CS 696 Functional Programming and Design
Fall Semester, 2015
Doc 10 Functional, Exceptions, Multi-methods
Sep 29, 2015

What is Functional Programming

Elements of Functional Programming

Pure Functions

First Class Functions

Higher-Order Functions

Immutability

Lazy Evaluation

Recursion

Currying

Memoization

Destructuring

Collection Pipelines

List Compressions

Raw Data + functions

Raw Data + functions

```
class Person {
    private String firstName;
    private String lastName;
    private int age;
```

{:first-name “Roger”
:last-name “Whitney”
:age 21 }

filter (select), remove
map (fold)
reduce
transducers (Clojure 7)

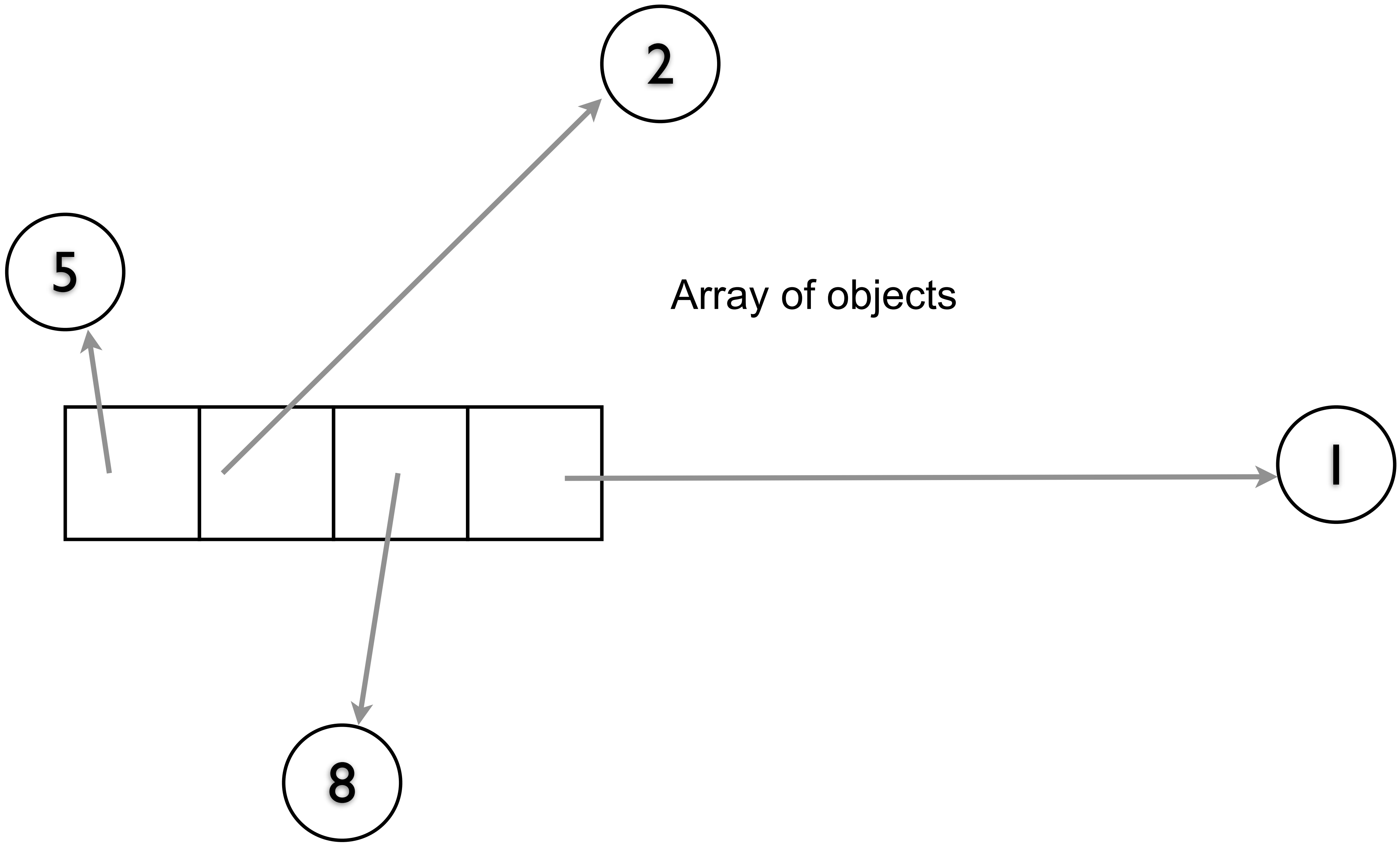
Cycles required to Fetch Data

Registers	~40 per core, sort of		0 cycles
L1	32KB per core	64B line	4 cycles
L2	256KB per core	64B line	11 cycles
L3	6MB	64B line	40-75 cycles
Main memory	8GB	4KB page	100-300 cycles

Locality of data helps keep data in same cache

5	2	8	1

Array of integers



Array of objects

Pure Functions

Functions with no side-effects

Only depend on arguments

Don't change state

```
class Foo {
    int bar

    public int notPure(int y) {
        return bar + y
    }

    public void alsoNotPure(int y) {
        bar = y
    }
```

Why important

Easier to
- debug
- test
- understand program

> OO makes code understandable by encapsulating moving parts.
> FP makes code understandable by minimizing moving parts.
>
> Michael Feathers

First Class Functions

Functions can be

- Assigned to variables
- Passed as arguments
- Returned from functions

Anonymous functions

- Lambdas
- Closures

Why important

- Flexibility
- Generality

Java Lambda Expression

Anonymous Function

```
(Integer a, Integer b) -> a + b
```

arguments

body

```
(Integer start, Integer stop) -> {
    for (int k = start; k < stop; k++)
        System.out.println(k);
    }
```

Short Version of Java Lambda Syntax

```
(String text) -> text.length();

text -> text.length();
```

```
(Integer a, Integer b) -> a + b

(a, b) -> a + b
```

Using Java Lambdas

```
Function<String,Integer> length =  text -> text.length();
int nameLength = length.apply("Roger Whitney");
```

```
BiFunction<Integer,Integer,Integer> adder = (a, b) -> a + b;
int sum = adder.apply(1, 2);
```

OnClickListener Example

```
button.setOnClickListener(new View.OnClickListener() {
	@Override
	public void onClick(View source) {
		makeToast();
	}
});
```

```
button.setOnClickListener( event -> makeToast());
```

Higher-Order Functions

Functions that operate on functions

map
reduce
filter
comp
partial
complement

Why important

Fewer details/
higher level logic

Concurrency

Java Stream methods

count()
distinct
filter
findAny
findFirst
flatMap
forEach
forEachOrdered
limit
map
max
min
nonMatch
reduce
sorted

Immutability

Data structures can not be modified

Like Java's Strings

> OO makes code understandable by encapsulating moving parts.
> FP makes code understandable by minimizing moving parts.
>
> Michael Feathers

Why important

Concurrency

No need for private data

Easier to
- debug
- test
- understand program

Java Immutability

Strings

Collections.unmodifiableList(List<? extends T> list)
Collections.unmodifiableMap(Map<? extends K,? extends V> m)
Collections.unmodifiableSet(Set<? extends T> s)
Collections.unmodifiableSortedMap(SortedMap<K,? extends V> m)
Collections.unmodifiableSortedSet(SortedSet<T> s)

Lazy Evaluation

Operations & functions evaluated

- When used
- Not when called

Why important

Simplifies logic

Java Lazy Evaluation

```
        String[] words = {"a", "ab", "abc", "abcd", "bat"};
        List<String> wordList = Arrays.asList(words);
        List<String> longWords
    longWords = wordList.stream()
                            .filter( s -> s.length() >
2)
                            .filter( s -> s.charAt(0)
== 'a')
                            .map( s ->
s.toUpperCase())

.collect(Collectors.toList());
        System.out.println(longWords);
```

Only One pass of List to do all operations

Recursion

```
function factorial(n)
    if n = 1 return 1
    return n * factorial(n-1)
```

Why important

Powerful tool

Tail recursion/Tail Call Optimization

When last statement is just the recursion

Compiler can convert recursion into loop

Currying

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

addTen = add(10);

addTen(3)  //returns 13
```

Why important

Memoization

Cache value of functions

Why important

memoize(factorial)

Performance

factorial(1000)   //1000 recursive calls
factorial(1001)   // 1 recursive call

Collection Pipelines

```java
String[] words = {"a", "ab", "abc", "abcd", "bat"};
List<String> wordList = Arrays.asList(words);
List<String> longWords;
longWords = wordList.stream()
                    .filter( s -> s.length() > 2)
                    .filter( s -> s.charAt(0) == 'a')
                    .map( s -> s.toUpperCase())
                    .collect(Collectors.toList());
```

Why important

Higher level logic

Concurrency

```clojure
(->> ["a", "ab", "abc", "abcd", "bat"]
    (filter #(< 2 (count %)))
    (filter #(= \a (first %)))
    (map clojure.string/upper-case))
```

Some Java

Accessing Static Methods & Fields

Static Fields	Static Methods
Class/fieldName	(Class/methodName arg1 arg2 …)
Math/PI	(Double/parseDouble "3.14159")
Float/MAX_VALUE	(Integer/toBinaryString 3)

Accessing Java instance methods

```
(.instanceMethod object arg1 …)
```

```
(.toUpperCase "cat")

(.isEmpty [1 2 3])

(.size [1 2 3])

(.get [1 2 3] 1)
```

Examples

```
(defn decimal-to-hex [x]
(-> x
   Integer/parseInt
   (Integer/toString 16)
    .toUpperCase))
```

```
(def iterator (.iterator [1 2 3]))
(while (.hasNext iterator)
  (println (.next iterator)))
```

Exceptions

```
(defn as-int
  [s]
  (try
    (Integer/parseInt s)
    (catch NumberFormatException e
       (.printStackTrace e))
    (finally
      (println "Attempted to parse as integer: " s))))
```

Raising an Exception

```
(throw (IllegalStateException. "I don't know what to do!"))
```

Common Exceptions

java.lang.IllegalArgumentException

java.lang.UnsupportedOperationException

java.lang.IllegalStateException

java.io.IOException

Text claims that these handle 90% of cases where you need exceptions

When to Use Exceptions?

Googles answer:

> Exceptions should be used for situation where a certain method or function could not execute normally.

Does this mean nil nodes in a tree?

Multimethods

Example

```
(defmulti even-odd even?)

(defmethod even-odd true
  [n]
  (str n " is even"))

(defmethod even-odd false
  [n]
  (str n " is odd"))
```

(even-odd 5)	5 is odd
(even-odd 4)	4 is even

Example

dispatch function

```
(defmulti even-odd even?)

(defmethod even-odd true
  [n]
  (str n " is even"))

(defmethod even-odd false
  [n]
  (str n " is odd"))
```

value of dispatch function
handled by this method

Default values

```
(defmulti fibonacci identity)

(defmethod fibonacci 0
  [n]
  0)

(defmethod fibonacci 1
  [n]
  1)

(defmethod fibonacci :default
  [n]
  (+ (fibonacci (dec n)) (fibonacci (- n 2))))
```

(fibonacci 1)	1
(fibonacci 10)	55

Dispatch Function can be any function

```
(defmulti types class)

(defmethod types java.lang.String
  [x]
  "it is a string")

(defmethod types java.lang.Long
  [x]
  "it is a Long")

(defmethod types :default
  [x]
  "Don't know")
```

(types "ca")	"it is a string"
(types 12)	"it is a Long"
(types 12.3)	"Don't know"

Multiple Arguments

```
(defmulti by-size (fn [a b] (size a)))

(defmethod by-size :small
  [x y]
  "small")

(defmethod by-size :small
  [x y]
  "small")

(defmethod by-size :medium
  [x y]
  "meduim")

(defmethod by-size :defualt
  [x y]
  "large & other")
```

```
(defn size
  [x]
  (cond
   (< x 5) :small
   (< x 20) :medium
   (< x 100) :large))
```

(by-size 2 20)	"small"
(by-size 10 20)	"meduim"

Vectors as Match

```
(defmulti by-size (fn [a b] [(size a) (size b)]))

(defmethod by-size [:small :small]
  [x y]
  "small-small")

(defmethod by-size [:small :large]
  [x y]
  "small-large")

(defmethod by-size [:medium :meduim]
  [x y]
  "meduim-medium")

(defmethod by-size :default
  [x y]
  "other")
```

```
(by-size 2 90)     "small-large"
(by-size 10 20)    "other"
```

Warning about defmulti

defmulti is define once

If you need to modify your defmulti need to remove it from the bindings

In previous example used

```
(ns-unmap *ns* 'by-size)
```

One Last Example

```
(defmulti by-children (fn [[a c b]] [(nil? b) (nil? c)]))

(defmethod by-children  [true true]
  [x]
  "no children")

(defmethod by-children  [true false]
  [x]
  "right child")

(defmethod by-children  [false true]
  [x]
  "left children")

(defmethod by-children  [false false]
  [x]
  "both children")
```

```
(by-children [1 4 nil])    "right child"
(by-children [1 nil nil])   "no children"
```

Open-Closed Principle

"software entities (classes, modules, functions, etc.) should be open for extension, but closed for modification"

Wikipedia