
Module 8: Abstraction

CPSC 110

Peyton Seigo

2018-10-26

Module 8: Abstraction

Learning goals

- Be able to identify 2 or more functions that are candidates for abstraction.
- Be able to design an abstract function starting with 2 or more highly repetitive functions (or expressions).
- Be able to design an abstract fold function from a template.
- Be able to write signatures for abstract functions.
- Be able to write signatures that use type parameters.
- Be able to identify a function which would benefit from using a built-in abstract function.
- Be able to use built-in abstract functions.

Refactoring

- Remember to:
 - Pass new parameter in natural recursive calls
 - Replace point(s) of variance with variable(s)
 - * Point of variance could be a value or function call

(**listof** T) instead of **ListOfT**

From now on, anytime you want a `ListOfT` type, you can use (`listof X`) instead of having to write a data definition for it.

The type (`listof T`) means:

```
1 ;; ListOfT is one of:  
2 ;;   - empty  
3 ;;   - (cons T ListOfT)  
4 ;; interp. a list of T  
5  
6 (@add-template-rules compound self-ref)  
7 (define (fn-for-lot lot)  
8   (cond [(empty? lot) (...)]  
9         [else  
10          (... (first lot)  
11              (fn-for-lot (rest lot)))]))
```

Working through the recipe

With abstract functions, it gets **harder** as we go back towards the signature.

1. Write abstract function; replace bodies of original function(s)
2. Unit tests
 - Can be abstracted from `check-expects` of original function(s); copy all original tests and narrow down what you need
 - Insert appropriate additional parameter into tests
 - Revising existing examples may be easier than starting from scratch
3. Purpose
 - Can sometimes be abstracted from orig. purpose(s), but not always
 - Purpose statements can take A LOT of tries to get right. This is normal.
4. Signature
 - Lists: use `(listof <Type>)`
 - Functions: use `(<Type1> -> <Type2>)`
 - Consuming a generic type: use *type parameters* for consumed/produced types
 - Lists: `(listof T)`, a list containing one or more `T` objects
 - Functions: `(T -> U)` such that `T` is some type consumed and `U` is some type produced
 - Example: `(@signature (T -> U) (listof T) -> (listof U))`.
 - * The template is `(@template (listof T) add-param)`
 - * The definition is `(define (map fn lon) ...)`

HtDF: Writing functions that call abstract functions

Writing a function that calls an abstract function like `filter`, `map`, or an abstract function you write yourself.

- Template tag: `(@template use-abstract-fn)`
- Base case test is NOT needed when using built-in abstract functions—their base case is already tested

Functions that are **abstract functions themselves** and **consume** a generic function do not have any special `template` tags. Note that if an abstract function consumes a list, the template will have `(listof <T>)`.

Closures

A closure is a `local` function defined within a function body and **uses a parameter of its enclosing function**. In these cases, you MUST define the function using `local`.

Below, the helper `bigger?` is a closure. It “closes over” the value of `threshold` passed to `only-bigger`.

```
1 (define (only-bigger threshold lon)
2   (local [(define (bigger? n)
3             (> n threshold))]
4     (filter bigger? lon)))
```

Terminology

- **Abstraction:** generalizing repetitive code (through refactoring)
 - Make programs smaller + easier to read
 - Separates knowledge domains more clearly in code
- **Abstract function:** a helper shared between multiple functions
 - More general than the original code
- **Abstraction from examples:** abstracting/generalizing functions that have already been written
 - Backwards HtDF recipe: *Function definition* -> *Tests* -> *Purpose* -> *Signature*
- **Higher order function:** can a) consume one or more function, and b) produce a function
- **Type parameter:** a name for some generic type; often used in an abstract function’s signature and template tags (`X`, `Y`, `Z`, `T`, `U`, etc.)

Built-in abstract functions

Template for writing a function that calls a built-in abstract function:

```
1 (@template (listof t) use-abstract-fn)
2 (define (some-fn lot)
3   (<built-in-fn> ... lot))
```

Built-In Abstract Functions ISL and ASL have the following built-in abstract functions.

- `build-list`: make a list of elements based on their index (doesn’t have to be a list of numbers!)
 - `(build-list n identity)` makes a list of naturals for `[0, n)`
- `filter`: list of elements that satisfy a given predicate
- `map`: apply a fn to each element
- `andmap`: analogous to Elixir’s `all?`
- `ormap`: analogous to Elixir’s `any?`

- `foldl`
- `foldr`: reduce a list of elements to a single element
 - similar to Elixir's `reduce`, but `foldr` does not use an [apparent] accumulator
 - HexDocs actually says Reduce is sometimes called `fold`!

`foldr` is the abstract function for the `(listof T)` template:

Signatures for each built-in function:

```
1 (define (fn-for-lot lot)
2   (cond [(empty? lot) (...)]
3         [else
4          (... (first lot)
5               (fn-for-lot (rest lot)))]))
6
7 (foldr ... ... lot)
```

- The first ... in `foldr` is the **combination** in `fn-for-lot`
- The second ... in `foldr` is the **base case** in `fn-for-lot`

List of signatures **without their function arguments** for comparing to functions that have NOT yet implemented an abstract function:

CONSUMES	PRODUCES	ABSTRACT FUNCTION
Natural	-> (listof X)	build-list
(listof X)	-> (listof X)	filter
(listof X)	-> (listof Y)	map
(listof X)	-> Boolean	andmap
(listof X)	-> Boolean	ormap
Y (listof X)	-> Y	foldr
Y (listof x)	-> Y	foldl

Signature + purpose for each built-in abstract function according to *Language* page.

```
1 (@signature Natural (Natural -> X) -> (listof X))
2 ;; produces (list (f 0) ... (f (- n 1)))
3 (define (build-list n f) ...)
4
```

```

5 (@signature (X -> Boolean) (listof X) -> (listof X))
6 ;; produce a list from all those items on lox for which p holds
7 (define (filter p lox) ...)
8
9 (@signature (X -> Y) (listof X) -> (listof Y))
10 ;; produce a list by applying f to each item on lox
11 ;; that is, (map f (list x-1 ... x-n)) = (list (f x-1) ... (f x-n))
12 (define (map f lox) ...)
13
14 (@signature (X -> Boolean) (listof X) -> Boolean)
15 ;; produce true if p produces true for every element of lox
16 (define (andmap p lox) ...)
17
18 (@signature (X -> Boolean) (listof X) -> Boolean)
19 ;; produce true if p produces true for some element of lox
20 (define (ormap p lox) ...)
21
22 (@signature (X Y -> Y) Y (listof X) -> Y)
23 ;; (foldr f base (list x-1 ... x-n)) = (f x-1 ... (f x-n base))
24 (define (foldr f base lox) ...)
25
26 (@signature (X Y -> Y) Y (listof X) -> Y)
27 ;; (foldl f base (list x-1 ... x-n)) = (f x-n ... (f x-1 base))
28 (define (foldl f base lox) ...)

```

Fold functions

Going directly from type comments to abstract functions, rather than writing a bunch of redundant code and abstracting from examples afterwards.

Our fold functions are written from existing templates.

Tips

- For mutual ref templates, assign *type parameters* to the result of each function right away!
 - i.e. for `Element` and `ListOfElement`, let `fn-for-e -> X` and `fn-for-loe -> Y`
 - Makes writing the signature MUCH easier