CS11 – Advanced C++

Spring 2012-2013

Lecture 7

Today's Topics

- All about casting in C++
  - Implicit casting
  - **`explicit`** keyword on constructors
  - Explicit casting in C++
  - **`mutable`** keyword and **`const`**

Implicit Type-Conversions

- C++ has *implicit* type-conversions for primitive types
  - You don't explicitly cast from one type to the other
  - They just happen, without warning! ☺
- Promotions
  - Value is preserved, no information is lost
  - Examples: **`char`** → **`int`**, **`bool`** → **`int`**
- Conversions
  - Value may actually change or become invalid
  - Examples: **`double`** → **`char`**, **`double`** → **`float`**
- Beware! Compiler doesn't give you much help!

Conversion of User-Defined Types

- Can define implicit conversion ops for user-types

```
class Rational {
public:
  Rational(int num, int denom);
  ...
  // Convert from Rational to double
  operator double() const;
};
```

  - Provides implicit conversion from **`Rational`** to **`double`**

```
Rational r(1, 2);    // r is 1/2
double d = 0.5 * r;
```

  - **`r`** is converted to **`double`**, then multiplication is performed

Unexpected Results!

- Now you want to print **`Rational`** values with **<<**
  - Print them as "num/denom"
  - …but, you forgot to implement **<<**
- You write this code:

```
Rational r(1, 2);
cout << r;
```

  - You expect this to print **`1/2`**
  - (Or, actually, to not compile since you didn't implement **<<**)
  - But it *does* compile, and it prints out **`0.5`**
  - Not too surprising, just subtle.

Crafty Compilers

- Compiler sees no **<<** for **`Rational`**
  - "But **`Rational`** can be converted to **`double`**, and **`double`** can be output with **<<**…"
- Problem:
  - Implicit conversion operations can produce unexpected or undesirable results!
  - Violates the "Law of Least Surprise"
- Moral:
  - Be *very* careful with implicit conversion operations
  - Better yet, don't use them:

```
double Rational::asDouble() { ... }
```

More Implicit Conversion Options

- Single-argument constructors *also* enable implicit conversions in C++
- Example:

```
Rational(int num = 0, int denom = 1);
```

  - Defines default values for arguments
  - Also allows **`int`**s to be converted to **`Rational`**s

```
Rational r1(3);    // r1 = 3/1
Rational r2 = 5;   // r2 = 5/1
r1 = 6;            // r1 = Rational(6)
```

  - Compiler figures out the conversions to use!

Another Implicit Conversion Example

- An integer-array class:

```
class Array {
  ...
public:
  Array(int size);

  int & operator[](int index);

  bool operator==(const Array &) const;
  bool operator!=(const Array &) const;
};
```

More Unexpected Results

- Want to compare two arrays:

```
Array a(10), b(10);
...
for (int i = 0; i < 10; i++) {
  if (a == b[i]) {
    ... // Do stuff!
  }
}
```

- Oops; meant to type **`a[i] == b[i]`**
  - But, the code compiles!
- What happens:
  - Compiler guesses this: **`a == Array(b[i])`**
  - Wrong, not to mention *terribly* inefficient!

Disallowing Implicit Conversions

- Compiler should complain in these cases
  - Don't want it to make up stuff that compiles, but that you didn't mean!
- Enter the **`explicit`** keyword
  - Added to C++ *specifically* because of these issues
  - Can declare constructors to be **`explicit`**
  - C++ won't use them for implicit conversions
- Example:

```
explicit Array(int size);
```

Default Parameters and `explicit`

- If constructor can take just one argument, it will be used as an implicit conversion
  - …even multi-arg constructors with default values
- **`Rational`** example again:

```
Rational(int num = 0, int denom = 1);
```

  - Defines default values for arguments
  - *Also* provides implicit conversion from **`int`**
- Can also use **`explicit`** here:

```
explicit Rational(int num = 0, int denom = 1);
```

  - No longer allows implicit conversions from **`int`**

Explicit Casts in C and C++

- C has one explicit cast operator for everything
  - Can convert between related types
    - e.g. **`double`** to **`int`**
  - Can cast pointers to different types
    - e.g. **`void*`** to **`float*`**, or **`float*`** to **`char*`**
  - Can cast pointers to **`int`**, and vice versa
  - Can cast away **`const`**-ness
  - *Many unsafe or potentially unsafe scenarios!*
- C++ provides <u>four</u> explicit casting operators
  - Breaks down different kinds of casts into explicit operations
  - Provides more type-safety checks at compile-time, run-time
  - Easier for programmers to understand, too

C++ Cast Operations

- **`const_cast`**
  - Casts away **`const`**-ness
- **`static_cast`**
  - Performs safe conversions between related types, using static (compile-time) type information
- **`dynamic_cast`**
  - Uses runtime type information to safely cast down or across class hierarchies
- **`reinterpret_cast`**
  - For all the dangerous stuff.

Removing **`const`** Constraints

- **`const_cast`** removes **`const`** constraints
  - **`T const_cast<T>(const T value)`**
- Not for changing the type of **`value`** !
  - Using **`const_cast`** to change types will not compile
- Examples:

```
void output(SpecialWidget *psw);

const SpecialWidget csw;
output(&csw);                                   // COMPILE ERROR
output(const_cast<SpecialWidget*>(&csw));       // OK

Widget *pw = new SpecialWidget();
output(const_cast<SpecialWidget*>(pw));         // COMPILE ERROR
```

Cached Values and **`const`**

- **`const_cast`** sometimes used when objects cache temporary values that are expensive to compute

```
class Date {
    ...
    string cache;
    bool cacheValid;
    void updateCacheVals();    // sets cache value
public:
    ...
    string stringRep() const;
};
```

  - **`stringRep()`** returns a **`string`** version of the date value
  - Cache the result, as long as date value doesn't change

Cached Values and `const` (2)

- Implementation of **`stringRep()`**

```
string Date::stringRep() const {
    if (!cacheValid) {
        // Type of this is "const Date *", so
        // cast to non-const Date *
        Date *mut = const_cast<Date *>(this);
        mut->updateCacheVals();
        mut->cacheValid = true;
    }
    return cache;
}
```

  - **`this`** is **`const`** because the member function is **`const`**
  - Must *cast away* **`const`** to update cached values!

Cached Values and `const` (3)

- That solution isn't very elegant.
- Also, it might not actually work!
  - If original <u>variable</u> is declared as const, casting away const is not guaranteed to work on all implementations
    - e.g. compiler or OS might store variable in read-only memory
- Example:

```
Date d1;
const Date d2;
string s1 = d1.stringRep();
string s2 = d2.stringRep();  // ???
```

  - **`s2`** is not guaranteed to have a valid result across all implementations

Mutable Data-Members

- Better solution is to use the **`mutable`** keyword

```
class Date {
    ...
    mutable string cache;
    mutable bool cacheValid;
    void updateCacheVals() const;
public:
    ...
    string stringRep() const;
};
```

  - Compiler will ensure that **`cache`** can be changed, even on variables declared **`const`**
- **`mutable`** means "can never be **`const`**"

Mutable Data-Members (2)

- Implementation of **`stringRep()`** gets simpler:

```
string Date::stringRep() const {
    if (!cacheValid) {
        // Only mutable data-members are changed.
        updateCacheVals();
        cacheValid = true;
    }
    return cache;
}
```

- And this will always work now:

```
Date d1;
const Date d2;
string s1 = d1.stringRep();
string s2 = d2.stringRep();  // OK!
```

Proper Uses of `const_cast`

- **`const_cast`** is best for situations when a function doesn't use **`const`**, but it ought to!
  - The function doesn't change the argument, but argument wasn't declared **`const`** (usually by mistake)
- Example: dealing with bad standard library impls.

```
size_t strlen(char *s);  // should be const char *

const char *prompt = "Shall we play a game?";
size_t length = strlen(const_cast<char*>(prompt));
```

- *Very* uncommon situation!
  - You shouldn't need **`const_cast`** very often

Static Casts

- **`static_cast`** converts between related types
  - **`static_cast<T>(value)`**
  - Converts **`value`** to type **`T`**
  - Only uses static type information (compile-time check)
- Example use-cases:
  - Convert from an integer type to an enumeration
  - Convert from a floating-point type to an integer type
  - Convert from one pointer-type to another
    - Typically, within the same class hierarchy
- Example:

```
int *p = static_cast<int*>(malloc(100 * sizeof(int)));
```

  - **`malloc()`** returns a **`void*`** which needs to be casted

Dynamic Casts

- **`dynamic_cast`** converts between types in a class hierarchy, using run-time type information
  - **`dynamic_cast<T>(value)`**
  - **`T`** must be a pointer or reference to a polymorphic type (a class with **`virtual`** member-functions)
  - Performs a run-time type-check to see if **`value`** can be cast to **`T`**
    - If so, conversion takes place and result has type **`T`**
    - If not, **`dynamic_cast`** evaluates to 0 !
- Mainly used to cast a base-class pointer/reference to a derived class.
- Has very complex behavior with multiple inheritance!

Static and Dynamic Casts

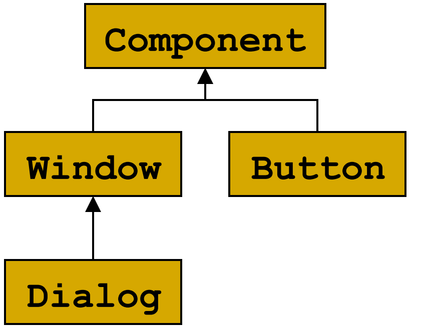
- Static casts are faster than dynamic casts
  - Compile-time check vs. a runtime check
- Static casts can't move down a class hierarchy
  - Requires run-time information about objects
- Example:

```
class Widget { };
class SpecialWidget : public Widget { };
Widget *pw = new SpecialWidget();

// COMPILE ERROR:  static type of pw is Widget*
SpecialWidget *spw = static_cast<SpecialWidget*>(pw);

// OK:  pw points to a SpecialWidget
SpecialWidget *spw = dynamic_cast<SpecialWidget*>(pw);
```

Static and Dynamic Cast Examples




```
Dialog *d = new Dialog();
Window *w = static_cast<Window *>(d);
// OK, compile-time check (fast)

Button *b = new Button();
Component *c = dynamic_cast<Component *>(b);
// OK, runtime check (slower)

Button *b2;
b2 = static_cast<Button *>(c);     // COMPILE ERROR
b2 = dynamic_cast<Button *>(c);    // OK, b2 == b

Dialog *d2;
d2 = static_cast<Dialog *>(b);     // COMPILE ERROR
d2 = dynamic_cast<Dialog *>(b);    // OK, d2 == 0
```

Reinterpreting Values

- **`reinterpret_cast<T>(value)`**
  - Converts between <u>unrelated</u> types
  - Again, converts **`value`** to type **`T`**
- Example use-cases:
  - Convert an integer to a pointer, or vice versa
  - Convert a pointer to a completely unrelated pointer type
  - If destination type is same bit-width, the result's bit-pattern is same as the source's bit-pattern
- Should need **`reinterpret_cast`** very rarely
  - If you do need it, encapsulate this functionality inside a class, and don't expose it to others!
  - (Make sure you really *do* need it!)

Reinterpreting Values (2)

- Example:
  - An API that represents windows and other GUI components with handles

```
/** Clears the specified window. **/
void clearWindow(int handle) {
    Window *pWnd = reinterpret_cast<Window*>(handle);
    ...
}
```

  - API users aren't exposed to implementation details
- A safer solution?
  - The API could use an STL **`map`** (or **`hash_map`**) to associate integer handles with GUI components
  - Slower, but less likely to fail spectacularly!

Smart Pointers and Casting

- Important to cast smart-pointers properly!
  - Heap-allocated object may become owned by two non-cooperating smart-pointer objects
- Boost example:

```
typedef boost::shared_ptr<Widget> SPWidget;
typedef boost::shared_ptr<SpecialWidget>
  SPSpecialWidget;

SPWidget spw(new SpecialWidget(35));
```

  - To get at the actual **`T*`** inside, use
    `T* shared_ptr<T>::get()`

Smart Pointers and Casting (2)

- Casting our Boost shared-pointer, take 1:

```
SPWidget spw(new SpecialWidget(35));
...
// Dynamic-cast to a special widget, then
// wrap with a smart-pointer.
SPSpecialWidget spsw(
  dynamic_cast<SpecialWidget *>(spw.get()));
```

- Problems?
  - The smart-pointer wrappers don't know about each other!
  - Each one will try to delete the object when its reference-count goes to zero. One will crash.

Smart Pointers and Casting (3)

- Good smart-pointer classes will provide casting operations for you to use
  - The functions return smart-pointer objects themselves
  - The returned smart-pointer knows that multiple smart-pointers are managing the object
- Casting our Boost shared-pointer, take 2:

```
SPWidget spw(new SpecialWidget(35));
...
// Safely dynamic-cast the smart-pointer.
SPSpecialWidget spsw(
  boost::dynamic_pointer_cast<SpecialWidget>(spw));
```

This Week's Assignment

- Add reflection and cylinders to the raytracer
- Reflection is pretty easy to implement
  - Can generate some cool pictures!
  - Can use default arguments to make it easier
- New scene-object: cylinders
  - Can be oriented along an arbitrary axis
  - Reuse some of the sphere computations
- Update the scene description language