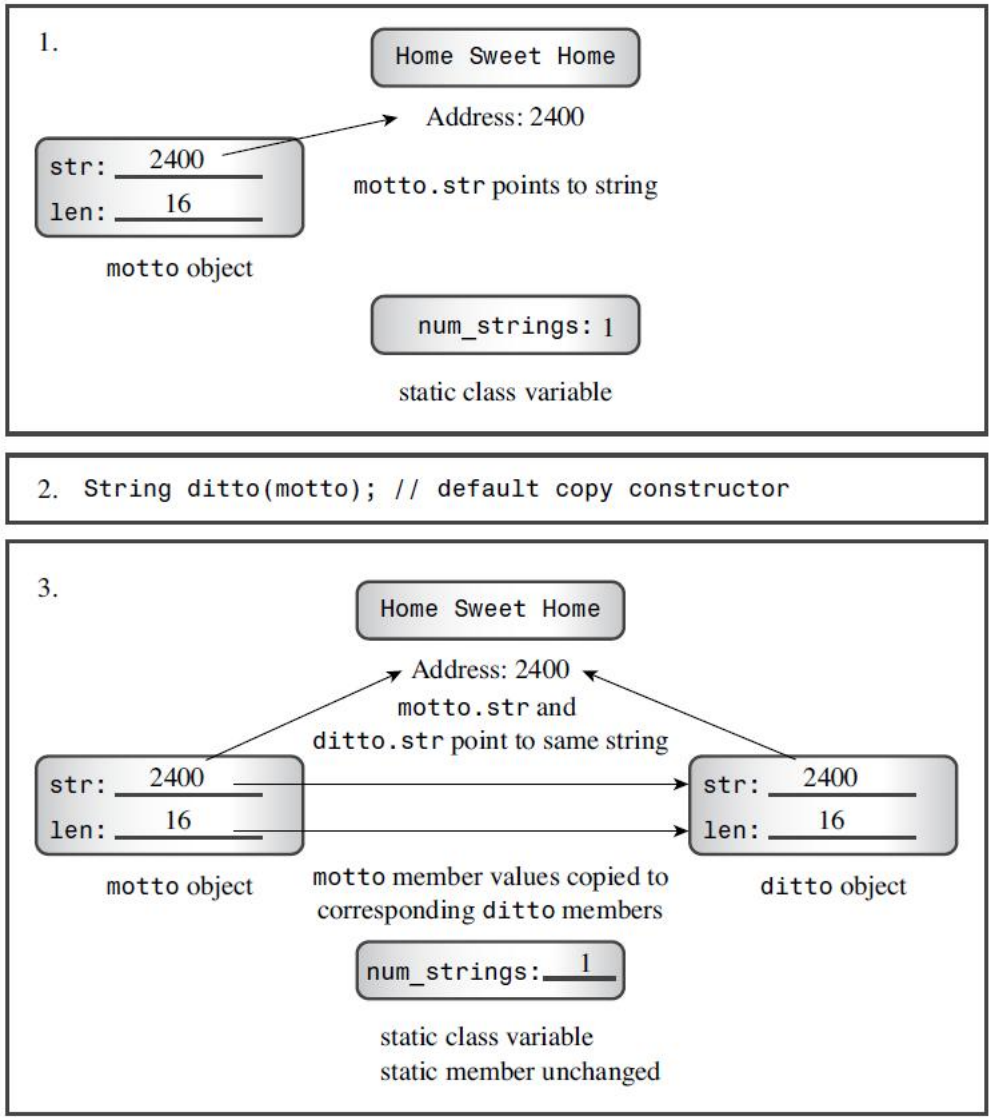
```
Klunk kar(10);     // clearly matches Klunt(int n)
Klunk bus;         // could match either constructor
```

Copy Constructors

- A copy constructor is used to copy an object to a newly created object
- When a copy constructor is used
  - A copy constructor is invoked whenever a new object is created and initialized to an existing object of the same kind
  - A compiler also uses a copy constructor whenever it generates temporary objects (passing value to functions)
- What a **default** copy constructor does
  - Perform a member-by-member copy of the **nonstatic** members
  - Static members are unaffected because they belong to the class as a whole instead of to individual objects

Default Copy Constructors

- An inside look at member-wise copying
- Two problems
  - Point to the same address
  - Static variables unchanged



Back to Stringbad: Where the Copy Constructor Goes Wrong

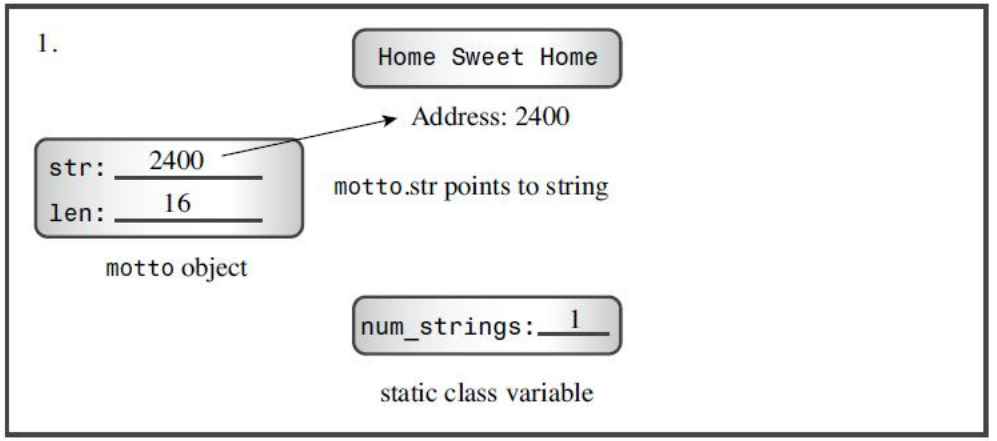
- First problem: two more objects destroyed than constructed
  - Default copy constructor doesn't increment the counter. However, the destructor does update the counter
  - The solution is to provide an explicit copy constructor
- Second problem: default copy constructor does not copy the string; it copies the pointer to a string
  - The same memory location that has already been freed by the destructor

Fixing the Problem by Defining an Explicit Copy Constructor

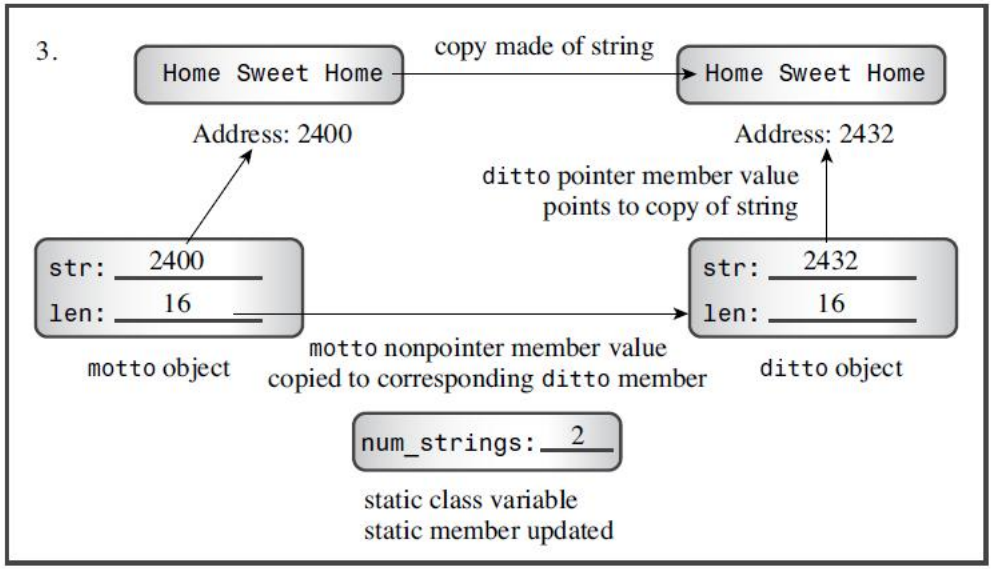
- The explicit copy constructor
  - Duplicate the string
  - Assign the address of the duplicate to the member

```
StringBad::StringBad(const StringBad & st)
{
    num_strings++;              // handle static member update
    len = st.len;               // same length
    str = new char [len + 1];   // allot space
    std::strcpy(str, st.str);   // copy string to new location
    cout << num_strings << ": \"" << str
         << "\" object created\n"; // For Your Information
}
```

- Uncomment copy constructor




```
2.  String ditto(motto); // deep copy constructor
```



More Stringbad Problems: Assignment Operators

- Default assignment operator
  - Allow class object assignment
  - Automatically overload an assignment operator for a class

```
Class_name & Class_name::operator=(const Class_name &);
```

- When an assignment operator is used and what it does
  - Assign one object to another ***existing*** object
  - Not used when initializing an object (copy constructor)
- What a default assignment operator does (the same to copy)
  - Perform a member-to-member copy
  - Static data members are unaffected

Default Assignment Operators

- Where assignment goes wrong
  - Cause both pointers to point to the same address
  - Attempt to delete the previously deleted string
  - How about static variables?
- Fixing assignment
  - Be similar to that of the copy constructor but have differences
    - ✓ Proceed to free the memory (existing object worked for previous tasks)
    - ✓ Protect against assigning an object to itself
    - ✓ Return a reference to the invoking object

```
S0 = S1 = S2;

S0.operator=(S1.operator=(S2));
```

```
StringBad & StringBad::operator=(const StringBad & st)
{
    if (this == &st)            // object assigned to itself
        return *this;           // all done
    delete [] str;              // free old string
    len = st.len;
    str = new char [len + 1];   // get space for new string
    std::strcpy(str, st.str);   // copy the string
    return *this;               // return reference to invoking object
}
```

- Revisit program

The New, Improved String Class

Add More Capabilities to the Class

- Add following methods

```
int length () const { return len; }
friend bool operator<(const String &st, const String &st2);
friend bool operator>(const String &st1, const String &st2);
friend bool operator==(const String &st, const String &st2);
friend operator>>(istream & is, String & st);
char & operator[](int i);
const char & operator[](int i) const;
static int HowMany();
```

Comparison

Print

Accessing

Static member

- Run sayings1.cpp, string1.h, string1.cpp

Comparison Members

- Use the standard strcmp() function
  - Return a negative value if its first argument precedes the second alphabetically
  - Return 0 if the strings are the same
  - Return a positive value if the first follows the second alphabetically
- And use built-in < operator

```
bool operator<(const String &st1, const String &st2)
{
    return (std::strcmp(st1.str, st2.str) < 0);
}
bool operator>(const String &st1, const String &st2)
{
    return st2 < st1;
}
bool operator==(const String &st1, const String &st2)
{
    return (std::strcmp(st1.str, st2.str) == 0);
}
```

Accessing Characters by Using Bracket Notation

```
char city[40] = "Amsterdam";
cout << city[0] << endl; // display the letter A
```

- A standard C-style string
  - Use brackets to access individual characters
- In C++, the two bracket symbols constitute a single operator
  - Place one operand in front of the first bracket
  - Place the other operand between the two brackets
- Declaring the return type as type char & allows you to assign values to a particular element

```
char & String::operator[](int i)
{
    return str[i];
}
```

```
String means("might");
means[0] = 'r';
```

Static Class Member Functions

- Declare a member function as being static
  - The keyword static should appear in the function declaration but not in the function definition
  - Doesn't have to be invoked by an object
  - Doesn't get a this pointer to play with
  - Public static function can be invoked using the class name and the scope-resolution operator
  - The only data members it can use are the static data members

```
static int HowMany() { return num_strings; }

int count = String::HowMany();  // invoking a static member function
```

Further Assignment Operator Overloading

- Copy an ordinary string to a String object which is user-defined

```
String name;
char temp[40];
cin.getline(temp, 40);
name = temp;  // use constructor to convert type
```

- If there is no op. overloading
  - Three steps:
    - ✓ Use the String(const char *) constructor to construct a temporary String object containing a copy of the string stored in temp
    - ✓ Use the String & String::operator=(const String &) function to copy information from the temporary object
    - ✓ Call the ~String() destructor to delete the temporary object
- Overload the assignment operator
  - One step

```
String & String::operator=(const char * s)
{
    delete [] str;
    len = std::strlen(s);
    str = new char[len + 1];
    std::strcpy(str, s);
    return *this;
}
```

Things to Remember When Using new in Constructors

- Use new to initialize a pointer member in a constructor and use delete in the destructor
- The uses of new and delete should be compatible
- For multiple constructors, all should use new the same way
- Define a copy constructor that initializes one object to another
  - Copy the data, not just the address of the data (why?)
  - Update any static class members (why?)
- Define an assignment operator that copies one object to another
  - Copy the data, not just the address of the data (why?)
  - Check for self-assignment, free memory, and return a reference (why?)

Observations About Returning Objects

- Returning a const reference to a const object
  - The usual reason for using a reference is efficiency
  - Doesn't invoke the copy constructor
  - Exist when the calling function is executing

```
Vector force1(50,60);
Vector force2(10,70);
Vector max;
max = Max(force1, force2);
```

- Returning a reference to a non-const object
  - Overloading the assignment operator (efficiency)
  - Overloading the << operator for use with cout (necessity)

```
String s1("Good stuff");
String s2, s3;
s3 = s2 = s1;
```

```
String s1("Good stuff");
cout << s1 << "is coming!";
```

- Returning an object (overloaded arithmetic operators)
  - Local object should not be returned by reference
- Run sayings1.cpp, string1.h, string1.cpp

```
Vector force1(50,60);
Vector force2(10,70);
Vector net;
net = force1 + force2;
```

Using Pointers to Objects

Use New and Delete on Two Levels

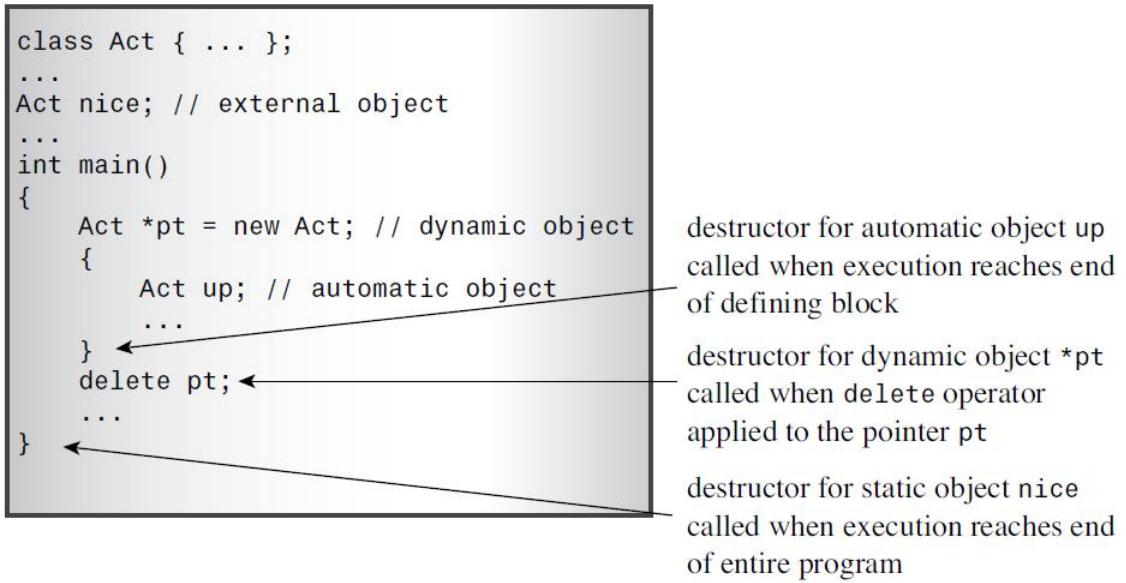
- Run sayings2.cpp (.h, .cpp files in the previous example)
  - Member pointers (scope-resolution operator)
    - ✓ Allocate storage space for each object that is created
    - ✓ Happen in the constructor functions
    - ✓ Destructor functions use delete to free that memory with brackets
  - Pointers point to objects (dereference)

```
String * favorite = new String(sayings[choice]);
```

    - ✓ Provide the only access to the **nameless** object created by new
    - ✓ Constructors allocate space and assign the address to member pointer
    - ✓ Use delete to delete this object when it is finished with it
    - ✓ Static member is stored separately from the objects

Destructor Takes Care of the Final Task

- Destructors are called in the following situations
  - If an object is an automatic variable, the object's destructor is called when the program exits the block
  - If an object is a static variable (external, static, static external, or from a namespace), its destructor is called when the program terminates
  - If an object is created by new, its destructor is called only when you explicitly use delete on the object



Summary 1 of Pointers for Objects

- Pointers and objects

Declaring a pointer to a class object:

```
String * glamour;
```

Initializing a pointer to an existing object:

```
String * first = &sayings[0];
```

(`String` object)

Initializing a pointer using `new` and the default class constructor:

```
String * gleep = new String;
```

Initializing a pointer using `new` and the `String(const char*)` class constructor:

```
String * glop = new String("my my my");
```

Initializing a pointer using `new` and the `String(const String &)` class constructor:

```
String * favorite = new String(sayings[choice]);
```

(`String` object)

Using the -> operator to access a class method via a pointer:

```
if (sayings[i].length() < shortest->length())
```

(`sayings[i]`: object; `shortest`: pointer to object)

Using the * deferencing operator to obtain an object from a pointer:

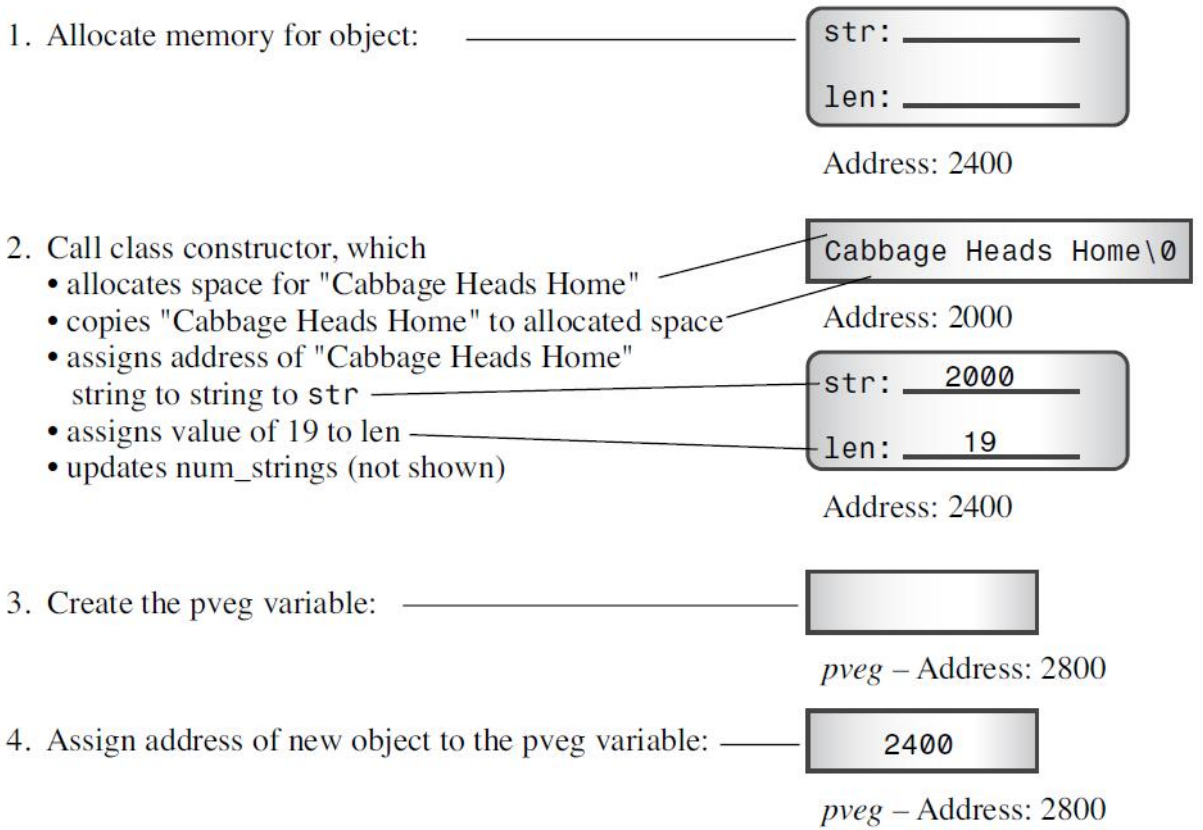
```
if (sayings[i] < *first)
```

(`sayings[i]`: object; `*first`: pointer to object)

Summary 2 of Pointers for Objects

- Creating an object with new

```
String *pveg = new String("Cabbage Heads Home");
```



Looking Again at Placement new

- Placement new
  - Allow you to specify the memory location used to allocate memory
- Run placenew1.cpp
  - Problems
    - ✓ Placement new overwrites the same location used for the first object with a new one
    - ✓ Using delete [] with buffer does not invoke the destructors for the objects created with placement new
- Solution 1
  - Manage the memory locations

```
pc1 = new (buffer) JustTesting;
pc3 = new (buffer + sizeof (JustTesting)) JustTesting("Better Idea", 6);
```

Arrange for Destructors for Placement new

- Reasons of the second problem:
  - delete works in conjunction with new but not with placement new
  - pc3 does not receive an address returned by new
  - pc1 has the same numeric value as buffer
  - delete [] buffer doesn't call the destructors for any objects
- Solution 2: arrange for the destructors to be called
  - Call the destructor explicitly for any object created by placement new
- Run placenew2.cpp

```
pc3->~JustTesting();  // destroy object pointed to by pc3
pc1->~JustTesting();  // destroy object pointed to by pc1
```

Reviewing Techniques

- Overloading the << operator

```
ostream & operator<<(ostream & os, const c_name & obj)
{
    os << ... ;  // display object contents
    return os;
}
```

- Conversion functions
  - Convert a single value to a class type

```
c_name(type_name value);
```

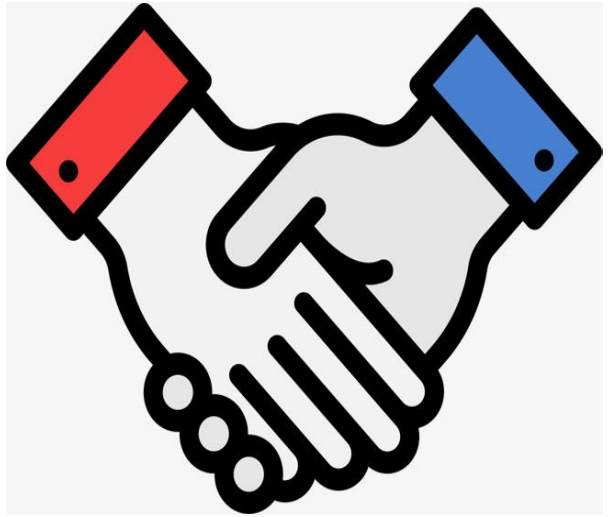
  - Convert a class type to some other types

```
operator type_name();
```

  - Keyword explicit when declaring a constructor to prevent it from being used for implicit conversions

Reviewing Techniques

- Classes whose constructors use new
  - Any class member that points to memory allocated by new should have the delete operator applied to it in the class destructor
  - If a destructor frees memory by applying delete to a pointer, every constructor should initialize that pointer, either by using new or by setting the pointer to the null pointer
  - Constructors should use either new [] or new, but not a mixture
  - Define a copy constructor that allocates new memory rather than copying a pointer to existing memory
  - Define a class member function that overloads the assignment operator



Thanks

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