



UMassAmherst

Manning College of Information
& Computer Sciences

Lab 2: Type Signatures and More Higher-order Functions

Wednesday September 13, 2023

Weekly Lab Agenda

- Go over reminders/goals
- Review past material
- Work in groups of 2-3 to solve a few exercises
 - Please sit with your group from last week.
- Discussion leaders will walk around and answer questions
- Solutions to exercises will be reviewed as a class
- Attendance taken at the end

Reminders

- Homework 1 is due tonight at 11:59pm
 - Come to office hours for help!
- Homework 2 will be released soon
- If you need to miss lab and have a valid reason according to the syllabus (medical, other personal) please fill out the questionnaire on moodle before the start time of your lab.
 - Waking up late, bus was late are NOT valid reasons to miss lab.

Today's Goals

- Practice writing correct type signatures
- Practice with more higher-order functions

Review of Type Signatures

We can infer types based on the operations done on values

```
// f(x: number, y: number): number    or  f: (number, number) => number
function f(x, y) {
  return x + (2*y);
  // product with y: y is number, x and result is number
}
```

Sometimes, we have several possibilities

```
// g: (number, number) => number    or    g: (string, string) => string
function g(x, y) { return x + y; }  // + can be string concatenation

// h(a: string): boolean    or    h<T>(a: T[]): boolean
function h(a) { return a.length > 5; } // both strings & arrays have length
```

The array could have any element type. We call T a **type variable**.

This lets us write **generic functions**.

Exercise 1: Type Signatures

What is the type signature for the following code?

```
const h = (a, g, f) => f(a.map(g)).filter(g);
```

Start by considering an arbitrary element type for the array, and continue to derive types for the map and filter callback functions.

Remember:

```
map<A,B>(arr: A[], f: (x: A) => B): B[]
```

```
filter<T>(arr: T[], f: (x: T) => boolean): T[]
```

Solution 1: Type Signatures

What is the type signature for the following code?

```
const h = (a, g, f) => f(a.map(g)).filter(g);
```

`a` must be an array of some type `T`.

Then `g: T => R` (as callback for `map`), resulting in an array of type `R[]`.

Function `f` takes the array of type `R[]` and returns an array (since we apply `filter` to the result). Since this array is filtered by `g: T => R`, its element type must be `T`, and `R = boolean`. The result is also an array of type `T[]`.

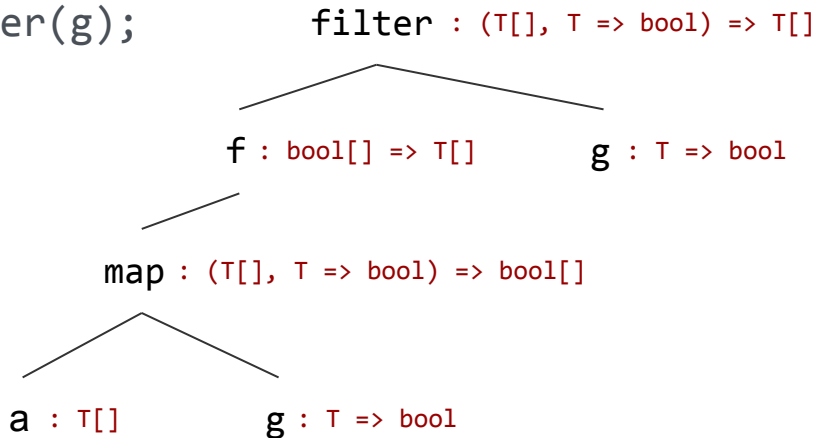
```
h: (a: T[], g: (x: T) => boolean, f: (a: boolean[]) => T[]): T[]
```

Solution 1: Type Signatures

```
const h = (a, g, f) => f(a.map(g)).filter(g);
```

Another method:

- Draw a tree for the call graph. Each node will be a function or an argument. Parents depend on children.
- Narrow down the types for each node, starting from either root or leaves
- Repeat until no more change is made.



Review of Reduce

```
function reduce<T, U>(
  a: T[],
  f: (acc: U, e: T) => U,
  init: U
): U {
  let result = init;
  for (let i = 0; i < a.length; ++i) {
    result = f(result, a[i]);
  }
  return result;
}
```

Reduce is used to combine array elements with the same function.

Example: Find the product of all elements of an array $a = [3, 2, 6, 2, 2, 0]$

```
a.reduce((prod, e) => prod * e, 1);
```

Exercise 2: Reduce

Write a function that counts how many pixels in an array are “mainly blue”.

- Input: An array of type `Color[]` (where `Color` is a triple `[R, G, B]`)
- Output: The number of pixels satisfying the following condition: the blue value is at least twice the red value and at least twice the green value
- Note: Define “`type Color = [number, number, number];`”

Can you solve the same problem for a 2D array of type `Color[][]` ?

Solution 2: Reduce

```
type Color = [number, number, number];  
const isBlue = (c: Color) => c[2] >= 2*c[0] && c[2] >= 2*c[1] ? 1 : 0;  
  
function countBlue(r: Color[]): number {  
    return r.reduce((acc, c) => acc + isBlue(c), 0);  
}  
  
function countBlue2D(m: Color[][]): number {  
    return m.reduce((acc, r) => acc + countBlue(r), 0);  
}
```

Exercise 3: Map, Filter & Reduce

Write a function without using loops or recursion to calculate the sum of the natural log of all positive numbers in an array.

Note: Use `Math.log()` to calculate the logarithm.

Example: Input: `[-1, 0, 2, 10, -5]` => Output: $\log(2) + \log(10) = 2.9957\dots$

Solution 3: Map, Filter & Reduce

Write a function without using loops or recursion to calculate the sum of the natural log of all positive numbers in an array.

Note: Use `Math.log()` to calculate the logarithm.

Example: Input: `[-1, 0, 2, 10, -5]` => Output: `log(2) + log(10) = 2.9957...`

```
function sumLog(nums: number[]): number {  
  return nums.filter(num => num > 0)  
    .map(num => Math.log(num)) // Can you simplify this further?  
    .reduce((sum, log) => sum + log, 0); // Can you use just reduce?  
}
```