CSE341: Programming Languages

Lecture 23
OO vs. Functional Decomposition; Adding Operations & Variants; Double-Dispatch

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Breaking things down

- In functional (and procedural) programming, break programs down into functions that perform some operation
- In object-oriented programming, break programs down into classes that give behavior to some kind of data

This lecture:

- These two forms of *decomposition* are so exactly opposite that they are two ways of looking at the same "matrix"
- Which form is "better" is somewhat personal taste, but also depends on how you expect to *change/extend software*
- For some operations over two (multiple) arguments, functions and pattern-matching are straightforward, but with OOP we can do it with *double dispatch* (multiple dispatch)

The expression example

Well-known and compelling example of a common *pattern*:

- Expressions for a small language
- Different variants of expressions: ints, additions, negations, …
- Different operations to perform: eval, toString, hasZero, …

Leads to a matrix (2D-grid) of variants and operations

- Implementation will involve deciding what "should happen" for each entry in the grid *regardless of the PL*

	eval	toString	hasZero	…
Int				
Add				
Negate				
…				

Standard approach in ML

	eval	toString	hasZero	…
Int				
Add				
Negate				
…				

- Define a *datatype*, with one *constructor* for each variant
  - (No need to indicate datatypes if dynamically typed)
- Define a *function* for each operation
- So "fill out the grid" via one function per column with one case-expression branch for each grid position
  - Can use a wildcard pattern if there is a default for multiple entries in a column

See lec23_stage1.sml

Standard approach in OOP

	eval	toString	hasZero	…
Int				
Add				
Negate				
…				

- Define a *class*, with one *abstract method* for each operation
  - (No need to indicate abstract methods if dynamically typed)
- Define a *subclass* for each variant
- So "fill out the grid" via one class per row with one method implementation for each grid position
  - Can use a method in the superclass if there is a default for multiple entries in a column

See lec23_stage1.rb and lec23_stage1.java

A big CSE341 punchline

	eval	toString	hasZero	…
Int				
Add				
Negate				
…				

- FP and OOP often doing the same thing in *exact* opposite way
  - Organize the program "by rows" or "by columns"
- Which is "most natural" may depend on what you are doing (e.g., an interpreter vs. a GUI) or personal taste
- Code layout is important, but there's no perfect way since software has many dimensions of structure
  - Tools, IDEs can help with multiple "views" (e.g., rows / columns)

Now for stage 2: FP

	eval	toString	hasZero	noNegConstants
Int				
Add				
Negate				
Mult				

- For implementing our grid so far, SML / Racket style usually by column and Ruby / Java style usually by row
- But beyond just style, this decision affects what (unexpected?) software *extensions* are easy and/or do not change old code
- Functions:
  - Easy to add a new operation, e.g., **`noNegConstants`**
  - Adding a new variant, e.g., **`Mult`** requires modifying old functions, but ML type-checker gives a to-do list if we avoided wildcard patterns in Stage 1

Now for stage 2: OOP

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Int				
Add				
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- For implementing our grid so far, SML / Racket style usually by column and Ruby / Java style usually by row
- But beyond just style, this decision affects what (unexpected?) software *extensions* are easy and/or do not change old code
- Objects:
  - Easy to add a new variant, e.g., **`Mult`**
  - Adding a new operation, e.g., **`noNegConstants`** requires modifying old classes, but Java type-checker gives a to-do list if we avoided default methods in Stage 1

The other way is possible

- Functions allow new operations and objects allow new variants without modifying existing code *even if they didn't plan for it*
  - The programming style "just works that way"
- Functions can support new variants somewhat awkwardly "if they plan ahead"
  - See **`datatype 'a ext_exp`** and **`eval_ext`** at bottom of lec23.sml if interested
- Objects can support new operations somewhat awkwardly "if they plan ahead"
  - The popular Visitor Pattern (not shown here), which uses the double-dispatch pattern (used next for another purpose)

Thoughts on Extensibility

- Making software extensible is valuable and hard
  - If you know you want new operations, use FP
  - If you know you want new variants, use OOP
  - If both? Languages like Scala try; it's a hard problem
  - Reality: The future is often hard to predict!
- Extensibility is a double-edged sword
  - Code more reusable without being changed later
  - But makes original code more difficult to reason about locally or change later (could break extensions)
  - Often language mechanisms to make code *less* extensible (ML modules hide datatypes; Java's **`final`** prevents subclassing/overriding)

Stage 3: Binary operations

- Situation is more complicated if an operation is defined over multiple arguments that can have different variants
  - Can arise in original program or after an extension
- Our example:
  - Include variants String and Rational
  - (Re)define **`Add`** to work on any pair of Int, String, Rational in either order
    - String-concatenation if >= 1 arg is a String, else math
  - (Just to keep example smaller, **`Negate`** and **`Mult`** still work only on Int, with a run-time error for a String or Rational)

Binary operation in SML

`Add` works differently for most combinations of Int, String, Rational

- Run-time error for any other kinds of expression

Natural approach: pattern-match on the pair of values

- For *commutative* possibilities, can re-call with **`(v2,v1)`**

```
fun add_values (v1,v2) =
  case (v1,v2) of
     (Int i, Int j) => Int (i+j)
   | (Int i, String s) => String (Int.toString i ^ s)
   | (Int i, Rational(j,k)) => Rational (i*k+j,k)
   | (Rational _, Int _) => add_values (v2,v1)
   | … (* 5 more cases (3^2 total): see lec23.sml *)

fun eval e =
  case e of
     …
   | Add(e1,e2) => add_values (eval e1, eval e2)
```

Binary operation in OOP: first try

- Normal dynamic dispatch gives us separate methods for the variant of the first argument (the receiver)
  - We could then abandon OOP style ☹ and use Racket-style type tests for branching on the 2nd argument's variant
  - 9 cases total: 3 in Int's **`add_values`**, 3 in String's **`add_values`**, 3 in Rational's **`add_values`**

```
class Int
  …
  def add_values other
    if other.is_a? Int
      …
    elsif other.is_a? Rational
      …
    else …
  end
end
class Add
  def eval ; e1.eval.add_values e2.eval ; end
end
```


A more OO style

- The FP approach had 3*3 case-expression branches
- Our half-OOP approach had 3 methods with 3 branches
- A full-OOP would have 9 methods, with dynamic dispatch picking the right one
  - There are languages that have such *multimethods*, i.e., method calls that use dynamic dispatch on > 1 argument
  - Ruby & Java (& C++ & C# & …) have no such feature
  - But we can code it up ourselves in an OOP way using the *double-dispatch idiom* (next slide)
    - (If we had three arguments, could use triple dispatch, etc., but double-dispatch is already fairly unwieldy)

The double-dispatch "trick"

- If **`Int`**, **`String`**, and **`Rational`** all define all of **`addInt`**, **`addString`**, and **`addRational`**, that's 9 cases
  - For example, **`String`**'s **`addInt`** is for additions of the form "i + s" where i is an int and s is a string (i.e., **`self`** is "on the right")
- **`Add`**'s **`eval`** method calls **`e1.eval.add_values e2.eval`**, which dispatches to **`add_values`** in **`Int`**, **`String`**, or **`Rational`**
  - Int's **`add_values`**: **`other.addInt self`**
  - String's **`add_values`**: **`other.addString self`**
  - Rational **`add_values`**: **`other.addRational self`**

  So **`add_values`** performs "the 2nd dispatch" to the correct case!

See lec23.rb

Works in Java too

- In a statically typed language, double-dispatch works fine
  - Just need all the dispatch methods in the type

```
abstract class Value extneds Exp {
  abstract Value add_values(Value other);
  abstract Value addInt(Int other);
  abstract Value addString(Strng other);
  abstract Value addRational(Rational other);
}
class Int extends Value { … }
class Strng extends Value { … }
class Rational extends Value { … }
```

See lec23.java

Summary

- "The 2-D grid" is a fundamental truth about software, essential to understanding how OOP and procedural decomposition relate
- Software extensibility is easy in some ways and hard in others
  - Which ways are which depend on how code is structured
- Double-dispatch is how you "stay OOP" in a language without multimethods for operations that take multiple arguments of different variants
  - Is "staying OOP" here worth it?