CSE341: Programming Languages

Lecture 22
OOP vs. Functional Decomposition;
Adding Operators & 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

<table>
<thead>
<tr>
<th></th>
<th>eval</th>
<th>toString</th>
<th>hasZero</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
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<tr>
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<td>...</td>
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- Define a *datatype*, with one *constructor* for each variant
  - (No need to indicate datatypes if dynamically typed)
- “Fill out the grid” via *one function per column*
  - Each function has one branch for each column entry
  - Can combine cases (e.g., with wildcard patterns) if multiple entries in column are the same

[See the ML code]
Standard approach in OOP

- 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 the Ruby and Java code]
A big course 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 is no perfect way since software has many dimensions of structure
  – Tools, IDEs can help with multiple “views” (e.g., rows / columns)
Extensibility

<table>
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<tr>
<td>Mult</td>
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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 need not change old code
- Functions [see ML code]:
  - 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 original code avoided wildcard patterns
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 [see Ruby code]:
- 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 original code avoided default methods.

### Extensibility

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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
  - Natural result of the decomposition

Optional:
- Functions can support new variants somewhat awkwardly “if they plan ahead”
  - Not explained here: Can use type constructors to make datatypes extensible and have operations take function arguments to give results for the extensions

- Objects can support new operations somewhat awkwardly “if they plan ahead”
  - Not explained here: The popular Visitor Pattern uses the double-dispatch pattern to allow new operations “on the side”
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)
Binary operations

| eval  | toString | hasZero | ...
|-------|----------|---------|------
| Int   |          |         |      
| Add   |          |         |      
| Negate|          |         |      
| ...   |          |         |      |

- Situation is more complicated if an operation is defined over multiple arguments that can have different variants
  - Can arise in original program or after extension

- Function decomposition deals with this much more simply…
Example

To show the issue:
- Include variants \texttt{String} and \texttt{Rational}
- (Re)define \texttt{Add} to work on any pair of \texttt{Int}, \texttt{String}, \texttt{Rational}
  - Concatenation if either argument a \texttt{String}, else math

Now just defining the addition operation is a different 2D grid:

\begin{center}
\begin{tabular}{|c|c|c|}
\hline
 & Int & String & Rational \\
\hline
 Int & & & \\
\hline
 String & & & \\
\hline
 Rational & & & \\
\hline
\end{tabular}
\end{center}
ML Approach

Addition is different for most Int, String, Rational combinations
   – Run-time error for non-value expressions

Natural approach: pattern-match on the pair of values
   – For commutative possibilities, can re-call with \((v2, v1)\)

```plaintext
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*3 total): see the code *)

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

To show the issue:

- Include variants *String* and *Rational*
- (Re)define *Add* to work on any pair of *Int, String, Rational*
  - Concatenation if either argument a *String*, else math

Now just defining the addition operation is a *different* 2D grid:

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<td></td>
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</tr>
<tr>
<td><strong>String</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rational</strong></td>
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Worked just fine with functional decomposition — what about OOP…
What about OOP?

Starts promising:
- Use OOP to call method `add_values` to one value with other value as result

```ruby
class Add
  ...
  def eval
    e1.eval.add_values e2.eval
  end
end
```

Classes `Int`, `MyString`, `MyRational` then all implement
- Each handling 3 of the 9 cases: “add `self` to argument”

```ruby
class Int
  ...
  def add_values v
    ...
    # what goes here?
  end
end
```
First try

- This approach is common, but is “not as OOP”
  - *So do not do it on your homework*

```ruby
class Int
  def add_values v
    if v.is_a? Int
      Int.new(v.i + i)
    elsif v.is_a? MyRational
      MyRational.new(v.i+v.j*i,v.j)
    else
      MyString.new(v.s + i.to_s)
    end
  end
end
```

- A “hybrid” style where we used dynamic dispatch on 1 argument and then switched to Racket-style type tests for other argument
  - Definitely not “full OOP”
Another way…

- `add_values` method in `Int` needs “what kind of thing” `v` has
  - Same problem in `MyRational` and `MyString`

- In OOP, “always” solve this by calling a method on `v` instead!

- But now we need to “tell” `v` “what kind of thing” `self` is
  - We know that!
  - “Tell” `v` by calling different methods on `v`, passing `self`

- Use a “programming trick” (?) called `double-dispatch`…
Double-dispatch “trick”

- **Int**, **MyString**, and **MyRational** each define all of `addInt`, `addString`, and `addRational`
  - For example, **String’s** `addInt` is for concatenating an integer argument to the string in `self`
  - 9 total methods, one for each case of addition

- **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`: `v.addInt self`
  - **MyString’s** `add_values`: `v.addString self`
  - **MyRational’s** `add_values`: `v.addRational self`
  - So `add_values` performs “2nd dispatch” to the correct case of 9!

[Definitely see the code]
Why showing you this

- Honestly, partly to belittle full commitment to OOP
- To understand dynamic dispatch via a sophisticated idiom
- Because required for the homework
- To contrast with *multimethods* (optional)
Works in Java too

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

```java
abstract class Value extends Exp {
    abstract Value add_values(Value other);
    abstract Value addInt(Int other);
    abstract Value addString(String other);
    abstract Value addRational(Rational other);
}
class Int extends Value { ... }
class String extends Value { ... }
class Rational extends Value { ... }
```

[See Java code]
Being Fair

Belittling OOP style for requiring the manual trick of double dispatch is somewhat unfair…

What would work better:

• Int, MyString, and MyRational each define three methods all named add_values
  – One add_values takes an Int, one a MyString, one a MyRational
  – So 9 total methods named add_values
  – e1.eval.add_values e2.eval picks the right one of the 9 at run-time using the classes of the two arguments

• Such a semantics is called multimethods or multiple dispatch
**Multimethods**

General idea:
- Allow multiple methods with same name
- Indicate which ones take instances of which classes
- Use dynamic dispatch on arguments in addition to receiver to pick which method is called

If dynamic dispatch is essence of OOP, this is more OOP
- No need for awkward manual multiple-dispatch

Downside: Interaction with subclassing can produce situations where there is “no clear winner” for which method to call
Ruby: Why not?

Multimethods a bad fit (?) for Ruby because:

• Ruby places no restrictions on what is passed to a method

• Ruby never allows methods with the same name
  – Same name means overriding/replacing
Java/C#/C++: Why not?

• Yes, Java/C#/C++ allow multiple methods with the same name

• No, these language do not have multimethods
  – They have static overloading
  – Uses static types of arguments to choose the method
    • But of course run-time class of receiver [odd hybrid?]  
    – No help in our example, so still code up double-dispatch manually

• Actually, C# 4.0 has a way to get effect of multimethods

• Many other language have multimethods (e.g., Clojure)
  – They are not a new idea