CSE341: Programming Languages
Lecture 22
OOP vs. Functional Decomposition;
Adding Operators & Variants;
Double-Dispatch

Dan Grossman
Spring 2017
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*

<table>
<thead>
<tr>
<th></th>
<th>eval</th>
<th>toString</th>
<th>hasZero</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Standard approach in ML

- 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**

| 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 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>
<thead>
<tr>
<th>eval</th>
<th>toString</th>
<th>hasZero</th>
<th>noNegConstants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mult</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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
### Extensibility

<table>
<thead>
<tr>
<th></th>
<th>eval</th>
<th>toString</th>
<th>hasZero</th>
<th>noNegConstants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mult</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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
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 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:

<table>
<thead>
<tr>
<th></th>
<th>Int</th>
<th>String</th>
<th>Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>String</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rational</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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 \((v2,v1)\)

```haskell
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 \((3*3 \text{ total}): \text{see the code} \)*)

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:

<table>
<thead>
<tr>
<th></th>
<th>Int</th>
<th>String</th>
<th>Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>String</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rational</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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:

• \texttt{Int}, \texttt{MyString}, and \texttt{MyRational} each define three methods all named \texttt{add\_values}
  – One \texttt{add\_values} takes an \texttt{Int}, one a \texttt{MyString}, one a \texttt{MyRational}
  – So 9 total methods named \texttt{add\_values}
  – \texttt{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 \textit{multimethods} or \textit{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