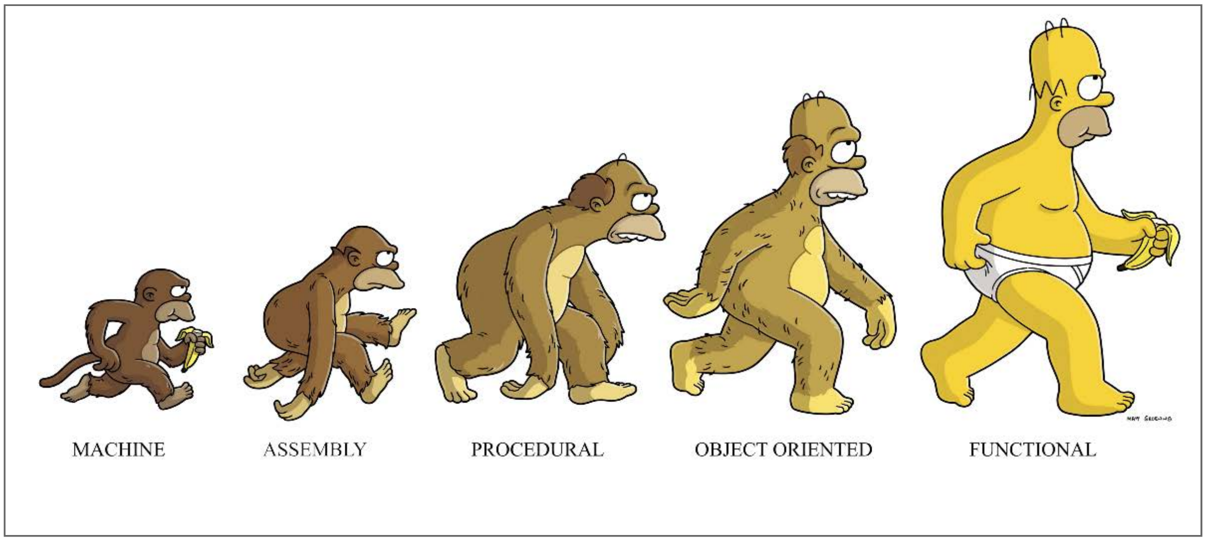
Functional Programming

What, Why and How

Just twitted the slides @JSDude005

ThatJSDude.com

youtube.com/ThatJSDude


MACHINE
ASSEMBLY
PROCEDURAL
OBJECT ORIENTED
FUNCTIONAL

We will talk about

- Three Basics of Functional Programming
- Five Popular patterns and techniques
- Three higher level Geeky things
- Compare OOP with FP
- Transform OOP to FP
- ...and lots of fun

Why

FP Shines

- Cloud/Big Data for data processing, filtering, aggregating
- Easier to figure out what the hell is going on in a larger code base
- Concepts are used in web application
- Easier to read, maintain, test
- Avoid a mess of states or multi threading issues

Ref: **Why FP matters**

What

Ask the geeky guy

- Monads, Monoids, Lift, Functors, actuators
- Immutable, Higher Order, Tail call optimization
- Lazy evaluation, composition, determinism

What the func?

- Dizzying number of “functional” characteristics
- Lambdas!!!
- Learn Haskell
- Is this only a hype or a geeky thing?
- Why it's called functional?
- Is everything else is dysfunctional?

Ref: **What is Functional Programming**

Fully lost!

Like everyone else

Learn driving

ref: **Charles Scalfani: So you want to be a functional programmer**


ROAD
TRACK

Forget everything

you know

Let's Start

Functional Programming

- Application evolves around function
- With only one ground rule: **No side effect**
- Don’t **rely on data outside** of the current function
- Don’t **change data outside** of the current function
- Every other “functional programing” things are derived from this property
- Use this as a guide rope

Ref: **Practical Functional Programming**

This is a function

```
function add(x, y){
  return x + y;
}
```

```
add(1, 2); // output is 3
add(1, 2); // output still is 3
add(1, 2); // WILL ALWAYS output 3
```

- Output relies solely on input values
- Always produce same output for same inputs.
- Does not produce an observable side effect
- Does not change the program's state
- Highly testable and reusable

What about this one?

```
function mouseOnLeftSide(mouseX) {
    return mouseX < window.innerWidth / 2;
}
```

Few more... impure function

```
writeFile(fileName);
updateDatabaseTable(sqlCmd);
sendAjaxRequest(ajaxRequest);
openSocket(ipAddress);
```

- Rely on things outside of input parameter
- Can't always predict their behavior/output
- They will have **side effect**
- Non FP (C#, Java, JS) has tons of these

Dark side of side effect

When a function produces a side effect you have to know more than just its inputs and output

- To understand what that function does
- You have to know the context and the history
- It makes function harder and unpredictable
- Harder to test and harder to debug

Convert Impure to pure

Make global variable local

```
const myFunc = function(y){
  const x = 10;
  return x + y;
}

console.log(myFunc(3)); //13
console.log(myFunc(3)); //13
```

Pass as parameter

```
const x = 10;
const myFunc = function(x, y){
  return x + y;
}

console.log(myFunc(x, 3)); //13
console.log(myFunc(x, 3)); //13
```

Basic Concept-1

Use Pure function

First Class

function is first class citizen

- Use function as value
- Set function to a variable
- Pass function as parameter
- return function as a value

```
// function expression
const doubleIt = x => x * 2;
```

Higher order function

- Either take function as argument
- Or return function

```
function greaterThan(n) {
  return function(m) {
    return m > n;
  };
}
```

```
const greaterThan10 = greaterThan(10);
greaterThan10(11); //true
greaterThan10(7); //false
```

```
const greaterThan15 = greaterThan(15);
greaterThan15(11); //false
greaterThan15(21); //true
```

Basic Concept-2

Function is First Class

Immutability

Treat data as Immutable

- Immutable is not Mutable
- Not changeable
- number, string, boolean are immutable
- Mutation has side effect
- Less changes means less things to keep track

Global Mutable State

Immutability creates simpler and safer code.

read **Programmer needs limit**

Programming vs Math

```
var x = 1;
x = x + 1;
```

- It's permitted in Imperative Programming
- In math, x can never be equal to x + 1
- In functional programming, x = x + 1 is illegal
- There are **no variables** in Functional Programming
- Stored values are still called variables because of history but they are constants
- Once x takes on a value, it’s that value for life

> *“HOW THE HELL AM I SUPPOSED TO DO ANYTHING WITHOUT VARIABLES?!”*

Just create a new variable

Hold on

Loop needs variable

for, while, do while, etc.

```
var sum = 0;
for (var i = 1; i <= 10; ++i){
  sum += i;
}
console.log(sum); // prints 55
```

> *“WHAT NO VARIABLES AND NOW NO LOOPS?! I HATE YOU!!!”*

Iterate over lists

```
let tasks = ['write code', 'drink coffee', 'hide from manager'
const lengths = tasks.map(word => word.length);
console.log(lengths); // [10, 12, 17]
```

```
const getLength = word => word.length;

tasks.map(getLength);
meals.map(getLength);
```

```
const doubleIt = x => x*2;

tasks.map(getLength).map(doubleIt);
```

use map

Filter

```
const numbers = [1, 2, 3, 4];
let newNumbers = [];

for(let i = 0; i < numbers.length; i++) {
    if(numbers[i] % 2 !== 0) {
        newNumbers[i] = numbers[i] * 2;
    }
}

console.log(newNumbers); // [2, 6]
```

```
const numbers = [1, 2, 3, 4];
const odd = n => n % 2;
const doubleIt = x => x * 2;

const newNumbers = numbers.filter(odd).map(doubleIt);
```

Ref: **map, filter, reduce**

Why map, filter, reduce

- Structure for looping always same
- Map, filter, reduce take care of the repeating parts
- Reduce typing- reduce chances of error
- Focus on the important parts of the iteration: **the operation**

Understand Immutability

- Think of Immutable data as a value (such as a number)
- A number never changes.
- The number 7, is always 7
- If you add 1 to 7 you get a new value: 8
- It doesn't change 7 itself

Use: **Human readable example in Immutable.js**

Basic Concept-3

Data is Immutable

Summary 1

So far

- Functional programming means: a lot functions
- Not just functions but **pure functions**
- With only one ground rule: **No side effect**
- Avoid shared state, mutable data, and side-effects
- Immutable: No variable, only constant
- No looping: use map, filter, reduce

Three basic Rules

1. No Side Effect
2. Function is first class citizen
3. Data is Immutable

Find the napper

Who was in the image "Fully Lost?"

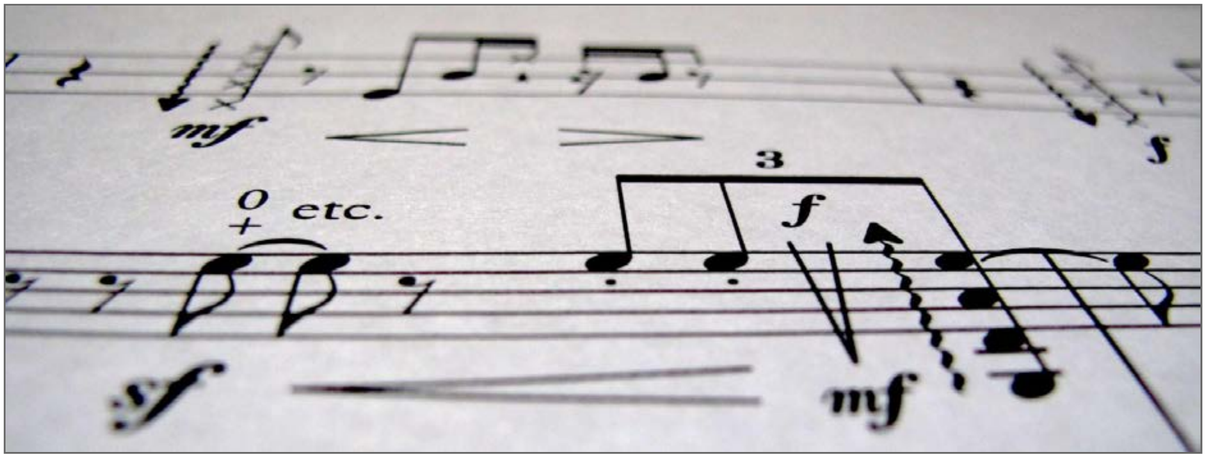
Patterns and Techniques

Used in Functional Programming

WARNING

- Everything you know has a obscure name
- There are **harder alternatives** to simple things
- Nerd means living dictionary of **Jargons**

Composition



$f(x) = 2x + 3$

$f(5) = ?$

```
f(5) = 2 * 5 + 3
     = 10 + 3
     = 13
```

$g(x) = x^2 + 1$

$g(2) = ?$

```
g(2) = 2 * 2 + 1
     = 4 + 1
     = 5
```

What is the value of f(g(x)) or f(g(2))?

```
f(g(2)) = f(5)
        = 2 * 5 + 3
        = 10 + 3
        = 13
```

Make this complicated

- What you saw as f(g(x))
- f ∘ g (read as f of g)
- f after g
- calling f after calling g with x
- or simply: **f composed with g**

g(x) inside f(x)...inside executes first

function composition

Wait! it's not new

```
const mult5 = x => x * 5;
const add10 = x => x + 10;
```

```
const mult5AfterAdd10 = x => mult5(add10(x));
```

f(g(x))

Function Composotion

```
var compose = function(f, g) {
  return function(x) {
    return f(g(x));
  };
};
```

```
const mult5 = x =>  x * 5;
const add10 = x =>  x + 10;

const mult5AfterAdd10 = compose(mult5, add10);
mult5AfterAdd10(5); //75
```

executes **right to left**

Direction matters

ref: **Coding by composing**

Why Composition

- Put multiple functions together to get one function
- Moves right to left
- Each step sequentially processing it before handing it to the next
- Encourages factoring (breaking apart) for maintainability and code reuse
- Cleans up nesting

Currying

Ref: **Haskell Brooks Curry**

Currying

- Call a function with one parameter at a time
- Returns a function that takes second parameter
- arguments are taken by a series of one-argument

```
const sum3 = (x, y, z) => x + y + z;
sum3(1,2,3); //6
```

```
function currySum3(x){
  return function (y){
    return function (z){
      return x + y + z;
    }
  }
}

const currySum3 = x => y => z => x + y + z;
currySum3(1)(2)(3); //= 6
```

Ref: **Why Curry Helps** and **Curry JS**

Why Curry?

```
const modulo = divisor => dividend => dividend % divisor;

modulo (3)(9); //0
```

```
const isOdd = modulo(2);

isOdd(6); //0

isOdd(5); //1
```

- Make reusable generic function
- Build new function by applying args
- Partially applied for higher order function
- Make types "line up" for composition

Ref: **advantages of currying**

Currying and Composition

```
const f = a => b => c => d => a + b + c + d
f(1)(2)(3)(4); // returns 10
```

```
const f = R.curry((a, b, c, d) => a + b + c + d);
f(1, 2, 3, 4); // returns 10
f(1, 2)(3, 4); // also returns 10
f(1)(2)(3, 4); // also returns 10
```

Ref: **Ramada JS**

Point Free

Point Free Programming

- Also known as **Tacit Programming**
- function definition does not include arguments
- Uses combinators and function composition instead of variable
- For simplicity you can think point is argument.
- Hence point free is argument free

You use point free: to focus on how rather than what

Ref: **Think point free**

Point free notation

```
const toUpperCase = str => str.toUpperCase();
const head = str => str[0];
const compose = (f, g) => x => f(g(x));

//not point free because we mention the data: name
const initials = function(name) {
 return name.split(' ').map(compose(toUpperCase,head)).join('.
};
```

```
initials("that js dude");
// 'T. J. D.'
```

```
//point free
const initials = compose(join('. '),
                    map(compose(toUpperCase, head)), split(' '
```

Ref **this** and **this as well** or **this**

Tail call Optimization

Tail call optimization

- A tail call is a function call that is the last action of a function
- Smart compiler recognizes tail calls and reuses the same call frame
- When calling function will simply return the value that it gets from the called function
- Optimized to use constant stack space
- The most common use is tail-recursion
- Can happen for non-recursive case as well

Ref: **Tail call optimization**

What is a tail call?

```
//Both f() and g() are in tail position
const a = x => x ? f() : g();
```

```
// g() is in a tail position
const a = () => f() || g();

const a = () => f() && g();
```

Ref: **Tail call optimization ES6**

fibonacci

```
function fib(n) {
  if (n <= 1){
    return n;
  } else {
    return fib(n-1) + fib(n - 2);
  }
}
```

```
                          fib(5)
                         /      \
                        /        \
                  fib(4)         fib(3)
                 /      \        /    \
                /        \      /      \
          fib(3)         fib(2)   .........
          /   \          /   \
         /     \        /     \
     fib(2)  fib(1)  fib(1)  fib(0)
      /   \
     /     \
 fib(1)  fib(0)
```

- Algorithm has O(n) memory complexity
- Calculating fib(1) the callstack has 5 frames on it
- Each remembering how to combine with the other calls

```
function fibIterRecursive(n, a, b){
  if (n === 0) {
    return b;
  } else {
    return fibIterRecursive(n-1, a + b, a);
  }
};

function fib(n){
  return fibIterRecursive(n, 1, 0);
}
```

- return invocation of a function
- that function does not need to access any of the current local variables
- Then ES6 strict mode will optimize that call by reusing the stack frame

Pipelines

Collection Pipelines

- A programming pattern
- Lays out a sequence of operations
- Feed output of one operation into the next
- Common in FP and OOP with Lambdas
- Put common operations (map, filter, reduce) together

ref: **Martin Fowler: Collection pipelines**

Pipelines in Unix

find all wiki that mention "nosql" in the text

```
grep -l 'nosql' wiki

grep -l 'nosql' wiki/* | xargs wc -w
```

```
grep -l 'nosql' wiki/* | xargs wc -w | sort -nr
```

```
grep -l 'nosql' wiki/* | xargs wc -w | sort -nr | head -4 | ta
```

ref: **Martin Fowler: Collection pipelines**

Pipeline in JS

```
const addOne = x => x + 1;
const square = x => x * x;
const minusTwo = x => x - 2;

// Not reusable
minusTwo(square(addOne(10)));
minusTwo(square(addOne(20)));
```

```
const someFormula = new Pipeline([ addOne, square, minusTwo ])
someFormula.process(10);
someFormula.process(20)
```

```
// alternative approach
const someFormula = (new Pipeline()).pipe(addOne)
                                    .pipe(square)
                                    .pipe(minusTwo);
```

Ref: **pipeline JS**

ESNext Proposal

```
const doubleSay = str => str + ", " + str;
const capitalize  = str => str[0].toUpperCase() + str.substrin
const exclaim = str => str + '!';
```

```
let result = exclaim(capitalize(doubleSay("hello")));

let result = "hello" |> doubleSay |> capitalize |> exclaim;
//Hello, hello!
```

ref: **JS pipeline proposal**

Partial application

Currying and partial application

- Currying is strict: always takes 1 parameter at a time
- Partial application is not this strict
- You can pass more than one parameter at a time

Ref: **here** or **this**

Summary 2

So far

- Compose puts functions together
- Curry takes one argument at a time
- Point free...doesn't take arguments
- Partial application takes one or more
- Tail call is a compiler magic

Code reuse

- Code reuse sounds great but is difficult to achieve.
- Make the code too specific and you can’t reuse it.
- Make it too general and it can be too difficult to use in the first place
- So what we need is a balance between the two, a way to make smaller

Find the napper

While cooking curry...how many people were adding spices?

Category Theory

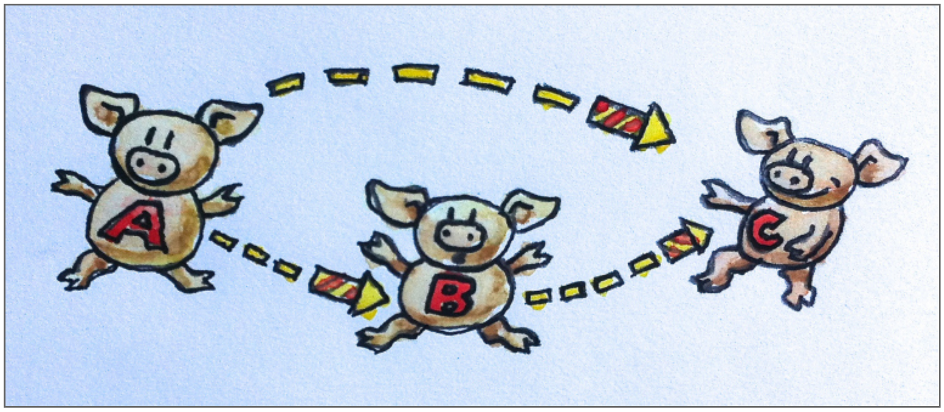
> *In theory, there is no difference between theory and practice. But, in practice, there is.*

Category Theory

- Mathematical discipline in theoretical computer science
- It has a wide range of applications
- Concepts like Category, Functor, Monad, and others
- Understanding Category Theory isn't a must to use FP

Ref: **Category Theory**

Categories



- A category consists of objects and arrows that go between them.
- Arrows are known as morphisms. Morphisms can be thought of as functions.

For any group of connected objects, a -> b -> c, there must be a composition which goes directly from a -> c

Ref: **Category Theory for Programmers: Book**

Functor

Functor in theory

- The term “functor” comes from category theory

> *A functor is a container of type a that, when subjected to a function that maps from a→b, yields a container of type b.*

ref: **what is functor**

Fun Fun Functor

- An object with a .map() method
- map method takes function as a parameter
- maps from one set of values to another
- Return another functor so that you can map further
- Think functor as something **mappable**
- Like array, streams, trees, objects

> *A functor supplies a box with zero or more things inside, and a mapping interface.*

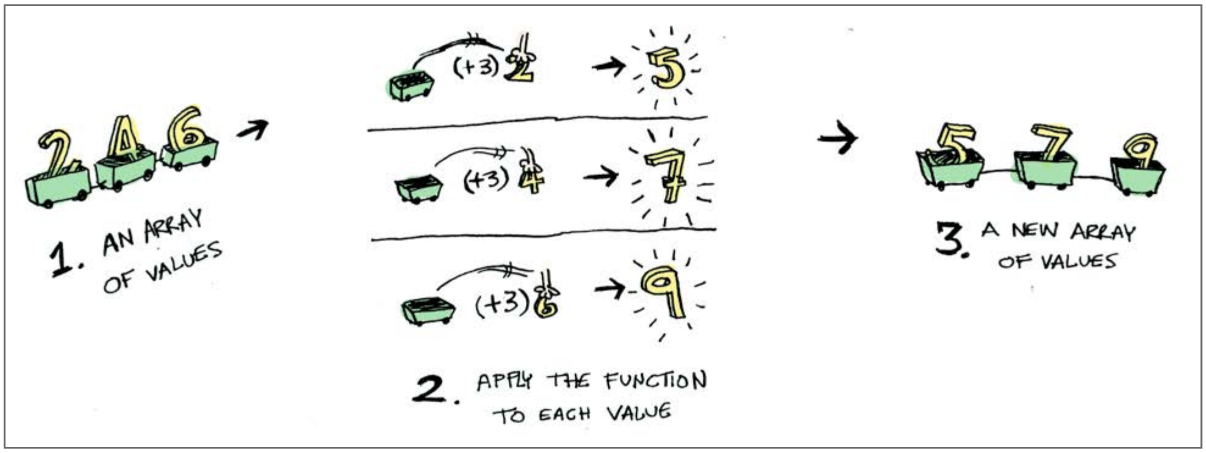
Functor has two laws

1. Identity
2. Composition

```
const functor = [1, 2, 3];
functor.map(x => x); // [1, 2, 3]
```

```
functor.map(x => f(g(x))) ≡ functor.map(g).map(f)
```

Ref: **Functors & Categories**


(+3)
(+3)
(+3)
1. AN ARRAY OF VALUES
2. APPLY THE FUNCTION TO EACH VALUE
3. A NEW ARRAY OF VALUES

Functor

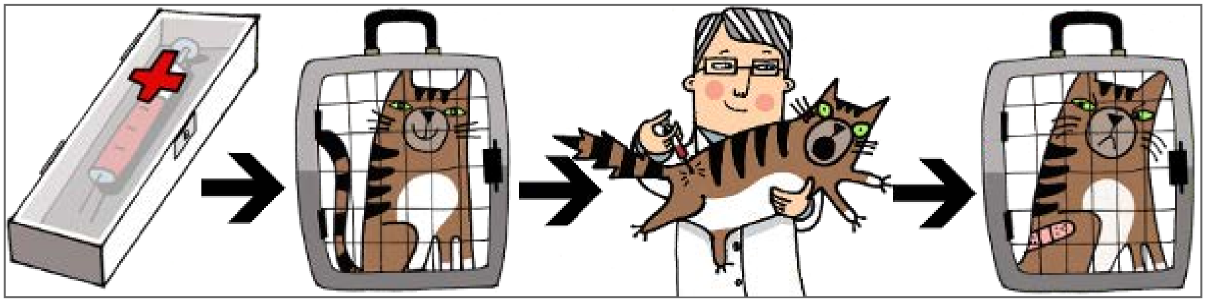
```
const Container = x => ({
    map:(f) => Container(f(x)),
    toString(){return `Container(${x})`}
});
```

```
const inContainer = Container(5);
const mapped = inContainer.map(x => x*2)
mapped.toString(); //Container(10)
```

```
const transformValue = x => Container(x)
                .map(x => x*2)
                .map(x => x*3)
                .map(x => x+46)
                .map(x => String.fromCharCode(x))
```

Applicative Functor

Combine multiple functor into one functor

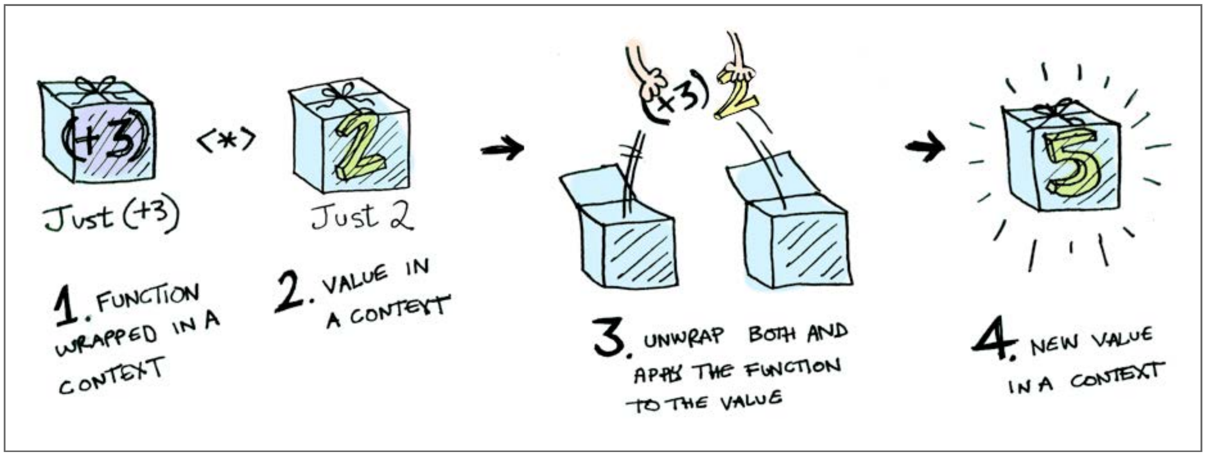


Ref: **applicatives**

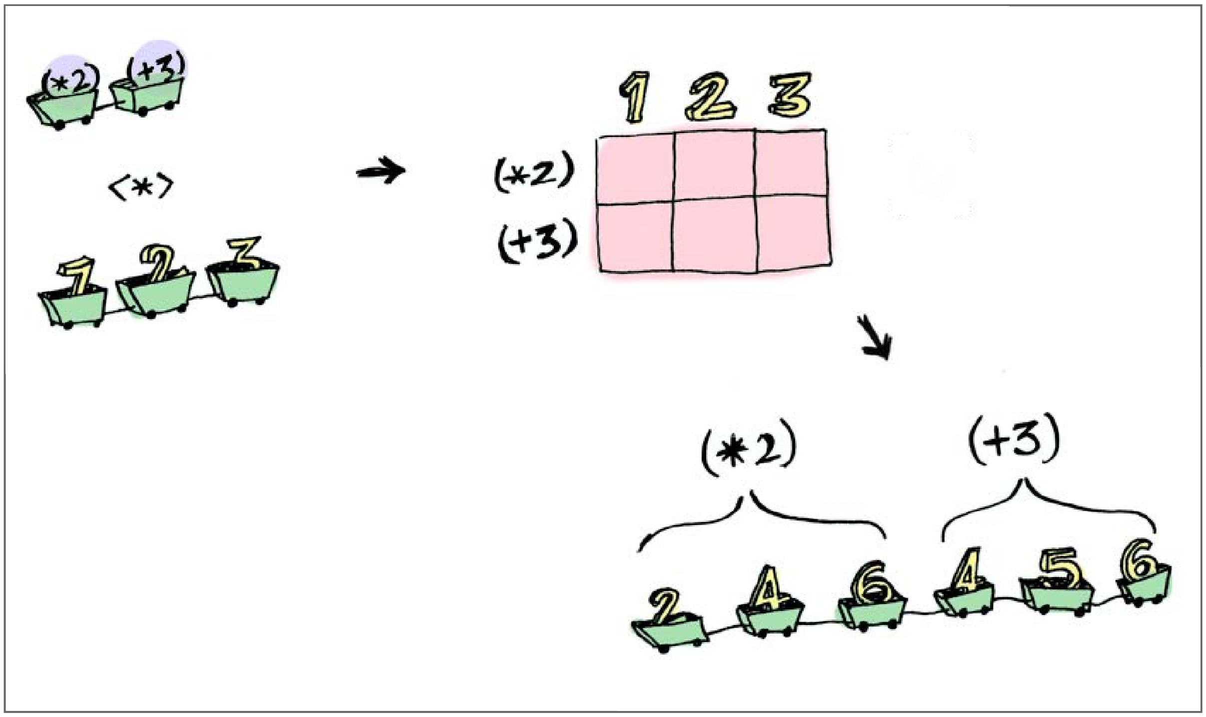
Wrapped values

```
var wrapped2 = [2];
var wrapped3 = [3];

//Won't work ! The values are wrapped.
add(wrapped2, wrapped3);
```



applicatives in JS



Ref: **applicatives**

Monads

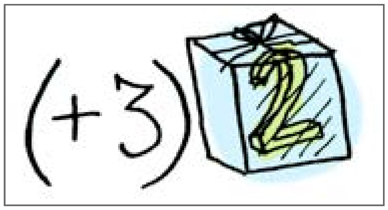
Monads in Two steps

1. Get a PhD in Computer Science
2. Throw it away because you don't need PhD to understand Monad

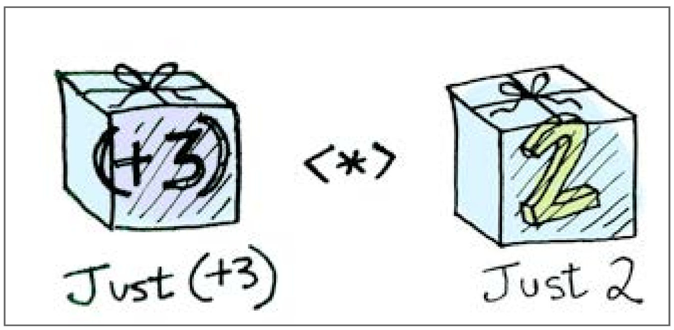
> *The moment you understand what is monads, is the moment you loose the ability to explain it to someone else.*

Functors, Applicatives

Functors apply a function to a wrapped value



Applicatives apply a wrapped function to a wrapped value



Monads

Monads apply a function that **returns a wrapped value to a wrapped value**

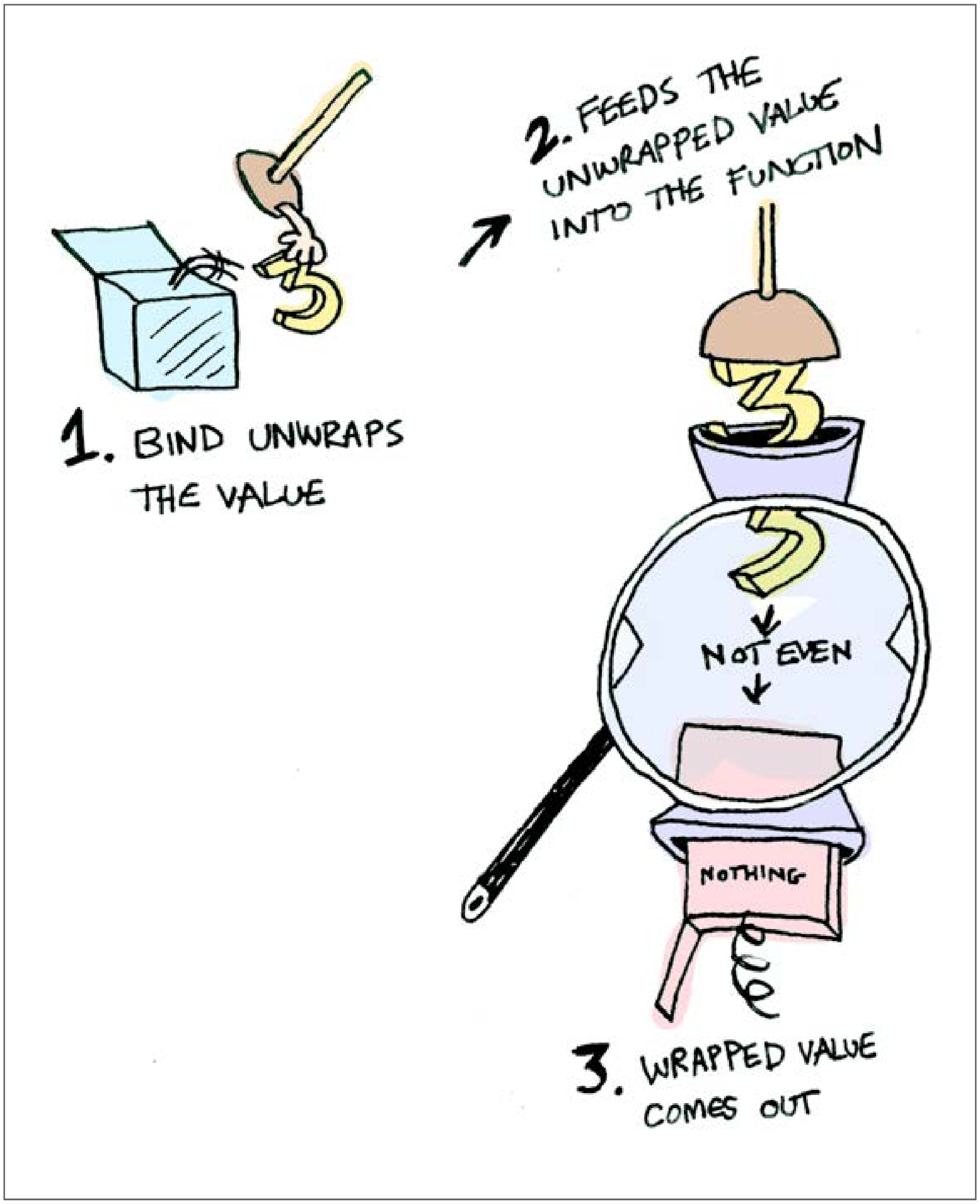
```
const half = x => (x%2 === 0) ? [x/2] : [];
```

```
Array.prototype.flatMap = function(lambda) {
  return [].concat.apply([], this.map(lambda));
};
```

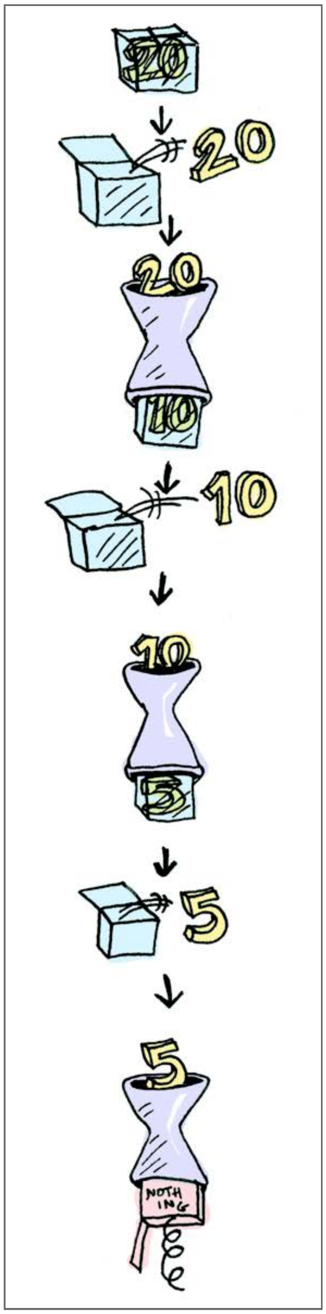
```
[3].flatMap(half); //[]
[4].flatMap(half); //[2]
[1,2,3,4,5,6,7,8].flatMap(half); //[1, 2, 3, 4]
```

Simple way: Monad is the container that Applies **flatMap**

Ref: **monad in JS**



1. BIND UNWRAPS THE VALUE
2. FEEDS THE UNWRAPPED VALUE INTO THE FUNCTION
NOT EVEN
NOTHING
3. WRAPPED VALUE COMES OUT


20
20
20
10
10
10
5
5
5
NOTH
ING

Few Types of Monad

- **Maybe moand**
- **Humble Monads**
- **Monads in JS**
- **Monads in Haskel**
- **Monads**
- **Explain monads by using this**

Summary 3

- functor means mappable
- wrapped value to wrapped value
- Monad is the container that Applies flatMap

Contrast with OOP

Inheritance

- Inertance says what they are

```
Dog
  .bark()
```

```
Cat
  .meow()
```

composition vs inheritance

Inheritance

```
Dog
  .poop()
  .bark()
```

```
Cat
  .poop()
  .meow()
```

composition vs inheritance

Inheritance

```
Animal
  .poop()

  Dog
    .bark()

  Cat
    .meow()
```

[composition vs inheritance]

Inheritance

```
CleaningRobot
  .drive()
  .clean()
```

```
Animal
  .poop()

  Dog
    .bark()

  Cat
    .meow()
```

composition vs inheritance

Inheritance

```
MurderRobot
  .drive()
  .kill()
```

```
CleaningRobot
  .drive()
  .clean()
```

```
Animal
  .poop()

  Dog
    .bark()

  Cat
    .meow()
```

composition vs inheritance

```
Robot
  .drive()

  MurderRobot
    .kill()

  CleaningRobot
    .clean()
```

```
Animal
  .poop()

  Dog
    .bark()

  Cat
    .meow()
```

Murder Robot Dog?

composition vs inheritance

Kill, drive & bark

```
Robot
  .drive()

  MurderRobot
    .kill()

  CleaningRobot
    .clean()
```

```
Animal
  .poop()

  Dog
    .bark()

  Cat
    .meow()
```

Higher level object???

```
GameObject
  .bark()

   Robot
    .drive()

    MurderRobot
      .kill()

    CleaningRobot
      .clean()

      MurderRobotDog
```

```
  Animal
    .poop()

    Dog
      .bark()

    Cat
      .meow()
```

```
Robot
  .drive()

  MurderRobot
    .kill()

  CleaningRobot
        .clean()

        MurderRobotDog
          .bark()
```

- Getting more functionality than needed
- Like **Gorilla - Banana Problem**
- You asked for a banana
- You get a gorilla holding a banana

Composition

- Inertance: Types are designed on what they are
- Composition: Types are designed on what they do

```
dog = pooper + barker
cat = pooper + meower

cleaningRobot = driver + cleaner
murderRobot = driver + killer

murderRobotDog = murderRobot + dog
```

```
killerDog = dog + killer
```

Composition benefit

- On error, you will see a stack trace
- Through every function down to the source of the bug
- In OOP: it could be confusing
- As you don’t always know the state of the rest of the object which led to the bug

OOP and FP are not mutually exclusive

- Start with less side affect mind set
- Prefer immutable data
- Use pure function
- Prefers declarative style
- Put Implementation detail packaged away
- Target cleaner, readable code

Free tip

My top 8 excuses

1. It worked on my machine
2. Browser might be caching old content. hit **Ctlr + F5**
3. You must have the wrong version
4. Ohh...I forgot to push the changes
5. That was only supposed to be a placeholder
6. It's not a true bug, it's a new feature
7. The guy who left, his code is causing this
8. It's a **known issue** in JavaScript

Final Summary

Functional Programming

Write pure functionas much as possible

Ref: **Functional Programming**

Who is

JS Dude?

- **@jsdude005**
- Organizer Chicago JavaScript meetup
- Organize Chicago front end developers group
- This is my fifth year in that conference
- Giving talk all over the places
- Run Marathon, sky diving, tough mudder

Thank you!!!

Slides: **khan4019.github.io/functional-programming**

ThatJSDude.com / **@jsdude005**

khan4019@gmail.com