Use Functional Programming to Make a Bulls and Cows Solver

用 Functional Programming 來解 1A2B 吧

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Any question? sli.do/coscup22-fp

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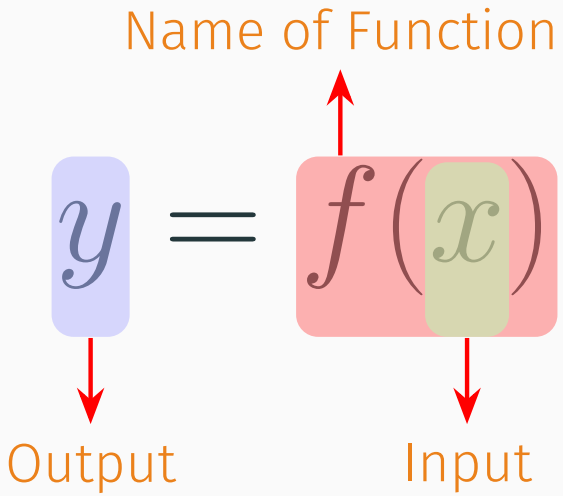
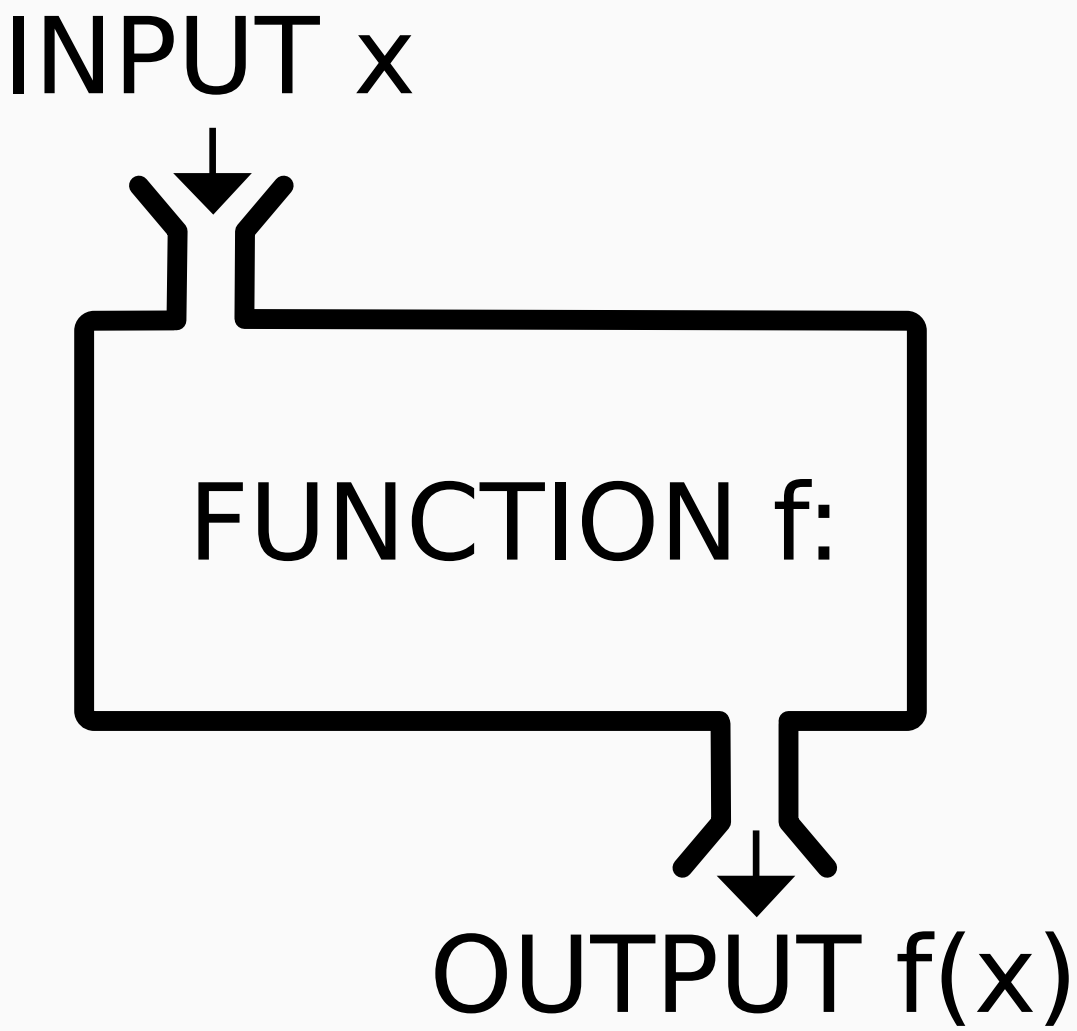


What is a Function?



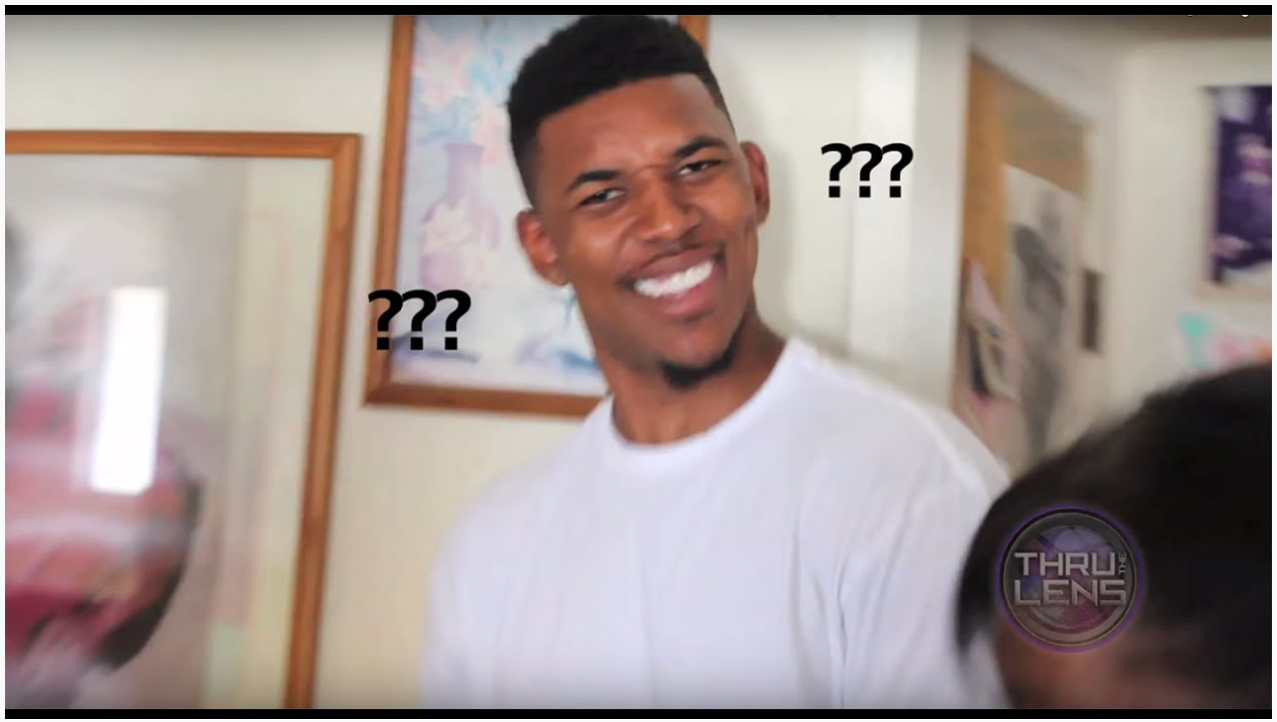
What is Functional Programming?

Functional programming represents a programming paradigm in which the computations are evaluated by mathematical functions. The paradigm avoids changing state and using mutable data.[1]

Functional programming **代表一種以數學函式來計算的程式設計法。這種設計法避免狀態改變及使用可變資料。**

[1] Stefania Loredana Nita and Marius Mihailescu. *Haskell Quick Syntax Reference*. Apress, 2019.

Huh???



What is Functional Programming?

In a nutshell, NO SIDE EFFECTS!

What is Functional Programming?

In a nutshell, NO SIDE EFFECTS!

“副作用就像是謊言。”

— **無瑕的程式碼**, Robert C. Martin

What is Side Effects?

```
1  var x = 2;
2
3  console.log(x) // 2
4
5  function add2(){
6      x = x + 2;
7  }
```

What is Side Effects?

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```

What is Side Effects?

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7  }

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10 console.log(x); // 4
```

Not functional, but how to fix it?

Let it be Functional

```
1  var x = 2;
2
3  console.log(x) // 2
4
5  function add2(y: number){
6      return y + 2;
7  }
```

Let it be Functional

```
1  var x = 2;
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No side effects ヽ(o ^ ▽ ^ o)ノ

Everything is function

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can be passed, returned, assigned, etc..

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Data is immutable

Everything is function

Functions are first class

can be passed, returned, assigned, etc..

Data is immutable

State cannot change after creation

Quite cute, right?

Questions?

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Let’s Make a Bulls and Cows Solver

1A2B

- Secret number: 4271
- Opponent's try: 1234
- Answer: 1A2B (1 bull and 2 cows)
  If the matching digits are in their right positions, they are "bulls", if in different positions, they are "cows".

Bulls and Cows Example

Secret number: `9527`

Source: `https://github.com/smailzhu/COSCUP2022`

Bulls and Cows Example

Secret number: `9527`

- I guess "`34`$\underline{\texttt{72}}$" $\rightarrow$ 0A2B

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Secret number: `9527`

- I guess "`34`$\underline{\texttt{72}}$" $\rightarrow$ 0A2B
- I guess "$\underline{\texttt{2}}$`064`" $\rightarrow$ 0A1B

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Bulls and Cows Example

Secret number: `9527`

- I guess "`34`$\underline{\texttt{72}}$" → 0A2B
- I guess "$\underline{\texttt{2}}$`064`" → 0A1B
- I guess "9$\underline{\texttt{7}}$`48`" → 1A1B

Source: `https://github.com/smailzhu/COSCUP2022`

Bulls and Cows Example

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- I guess "`34`$\underline{\texttt{72}}$" → 0A2B
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- I guess "`1547`" → 2A0B

Source: `https://github.com/smailzhu/COSCUP2022`

Bulls and Cows Example

Secret number: `9527`

- I guess "`3472`" → 0A2B
- I guess "`2064`" → 0A1B
- I guess "`9748`" → 1A1B
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Bulls and Cows Example

Secret number: `9527`

- I guess "`3472`" → 0A2B
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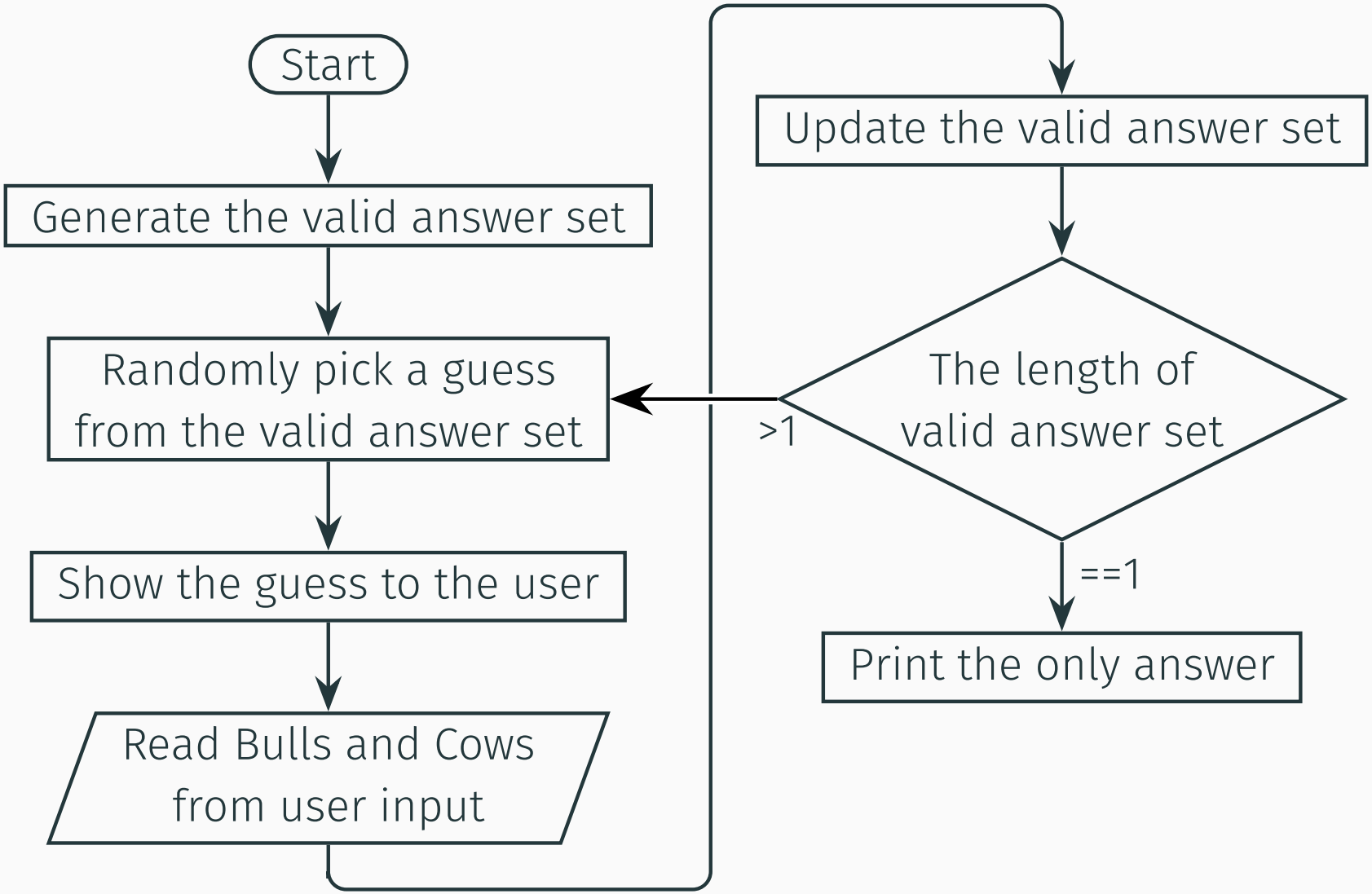
- I guess "`1547`" → 2A0B
- I guess "`1349`" → 0A1B
- "9527"

Source: `https://github.com/smailzhu/COSCUP2022`

Flow Chart


Start
Generate the valid answer set
Randomly pick a guess from the valid answer set
Show the guess to the user
Read Bulls and Cows from user input
Update the valid answer set
The length of valid answer set
>1
==1
Print the only answer

Generate all valid answer

What is valid answer?

- without duplicate digit. e.g. 1234, 9527, ~~1231~~, ~~6666~~

Generate all valid answer

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so,

1. Generate all permutation
2. Remove invalid permutation

Check list has any duplicate elements

- **nub** can remove duplicate elements in a list

```
nub [1,2,3,4,3,2,1,2,4,3,5] -- [1,2,3,4,5]
```

Check list has any duplicate elements

- `nub` can remove duplicate elements in a list

```
nub [1,2,3,4,3,2,1,2,4,3,5] -- [1,2,3,4,5]
```

- make magic happen

```
1 {- check if list has duplicate element
2  -
3  - hasDuplicates [1,2,3,4] == False
4  - hasDuplicates [1,2,3,1] == True -}
5
6 hasDuplicates :: Eq a => [a] -> Bool
7 hasDuplicates xs = length (nub xs) /= length xs
```

Generate all valid answer

1. `replicateM`: replicateM n act performs the action act n times, and then returns the list of results:

```
replicateM 4 [1,2,3,4,5]
--[[1,1,1,1],[1,1,1,2],...,[5,5,5,4],[5,5,5,5]]
```

Generate all valid answer

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```

2. Remove invalid permutation

```
filter (>5) [1,2,3,4,5,6,7,8] -- [6,7,8]
filter (\x -> length x > 2) ["aaaa","bbb","cc"]
    -- ["aaaa", "bbb"]
```

Generate all valid answer

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replicateM 4 [1,2,3,4,5]
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    -- ["aaaa", "bbb"]
```

3. Combine them

```
allAnswer n x = filter (\x -> not $
   hasDuplicates x) $ replicateM n x
allAnswer 4 [0..9] --
   [[1,2,3,4],[1,2,3,5],...,[6,7,8,9]]
```

Before We Count Bulls

- What is `(x:xs)`?

```
sum :: [Int] -> Int
sum [] = 0
sum (x:xs) = x + sum xs
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sum [1,2,3] = 1 + sum [2,3]
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sum [1,2,3] = 1 + sum [2,3]
sum [2,3] = 2 + sum [3]
```

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sum [1,2,3] = 1 + sum [2,3]
sum [2,3] = 2 + sum [3]
sum [3] = 3 + sum []
```

Before We Count Bulls

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sum :: [Int] -> Int
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- For example: `sum [1,2,3]`

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sum [3] = 3 + sum []
sum [] = 0
```

Count Bulls

- What is `(x:xs)` ?

```
sum :: [Int] -> Int
sum [] = 0
sum (x:xs) = x + sum xs
```

- How to count Bulls?

```
checkA :: Eq a => [a] -> [a] -> Int
checkA [] [] = 0
checkA (x:xs) (y:ys)
           | x == y    = 1 + (checkA xs ys)
           | otherwise = checkA xs ys
```

Count Bulls

- How to count Bulls?

```haskell
checkA :: Eq a => [a] -> [a] -> Int
checkA [] [] = 0
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```

- Example

```haskell
checkA [4,2,7,1] [1,2,3,4]
```

Count Bulls

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- Example

```
checkA [4,2,7,1] [1,2,3,4]
4\=1 -> checkA [2,7,1] [2,3,4]
```

Count Bulls

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```

- Example

```
checkA [4,2,7,1] [1,2,3,4]
4\=1 -> checkA [2,7,1] [2,3,4]
2==2 -> 1 + checkA [7,1] [3,4]
```

Count Bulls

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- Example

```
checkA [4,2,7,1] [1,2,3,4]
4\=1 -> checkA [2,7,1] [2,3,4]
2==2 -> 1 + checkA [7,1] [3,4]
7\=3 -> checkA [1] [4]
```

Count Bulls

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checkA :: Eq a => [a] -> [a] -> Int
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- Example

```
checkA [4,2,7,1] [1,2,3,4]
4\=1 -> checkA [2,7,1] [2,3,4]
2==2 -> 1 + checkA [7,1] [3,4]
7\=3 -> checkA [1] [4]
1\=4 -> checkA [] []
```

Before We Count Cows

1. Subtract

```
subtract 3 5 -- 2
subtract 6 3 -- -3
```

Before We Count Cows

1. Subtract

```
subtract 3 5 -- 2
subtract 6 3 -- -3
```

2. Check if element in a list

```
elem 1 [1,2,3,4,5] -- True
elem 14 [1..10] -- False
```

Before We Count Cows

1. Subtract

```
subtract 3 5 -- 2
subtract 6 3 -- -3
```

2. Check if element in a list

```
elem 1 [1,2,3,4,5] -- True
elem 14 [1..10] -- False
```

3. Count elements in a list

```
filter (>5) [1,2,3,4,5,6,7,8] -- [6,7,8]
length [6,7,8] -- 3
length $ filter (>5) [1..8] -- 3
```

Before We Count Cows

1. Subtract

```
subtract 3 5 -- 2
subtract 6 3 -- -3
```

2. Check if element in a list

```
elem 1 [1,2,3,4,5] -- True
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3. Count elements in a list

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filter (>5) [1,2,3,4,5,6,7,8] -- [6,7,8]
length [6,7,8] -- 3
length $ filter (>5) [1..8] -- 3
```

4. Map (higher-order function)

```
map square [1, 2, 3, 4, 5] -- [1, 4, 9, 16, 25]
```

Magic to Count Cows

1. Before we count Cows

```
elem 1 [1,2,3,4,5] -- True
map square [1..5] -- [1,4,9,16,25]
```

2. Count the number of same elements in two lists

```
f1 xs ys = map (\y -> elem y xs) ys
f1 [2,3,4] [5,2,4] -- [False,True,True]
-- map (\y -> elem y [2,3,4]) [5,2,4]
```

Magic to Count Cows

1. Before we count Cows

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elem 1 [1,2,3,4,5] -- True
map square [1..5] -- [1,4,9,16,25]

length $ filter (>5) [1..8] -- 3
```

2. Count the number of same elements in two lists

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-- map (\y -> elem y [2,3,4]) [5,2,4]

f2 xs ys = length $ filter (True==) $ f1 xs ys
f2 [2,3,4] [5,2,4] -- 2
-- length $ filter (True==) [False,True,True]
```

Let's Count Cows

1. Count the number of same elements in two lists

```
f1 xs ys = map (\y -> elem y xs) ys
f1 [2,3,4] [5,2,4] -- [False,True,True]
-- map (\y -> elem y [2,3,4]) [5,2,4]

f2 xs ys = length $ filter (True==) $ f1 xs ys
f2 [2,3,4] [5,2,4] -- 2
-- length $ filter (True==) [False,True,True]
```

2. How to count cows?

```
checkAB :: Eq a => [a] -> [a] -> (Int, Int)
checkAB xs ys = (a_num, b_num)
  where a_num = checkA xs ys
        b_num = subtract a_num $ length $
           filter (True==) $ map (\y -> elem y
           xs) ys
```

Questions?

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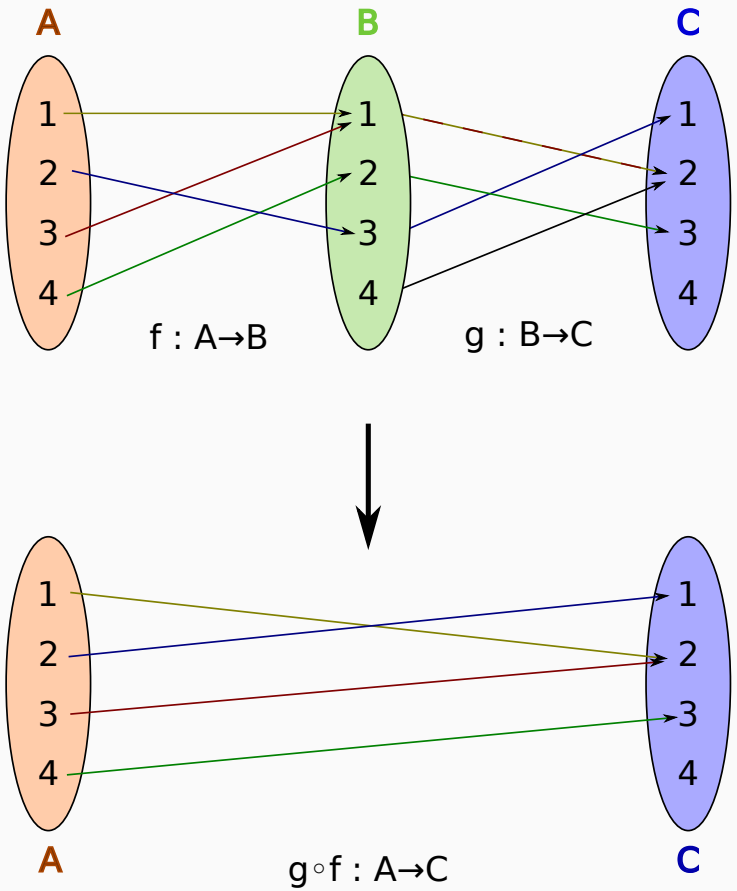
Function Composition

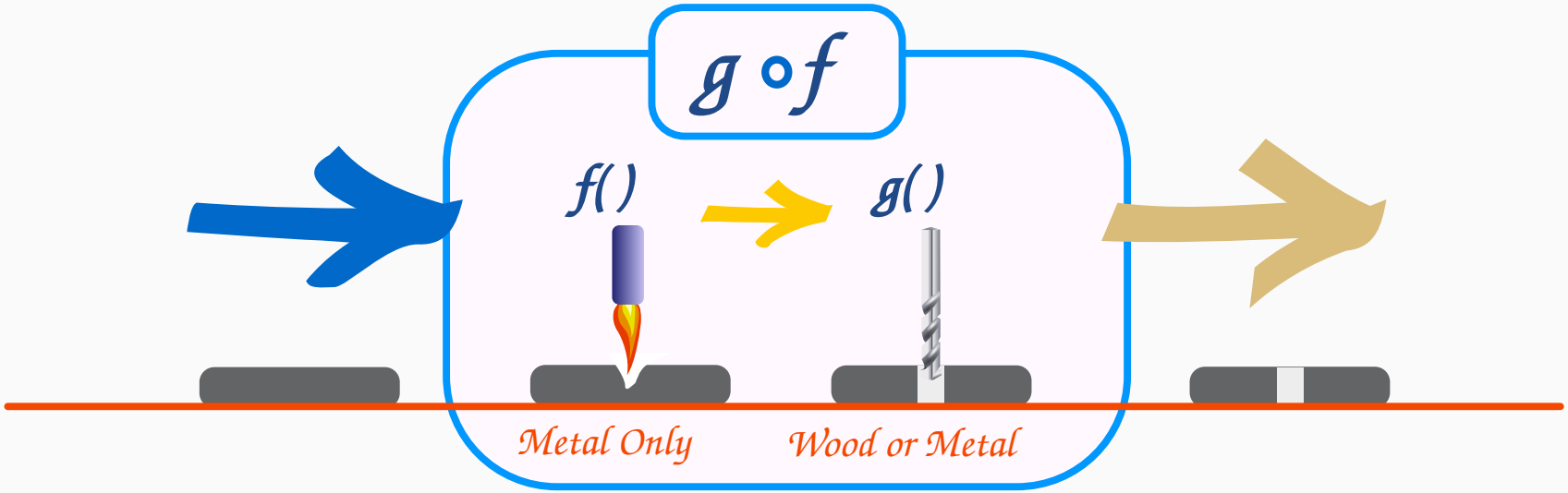
$$g \circ f(x) = g(f(x))$$



Example for a composition of two functions [2]

[2] From wikimedia commons by Stephan Kulla

Function Composition



Composition of Functions [3]

[3] https://www.mathsisfun.com/sets/functions-composition.html

Update Valid Answer

```
{- Update answer pool
 - choose the solutions which match the rules base
    on the test
 -}
updateAnswers :: Eq a => [[a]] -> [a] -> (Int, Int)
    -> [[a]]
updateAnswers ans test rules
        = filter ((rules==).(checkAB test)) ans
```

Questions?

sli.do/coscup22-fp