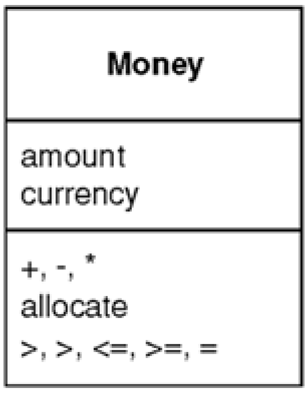
Money

Represents a monetary value.



A large proportion of the computers in this world manipulate money, so it's always puzzled me that money isn't actually a first class data type in any mainstream programming language. The lack of a type causes problems, the most obvious surrounding currencies. If all your calculations are done in a single currency, this isn't a huge problem, but once you involve multiple currencies you want to avoid adding your dollars to your yen without taking the currency differences into account. The more subtle problem is with rounding. Monetary calculations are often rounded to the smallest currency unit. When you do this it's easy to lose pennies (or your local equivalent) because of rounding errors.

The good thing about object-oriented programming is that you can fix these problems by creating a Money class that handles them. Of course, it's still surprising that none of the mainstream base class libraries actually do this.

How It Works

The basic idea is to have a Money class with fields for the numeric amount and the currency. You can store the amount as either an integral type or a fixed decimal type. The decimal type is easier for some manipulations, the integral for others. You should absolutely avoid any kind of floating point type, as that will introduce the kind of rounding problems that *Money* is intended to avoid. Most of the time people want monetary values rounded to the smallest complete unit, such as cents in the dollar. However, there are times when fractional units are needed. It's important to make it clear what kind of money you're working with, especially in an application that uses both kinds. It makes sense to have different types for the two cases as they behave quite differently under arithmetic.

Money is a *Value Object (486),* so it should have its equality and hash code operations overridden to be based on the currency and amount.

Money needs arithmetic operations so that you can use money objects as easily as you use numbers. But arithmetic operations for money have some important differences to money operations in numbers. Most obviously, any addition or subtraction needs to be currency aware so you can react if you try to add together monies of different currencies. The simplest, and most common, response is to treat the adding together of disparate currencies as an error. In some more sophisticated situations you can use Ward Cunningham's idea of a money bag. This is an object that contains monies of multiple currencies together in one object. This object can then participate in calculations just like any money object. It can also be valued into a currency.

Multiplication and division end up being more complicated due to rounding problems. When you multiply money you do it with a scalar. If you want to add 5% tax to a bill you multiply by 0.05, so you see multiplication by regular numeric types.

The awkward complication comes with rounding, particularly when allocating money between different places. Here's Matt Foemmel's simple conundrum. Suppose I have a business rule that says that I have to allocate the whole amount of a sum of money to two accounts: 70% to one and 30% to another. I have 5 cents to allocate. If I do the math I end up with 3.5 cents and 1.5 cents. Whichever way I round these I get into trouble. If I do the usual rounding to nearest then

1.5 becomes 2 and 3.5 becomes 4. So I end up gaining a penny. Rounding down gives me 4 cents and rounding up gives me 6 cents. There's no general rounding scheme I can apply to both that will avoid losing or gaining a penny.

I've seen various solutions to this problem.

- Perhaps the most common is to ignore it—after all, it's only a penny here and there. However this tends to make accountants understandably nervous.
- When allocating you always do the last allocation by subtracting from what you've allocated so far. This avoids losing pennies, but you can get a cumulative amount of pennies on the last allocation.
- Allow users of a Money class to declare the rounding scheme when they call the method. This permits a programmer to say that the 70% case rounds up and the 30% rounds down. Things can get complicated when you allocate across ten accounts instead of two. You also have to remember to round. To encourage people to remember I've seen some Money classes force a rounding parameter into the multiply operation. Not only does this force the programmer to think about what rounding she needs, it also might remind her of the tests to write. However, it gets messy if you have a lot of tax calculations that all round the same way.
- My favorite solution: have an allocator function on the money. The parameter to the allocator is a list of numbers, representing the ratio to be allocated (it would look something like `aMoney.allocate([7,3])`). The allocator returns a list of monies, guaranteeing that no pennies get dropped by scattering them across the allocated monies in a way that looks pseudo-random from the outside. The allocator has faults: You have to remember to use it and any precise rules about where the pennies go are difficult to enforce.

The fundamental issue here is between using multiplication to determine proportional charge (such as a tax) and using it to allocate a sum of money across multiple places. Multiplication works well for the former, but an allocator works better for the latter. The important thing is to consider your intent in using multiplication or division on a monetary value.

You may want to convert from one currency to another with a method like `aMoney.convertTo(Currency.DOLLARS)`. The obvious way to do this is to look up an exchange rate and multiply by it. While this works in many situations, there are cases where it doesn't—again due to rounding. The conversion rules between the fixed euro currencies had specific roundings applied that made simple multiplication unworkable. Thus, it's wise to have a convertor object to encapsulate the algorithm.

Comparison operations allow you to sort monies. Like the addition operation, conversions need to be currency aware. You can either choose to throw an exception if you compare different currencies or do a conversion.

A *Money* can encapsulate the printing behavior. This makes it much easier to provide good display on user interfaces and reports. A Money class can also parse a string to provide a currency-aware input mechanism, which again is very useful for the user interface. This is where your platform's libraries can provide help. Increasingly platforms provide globalization support with specific number formatters for particular countries.

Storing a *Money* in a database always raises an issue, since databases also don't seem to understand that money is important (although their vendors do.) The obvious route to take is to use *Embedded Value (268),* which results in storing a currency for every money. That can be overkill when, for instance, an account may have all its entries be in pounds. In this case you may store the currency on the account and alter the database mapping to pull the account's currency whenever you load entries.

When to Use It

I use *Money* for pretty much all numeric calculation in object-oriented environments. The primary reason is to encapsulate the handling of rounding behavior, which helps reduce the problems of rounding errors. Another reason to use *Money* is to make multi-currency work much easier. The most common objection to *Money* is performance, although I've only rarely heard of cases where it makes any noticeable difference, and even then the encapsulation often makes tuning easier.

Example: A Money Class (Java)

by Matt Foemmel and Martin Fowler

The first decision is what data type to use for the amount. If anyone needs convincing that a floating point number is a bad idea, ask them to run this code.

```
double val = 0.00;
for (int i = 0; i < 10; i++) val += 0.10;
System.out.println(val == 1.00);
```

With floats safely disposed of, the choice lies between fixed-point decimals and integers, which in Java boils down to `BigDecimal`,`BigInteger` and `long`. Using an integral value actually makes the internal math easier, and if we use `long` we can use primitives and thus have readable math expressions.

```
class Money...

   private long amount;
   private Currency currency;
```

I'm using an integral amount, that is, the amount of the smallest base unit, which I refer to as cents in the code because it's as good a name as any. With a long we get an overflow error if the number gets too big. If you give us $92,233,720,368,547,758.09 we'll write you a version that uses `BigInteger`.

It's useful to provide constructors from various numeric types.

```
public Money(double amount, Currency currency) {
   this.currency = currency;
   this.amount = Math.round(amount * centFactor());
}
public Money(long amount, Currency currency) {
   this.currency = currency;
   this.amount = amount * centFactor();
}
   private static final int[] cents = new int[] {1, 10, 100, 1000 };
private int centFactor() {
   return cents[currency.getDefaultFractionDigits()];
}
```

Different currencies have different fractional amounts. The Java 1.4 Currency class will tell you the number of fractional digits in a class. We can determine how many minor units there are in a major unit by raising ten to the power, but that's such a pain in Java that the array is easier (and probably quicker). We're prepared to live with the fact that this code breaks if someone uses four fractional digits.

Although most of the time you'll want to use money operation directly, there are occasions when you'll need access to the underlying data.

```
class Money...

   public BigDecimal amount() {
      return BigDecimal.valueOf(amount,
currency.getDefaultFractionDigits());
   }
   public Currency currency() {
      return currency;
   }
```

You should always question your use of accessors. There's almost always a better way that won't break encapsulation. One example that we couldn't avoid is database mapping, as in *Embedded Value (268).*

If you use one currency very frequently for literal amounts, a helper constructor can be useful.

```
class Money...

   public static Money dollars(double amount) {
      return new Money(amount, Currency.USD);
   }
```

As *Money* is a *Value Object* *(486)* you'll need to define equals.

```
class Money...

   public boolean equals(Object other) {
      return (other instanceof Money) && equals((Money)other);
   }
   public boolean equals(Money other) {
      return currency.equals(other.currency) && (amount == other.amount);
   }
```

And wherever there's an equals there should be a hash.

```
class Money...

   public int hashCode() {
      return (int) (amount ^ (amount >>> 32));
   }
```

We'll start going through the arithmetic with addition and subtraction.

```
class Money...

   public Money add(Money other) {
      assertSameCurrencyAs(other);
      return newMoney(amount + other.amount);
   }
   private void assertSameCurrencyAs(Money arg) {
      Assert.equals("money math mismatch", currency, arg.currency);
   }
   private Money newMoney(long amount) {
      Money money = new Money();
      money.currency = this.currency;
      money.amount = amount;
      return money;
   }
```

Note the use of a private factory method here that doesn't do the usual conversion into the cent-based amount. We'll use that a few times inside the *Money* code itself.

With addition defined, subtraction is easy.

```
class Money...

   public Money subtract(Money other) {
      assertSameCurrencyAs(other);
      return newMoney(amount - other.amount);
   }
```

The base method for comparison is `compareTo`.

```
class Money...

   public int compareTo(Object other) {
      return compareTo((Money)other);
   }
   public int compareTo(Money other) {
      assertSameCurrencyAs(other);
      if (amount < other.amount) return -1;
      else if (amount == other.amount) return 0;
      else return 1;
   }
```

Although that's all you get on most Java classes these days, we find code is more readable with the other comparison methods such as these.

```
class Money...

   public boolean greaterThan(Money other) {
      return (compareTo(other) > 0);
   }
```

Now we're ready to look at multiplication. We're providing a default rounding mode but you can set one yourself as well.

```
class Money...

   public Money multiply(double amount) {
      return multiply(new BigDecimal(amount));
   }
   public Money multiply(BigDecimal amount) {
      return multiply(amount, BigDecimal.ROUND_HALF_EVEN);
   }
   public Money multiply(BigDecimal amount, int roundingMode) {
      return new Money(amount().multiply(amount), currency, roundingMode);
   }
```

If you want to allocate a sum of money among many targets and you don't want to lose cents, you'll want an allocation method. The simplest one allocates the same amount (almost) amongst a number of targets.

```
class Money...

   public Money[] allocate(int n) {
      Money lowResult = newMoney(amount / n);
      Money highResult = newMoney(lowResult.amount + 1);
      Money[] results = new Money[n];
      int remainder = (int) amount % n;
      for (int i = 0; i < remainder; i++) results[i] = highResult;
      for (int i = remainder; i < n; i++) results[i] = lowResult;
      return results;
   }
```

A more sophisticated allocation algorithm can handle any ratio.

```
class Money...

   public Money[] allocate(long[] ratios) {
      long total = 0;
      for (int i = 0; i < ratios.length; i++) total += ratios[i];
      long remainder = amount;
      Money[] results = new Money[ratios.length];
      for (int i = 0; i < results.length; i++) {
         results[i] = newMoney(amount * ratios[i] / total);
         remainder -= results[i].amount;
      }
      for (int i = 0; i < remainder; i++) {
         results[i].amount++;
      }
      return results;
   }
```

You can use this to solve Foemmel's Conundrum.

```
class Money...

   public void testAllocate2() {
      long[] allocation = {3,7};
      Money[] result = Money.dollars(0.05).allocate(allocation);
      assertEquals(Money.dollars(0.02), result[0]);
      assertEquals(Money.dollars(0.03), result[1]);
   }
```