Abstraction

November 13, 2019

https://en.wikipedia.org/wiki/Abstract_nonsense

Software Engineers and Patterns

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- The authors were actually inspired by a book that came up with a pattern language in architecture
- Such patterns were meant to provide guidelines across buildings in multiple style *abstracting* away concrete details of individual buildings.
- Software design patterns are thus all about providing *abstractions*.

Theories of Abstraction

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- Abstraction in visual art is about avoiding concrete subjects. It attempts to convey something (often an emotion) without appealing to sentiment.
- Oddly enough there's a bit of a stigma against it, despite the fact that music without lyrics has far less stigma.
- Abstraction in mathematics and computer science is about *generalization*. Take away the concrete details of certain objects and see how they are similar.

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- This is important to computing because the point of programs are to construct some form of answer.
- Although categorical abstractions are powerful, I will not discuss them much (and most of the really powerful abstractions go over my head).
- But we will study abstraction from a less mathematical viewpoint.
- I will show instances of *almost identical* code and how a programming language feature allows the two pieces of code to be generalized.

Buddy Functions

Let's consider the following functions in Java:

```java
public boolean hasSmith(List<String> names) {
  for (String name : names) {
    if (name == "Smith")
      return true;
  }
  return false;
}

public  boolean hasBob(List<String> names) {
  for (String name : names) {
    if (name == "Bob")
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}
```

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    if (name == "Bob")
      return true;
  }
  return false;
}
```

These look pretty similar, right?

Eliminate Redundancy!

So, let's eliminate the redundancy of searching for different names by abstracting out towards a definition that takes in a string parameter to search for. This generalizes writing functions to search for specific strings.

```
public boolean hasName(String searchName, List<String> names) {
  for (String name : names) {
    if (name == searchName)
      return true;
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- Why only design a function that searches for names?
- Why not search for arbitrary items so long as they are comparable?

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- Why only design a function that searches for names?
- Why not search for arbitrary items so long as they are comparable?
- Then searching for names becomes an instance of a more general problem that is solved.

Generic Structure

So, let's use some Java *generics* to generalize our program.

```
public <T extends Comparable<T>>
  boolean hasItem(T searchItem, List<T> items) {
  for (T item : items) {
    if (item.equals(searchItem))
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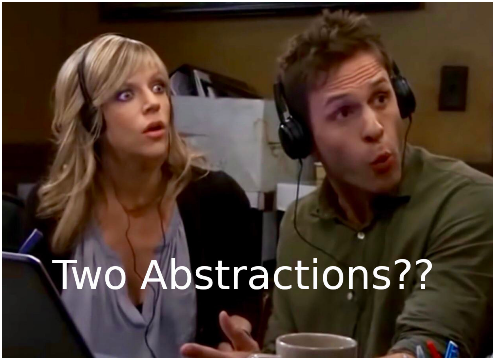
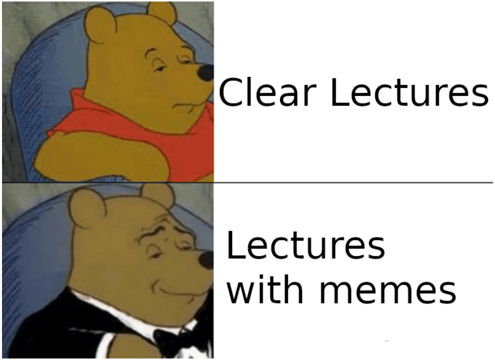
- This is nice and general!
- Can we generalize any more?
- We actually have 2 more abstractions that we can apply!

Two Abstractions??



I'm Sorry



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- So if we wanted to check if a string equaled smith we could write:

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Predicate<String> isSmith = str -> str == "Smith";
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- We can actually consider searching for a specific item via equality as the process of seeing if an arbitrary predicate returns true for an item in a list.
- So if we wanted to check if a string equaled smith we could write:
`Predicate<String> isSmith = str -> str == "Smith";`
- I could then pass this as the first argument to a funciton `TestItems` that I will now define.

Last Abstraction

Here is that function now:

```
public <T extends Comparable<T>>
  boolean testItems(Predicate<T> pred, List<T> items) {
  for (T item : items) {
    if (pred.test(searchItem))
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public <T extends Comparable<T>>
  boolean testItems(Predicate<T> pred, Iterable<T> items) {
    for (T item : items) {
      if (pred.test(searchItem))
        return true;
    }
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- It then applied this function to every element in the list and observed whether it returned `true` for that element.
- This is a very powerful concept where we can determine if perhaps all elements in a collection satisfy a property or even one element. Or we can collect all individuals in a collection that satisfy some property.

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- It then applied this function to every element in the list and observed whether it returned `true` for that element.
- This is a very powerful concept where we can determine if perhaps all elements in a collection satisfy a property or even one element. Or we can collect all individuals in a collection that satisfy some property.
- For example, let's consider writing a program that only admits people that are 18 and older.

Guarding Entry

Let's consider that we have a list of people whose ages are represented by Natural numbers and that we want to only collect the people over 18. Assume a person has an age field that we can project.

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```
;; List<Person> -> List<Person>
;; Only allows patrons over 18 to enter the bar
(define (bar-entry patrons)
  (cond
    [(empty? patrons) patrons]
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       (... (first patrons)) ... (bar-entry (rest patrons))]))
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- How do I check whether the age is less than 18?
- `(< (person-age (first patrons)) 18)`
- Thus, we should get `(< 26 18)` since we are getting Sara as our person, and this should return false.
- Since this returns false, we should throw Sara into the list we're building. How do we do that?
- With `(cons (first patrons) ...)`

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- Does this function need to do recursion itself?

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- So, our helper function simply takes in a person and a list and only conses the person onto the list if they are over 18.

```
;; List<person> -> List<person>
;; Add a person to the patron list as
;; long as they are over 18.
(define (cons-over-18 possible-patron patrons)
  (if (>= (person-age possible-patron) 18)
      (cons possible-patron patrons)
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- In general, if it seems like the list you're building depends on the structure of the values in the list, then you need some kind of cons operation that checks properties on the head of the list.
- But what happens if the condition we are checking needs to change?

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- Now our bar can't afford to give drinks to patrons under 21 years old. We decide that the easiest solution is to only allow 21 and over patrons, to prevent underage people from getting in and sneakily get drinks.
- To model this behavior, our program must change `cons-over-18` to something named `cons-over-21` that changes its check to make sure patrons are at least 21.
- But let's say we still need to model another bar that allows people over 18, but charges them covers. Then we will need four functions for our program.

Repetitive Bar Program

```
(define (cons-over-18 possible-patron patrons)
  (if (>= (person-age possible-patron) 18)
      (cons possible-patron patrons)
      patrons))
(define (bar-entry-18 patrons)
  (cond
    [(empty? patrons) patrons]
    [(cons? patrons) (cons-over-18
                       (first patrons)
                       (bar-entry-18 (rest patrons)))]))
(define (cons-over-21 possible-patron patrons)
  (if (>= (person-age possible-patron) 21)
       (cons possible-patron patrons)
       patrons))
(define (bar-entry-21 patrons)
  (cond
    [(empty? patrons) patrons]
    [(cons? patrons) (cons-over-21
                      (first patrons)
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- Redundant code should cause developers an itch.
- On the one hand, there are more places for the program to go wrong.

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- So, how do we get started?

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(define (cons-over age possible-patron patrons)
  (if (>= (person-age possible-patron) age)
      (cons possible-patron patrons)
      patrons))
(define (bar-entry age patrons)
  (cond
    [(empty? patrons) patrons]
    [(cons? patrons) (cons-over age
                                (first patrons)
                                (bar-entry (rest patrons)))]))
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- We then only cons items that meet this predicate!
- This is the power of having first class functions in your language!

Filtering Functions

You must be thinking "show me the code!" by now, so here it is:

```
(define (over-18? patron) (>= (person-age patron) 18))
(define (over-21? patron) (>= (person-age patron) 21))

(define (cons-over-p pred possible-patron patrons)
  (if (pred possible-patron)
      (cons possible-patron patrons)
      patrons))

(define (bar-entry pred patrons)
  (cond
    [(empty? patrons) patrons]
    [(cons? patrons) (cons-over-p
                       pred
                       (first patrons)
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- The name of this function is `filter`

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- It is an anonymous function, just like the one I previously showed in Java.

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- `(filter (lambda (x) (< x 5)) '(1 2 4 8 16))` provides an anonymous function (that is a predicate) as an argument to `filter`
- We can also write functions that return functions.
- Here is a small example:

```
(define (add x)
  (lambda (y)
    (+ x y)))
```

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- So, in the first case we are returning an anonymous function that adds 2 to y, and in the latter case we are returning an anonymous function that adds 3 to y.
- So, in a sense we are deanonymizing these two functions by using define with add-two and add-three.

Famous Higher Order Functions

There are a couple of famous higher order functions that you learn about in math. Namely derivation, integration, and composition.