clojure

http://github.com/stuarthalloway/clojure-presentations

stuart halloway
http://thinkrelevance.com

clojure's four elevators

java interop

lisp

functional

state

1. java interop

java new

java	`new Widget("foo")`
clojure	`(new Widget "foo")`
clojure sugar	`(Widget. "red")`

access static members

java	`Math.PI`
clojure	`(. Math PI)`
clojure sugar	`Math/PI`

access instance members

java	`rnd.nextInt()`
clojure	`(. rnd nextInt)`
clojure sugar	`(.nextInt rnd)`

chaining access

java	`person.getAddress().getZipCode()`
clojure	`(. (. person getAddress) getZipCode)`
clojure sugar	`(.. person getAddress getZipCode)`

parenthesis count

java	()()()()
clojure	()()()

atomic data types

type	example	java equivalent
string	"foo"	String
character	\f	Character
regex	#"fo*"	Pattern
a. p. integer	42	Integer/Long/BigInteger
double	3.14159	Double
a.p. double	3.14159M	BigDecimal
boolean	TRUE	Boolean
nil	nil	null
symbol	foo, +	N/A
keyword	:foo, ::foo	N/A

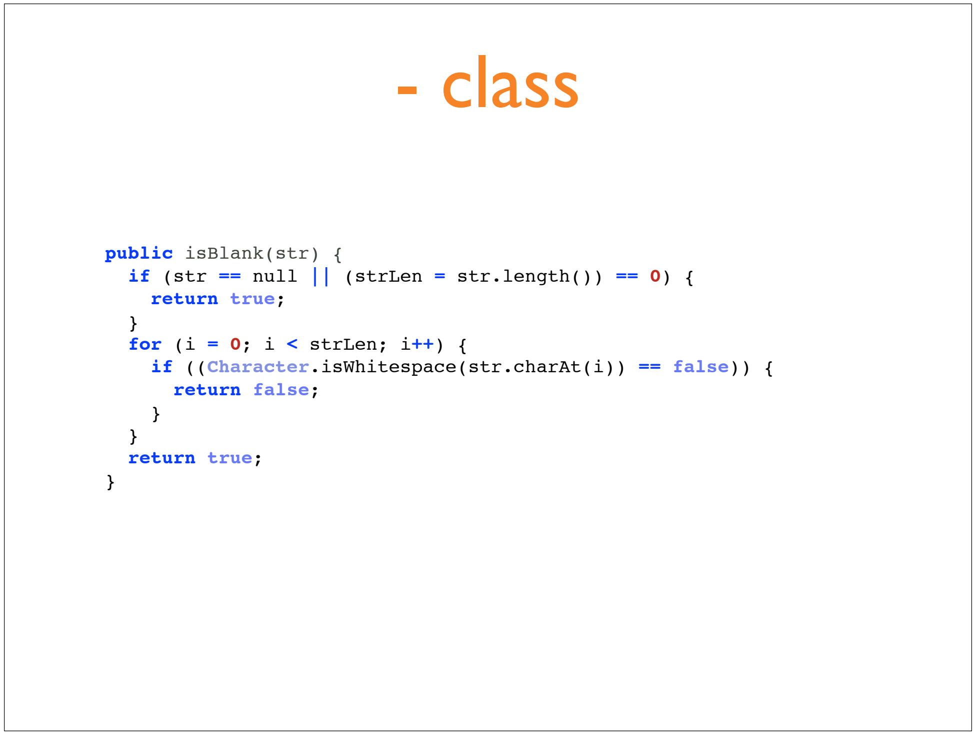
example: refactor apache commons isBlank

initial implementation

```
public class StringUtils {
  public static boolean isBlank(String str) {
    int strLen;
    if (str == null || (strLen = str.length()) == 0) {
      return true;
    }
    for (int i = 0; i < strLen; i++) {
      if ((Character.isWhitespace(str.charAt(i)) == false)) {
        return false;
      }
    }
    return true;
  }
}
```

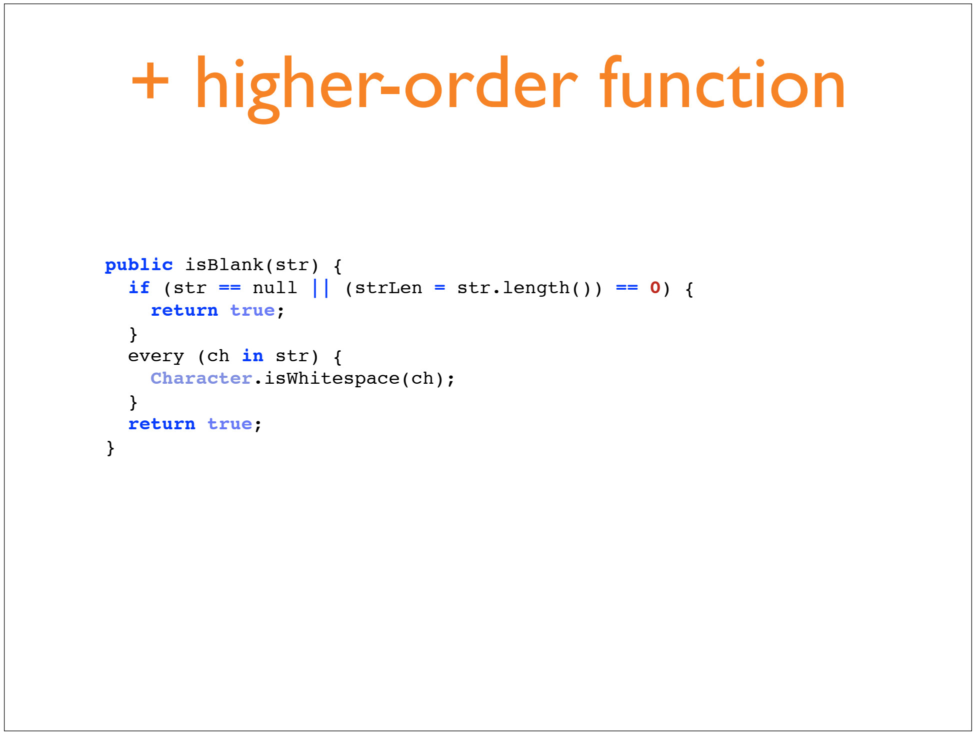
- type decls

```
public class StringUtils {
  public isBlank(str) {
    if (str == null || (strLen = str.length()) == 0) {
      return true;
    }
    for (i = 0; i < strLen; i++) {
      if ((Character.isWhitespace(str.charAt(i)) == false)) {
        return false;
      }
    }
    return true;
  }
}
```



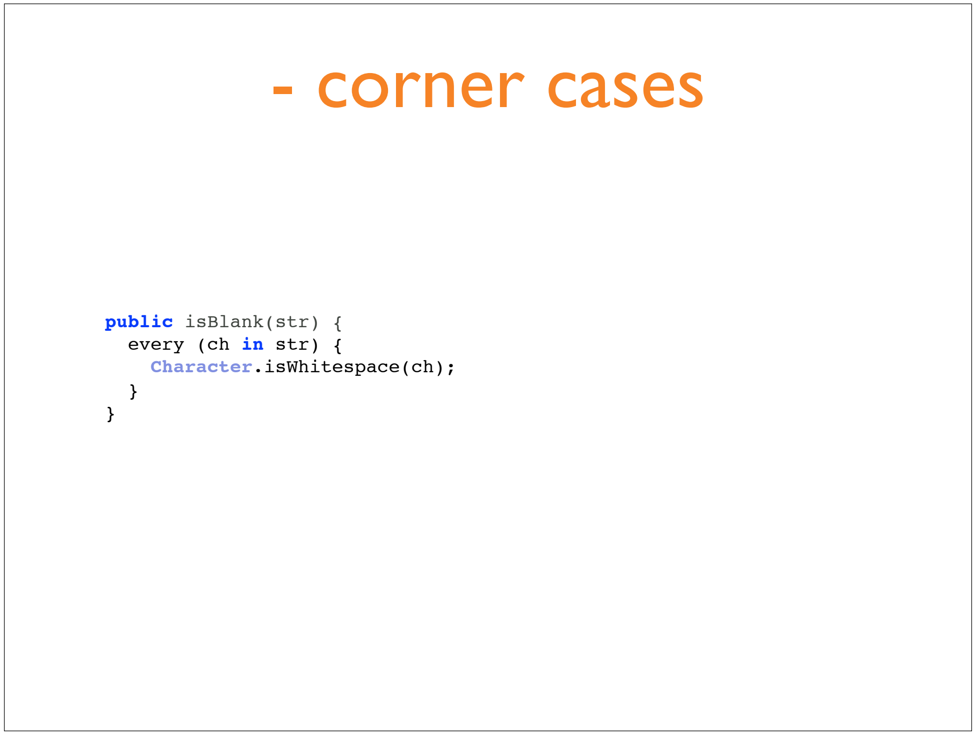
- class

```
public isBlank(str) {
  if (str == null || (strLen = str.length()) == 0) {
    return true;
  }
  for (i = 0; i < strLen; i++) {
    if ((Character.isWhitespace(str.charAt(i)) == false)) {
      return false;
    }
  }
  return true;
}
```



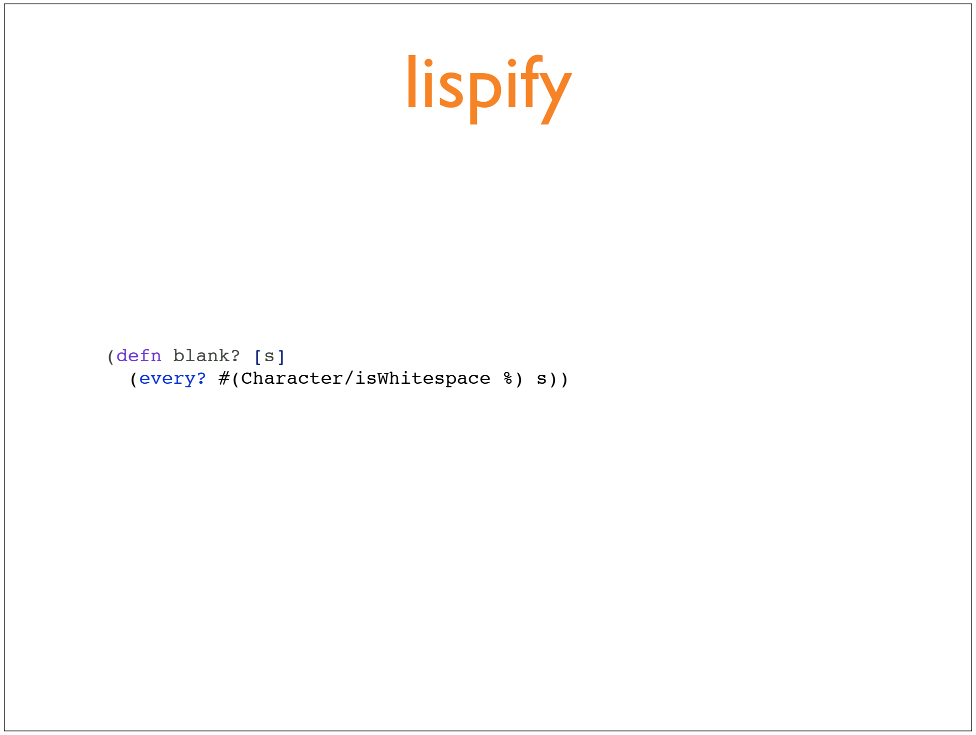
+ higher-order function

```
public isBlank(str) {
  if (str == null || (strLen = str.length()) == 0) {
    return true;
  }
  every (ch in str) {
    Character.isWhitespace(ch);
  }
  return true;
}
```



- corner cases

```
public isBlank(str) {
  every (ch in str) {
    Character.isWhitespace(ch);
  }
}
```



lispify

```
(defn blank? [s]
  (every? #(Character/isWhitespace %) s))
```

clojure is a better java than java

2. lisp

what makes lisp different

feature	industry norm	cool kids	clojure
conditionals	✔	✔	✔
variables	✔	✔	✔
garbage collection	✔	✔	✔
recursion	✔	✔	✔
function type		✔	✔
symbol type		✔	✔
whole language available		✔	✔
everything’s an expression			✔
homoiconicity			✔

http://www.paulgraham.com/diff.html

regular code

```
foo.bar(x,y,z);

 foo.bar x y z
```

special forms

imports

scopes

protection

metadata

control flow

anything using a keyword

outside lisp, special forms

look different

may have special semantics unavailable to you

prevent reuse

in a lisp, special forms

look just like anything else

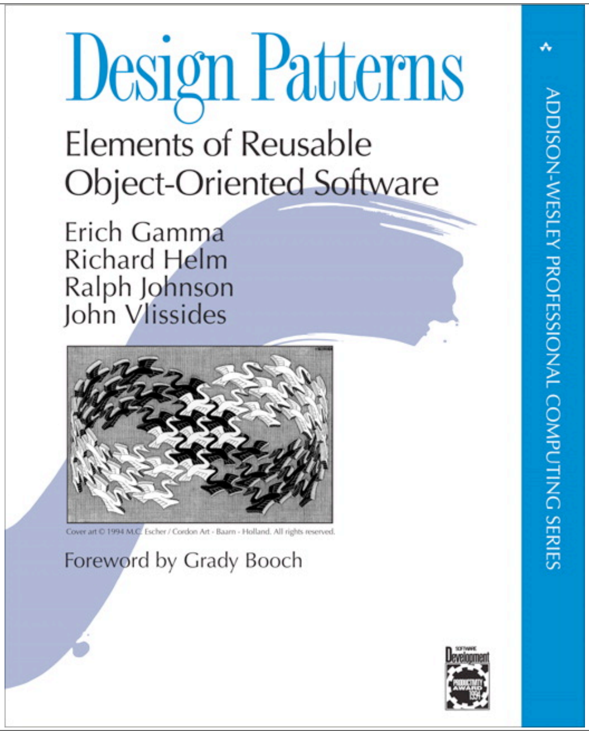
may have special semantics **available** to you

can be augmented with macros

all forms created equal

form	**syntax**	**example**
function	list	`(println "hello")`
operator	list	`(+ 1 2)`
method call	list	`(.trim " hello ")`
import	list	`(require 'mylib)`
metadata	list	`(with-meta obj m)`
control flow	list	`(when valid? (proceed))`
scope	list	`(dosync (alter ...))`

who cares?



Design Patterns

Elements of Reusable Object-Oriented Software

Erich Gamma
Richard Helm
Ralph Johnson
John Vlissides

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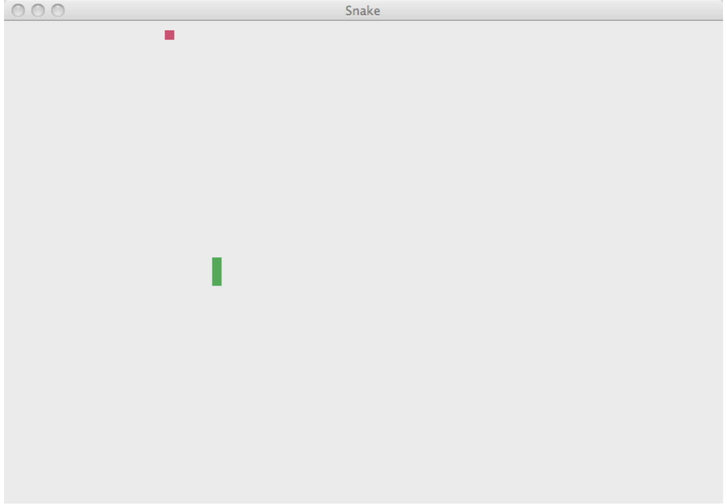
Foreword by Grady Booch

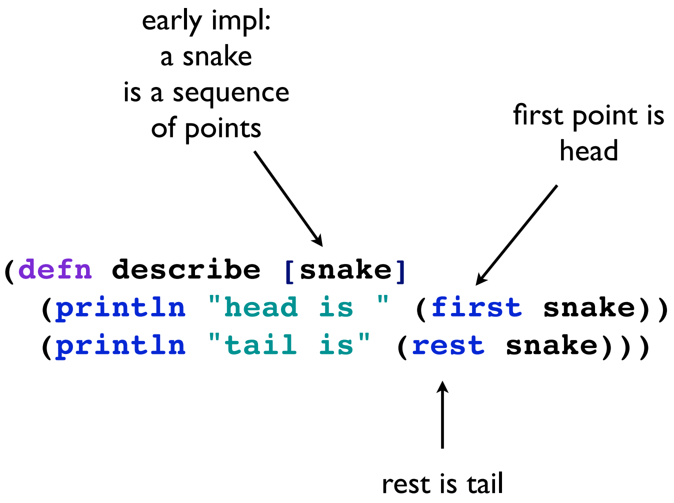
ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES

clojure is turning the tide in a fifty-year struggle against bloat

game break!



Sample Code:
http://github.com/stuarthalloway/programming-clojure

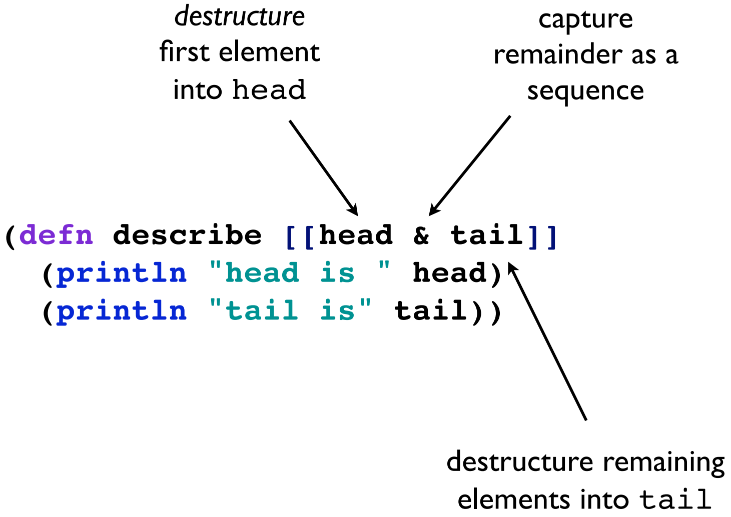


early impl:
a snake
is a sequence
of points

first point is
head

```
(defn describe [snake]
  (println "head is " (first snake))
  (println "tail is" (rest snake)))
```

rest is tail



destructure first element into `head`

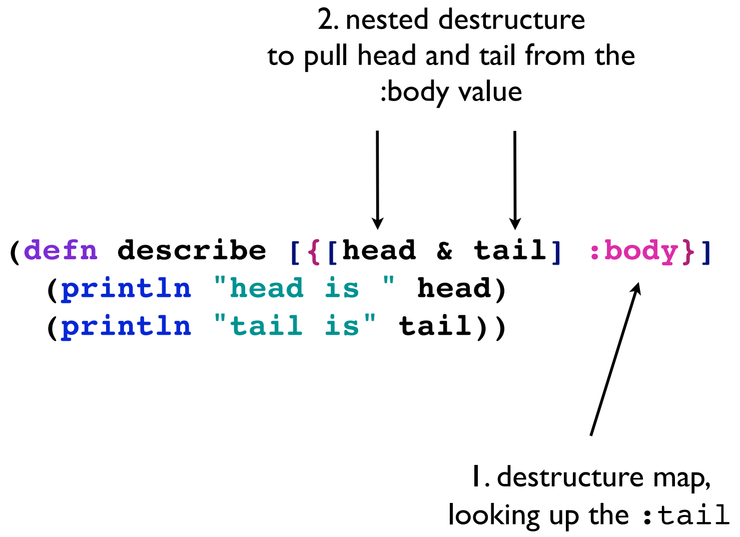
capture remainder as a sequence

```
(defn describe [[head & tail]]
  (println "head is " head)
  (println "tail is" tail))
```

destructure remaining elements into `tail`

snake is more than location

```
(defn create-snake []
  {:body (list [1 1])
   :dir [1 0]
   :type :snake
   :color (Color. 15 160 70)})
```



2. nested destructure
to pull head and tail from the
:body value

```
(defn describe [{[head & tail]  :body}]
  (println "head is " head)
  (println "tail is" tail))
```

1. destructure map,
looking up the :tail

losing the game

```
(defn lose? [{[head & tail]  :body}]
  (includes? tail head))
```

3. functional

data literals

type	properties	example
list	singly-linked, insert at front	`(1 2 3)`
vector	indexed, insert at rear	`[1 2 3]`

map	key/value	`{:a 100`
		` :b 90}`

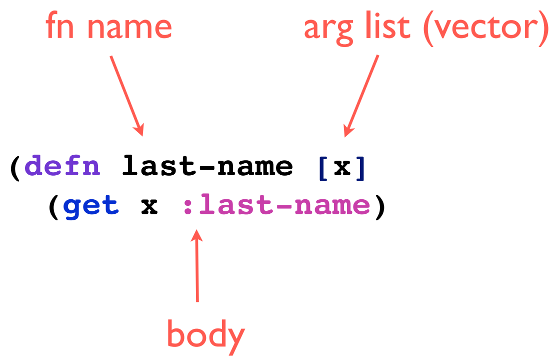
set	key	`#{:a :b}`

higher-order functions

some data

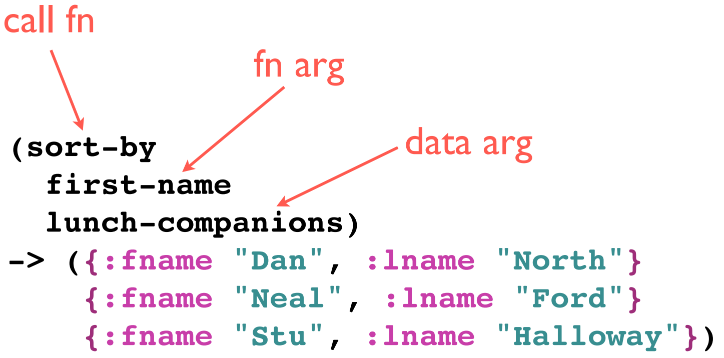
```
lunch-companions
-> ({:fname "Neal", :lname "Ford"}
    {:fname "Stu", :lname "Halloway"}
    {:fname "Dan", :lname "North"})
```

“getter” function



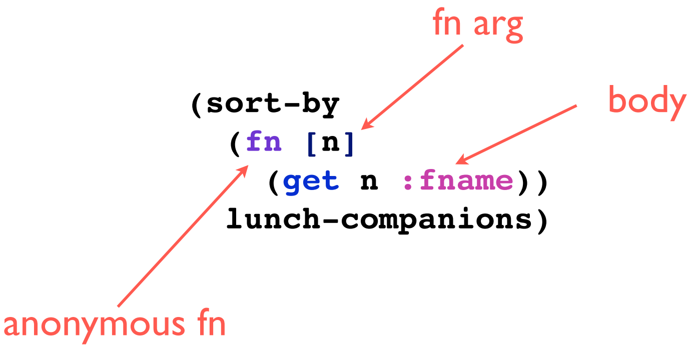
```
(defn last-name [x]
  (get x :last-name))
```

pass fn to fn



```
(sort-by
  first-name
  lunch-companions)
-> ({:fname "Dan", :lname "North"}
    {:fname "Neal", :lname "Ford"}
    {:fname "Stu", :lname "Halloway"})
```

anonymous fn



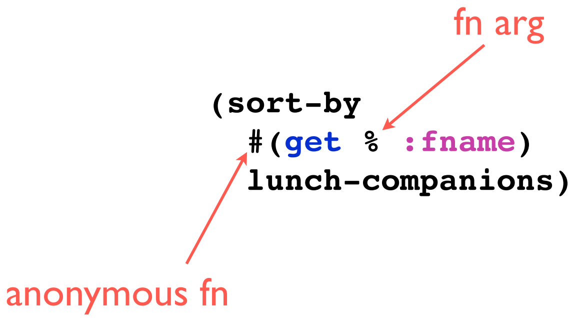
fn arg

body

```
(sort-by
  (fn [n]
    (get n :fname))
  lunch-companions)
```

anonymous fn

anonymous #()

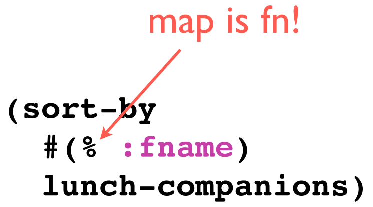


fn arg

```
(sort-by
  #(get % :fname)
  lunch-companions)
```

anonymous fn

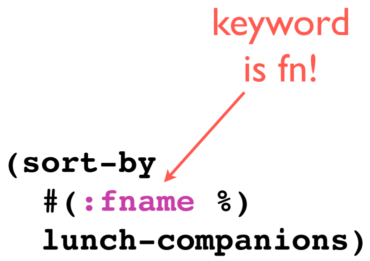
maps are functions



map is fn!

```
(sort-by
  #(% :fname)
  lunch-companions)
```

keywords are functions



keyword
is fn!

```
(sort-by
  #(:fname %)
  lunch-companions)
```

beautiful

```
(sort-by :fname lunch-companions)
```

real languages give a 1-1 ratio of pseudocode/code

persistent data structures

persistent data structures

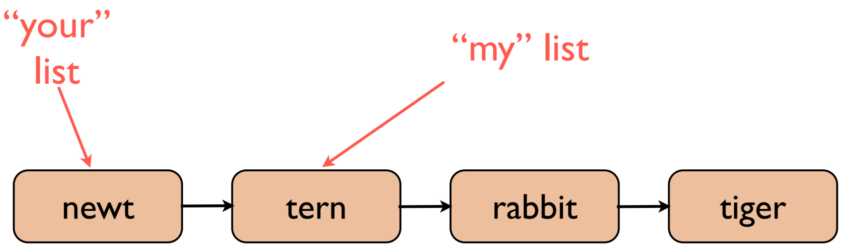
immutable

“change” by function application

maintain performance guarantees

full-fidelity old versions

persistent example: linked list



“your” list

“my” list

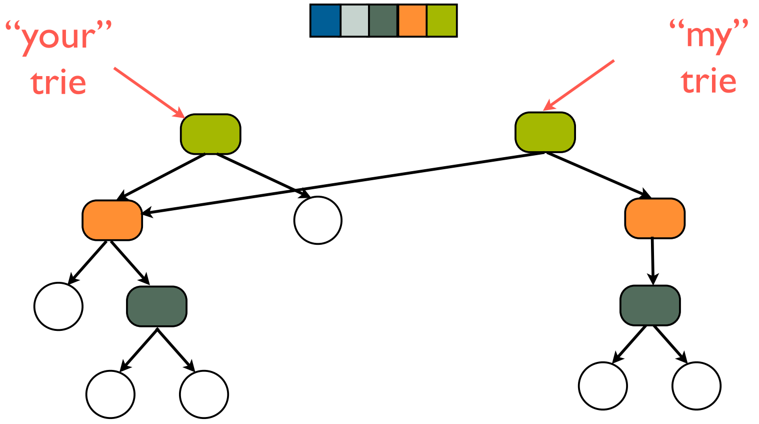
newt

tern

rabbit

tiger

bit-partitioned tries

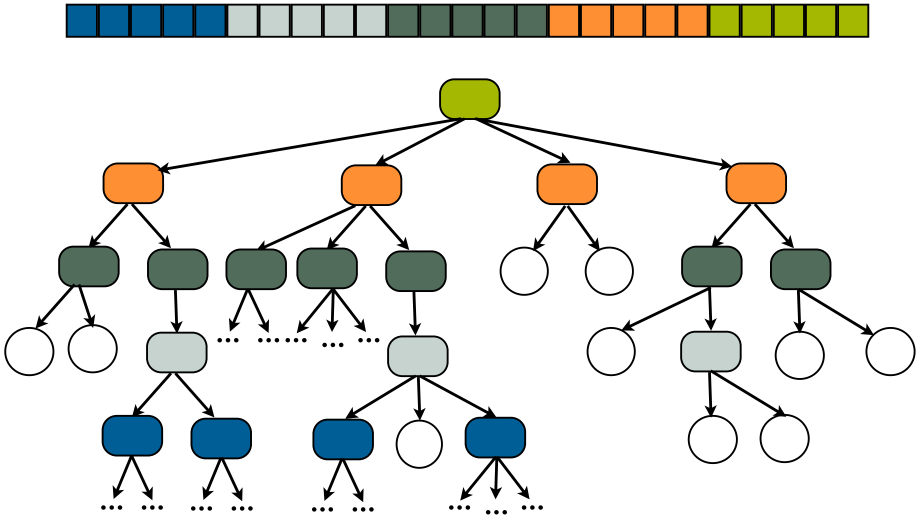


“your” trie

“my” trie

log2 n: too slow!

32-way tries



clojure: ‘cause log32 n is fast enough!

sequence library

first / rest / cons

```
(first [1 2 3])
-> 1

(rest [1 2 3])
-> (2 3)

(cons "hello" [1 2 3])
-> ("hello" 1 2 3)
```

take / drop

```
(take 2 [1 2 3 4 5])
-> (1 2)

(drop 2 [1 2 3 4 5])
-> (3 4 5)
```

map / filter / reduce

```
(range 10)
-> (0 1 2 3 4 5 6 7 8 9)

(filter odd? (range 10))
-> (1 3 5 7 9)

(map odd? (range 10))
-> (false true false true false true
false true false true)

(reduce + (range 10))
-> 45
```

sort

```
(sort [ 1 56 2 23 45 34 6 43])
-> (1 2 6 23 34 43 45 56)

(sort > [ 1 56 2 23 45 34 6 43])
-> (56 45 43 34 23 6 2 1)

(sort-by #(.length %)
  ["the" "quick" "brown" "fox"])
-> ("the" "fox" "quick" "brown")
```

conj / into

```
(conj '(1 2 3) :a)
-> (:a 1 2 3)

(into '(1 2 3) '(:a :b :c))
-> (:c :b :a 1 2 3)

(conj [1 2 3] :a)
-> [1 2 3 :a]

(into [1 2 3] [:a :b :c])
-> [1 2 3 :a :b :c]
```

lazy, infinite sequences

```
(set! *print-length* 5)
-> 5

(iterate inc 0)
-> (0 1 2 3 4 ...)

(cycle [1 2])
-> (1 2 1 2 1 ...)

(repeat :d)
-> (:d :d :d :d :d ...)
```

interpose

```
(interpose \, ["list" "of" "words"])
-> ("list" \, "of" \, "words")

(apply str
  (interpose \, ["list" "of" "words"]))
-> "list,of,words"

(use 'clojure.contrib.str-utils)
(str-join \, ["list" "of" "words"]))
-> "list,of,words"
```

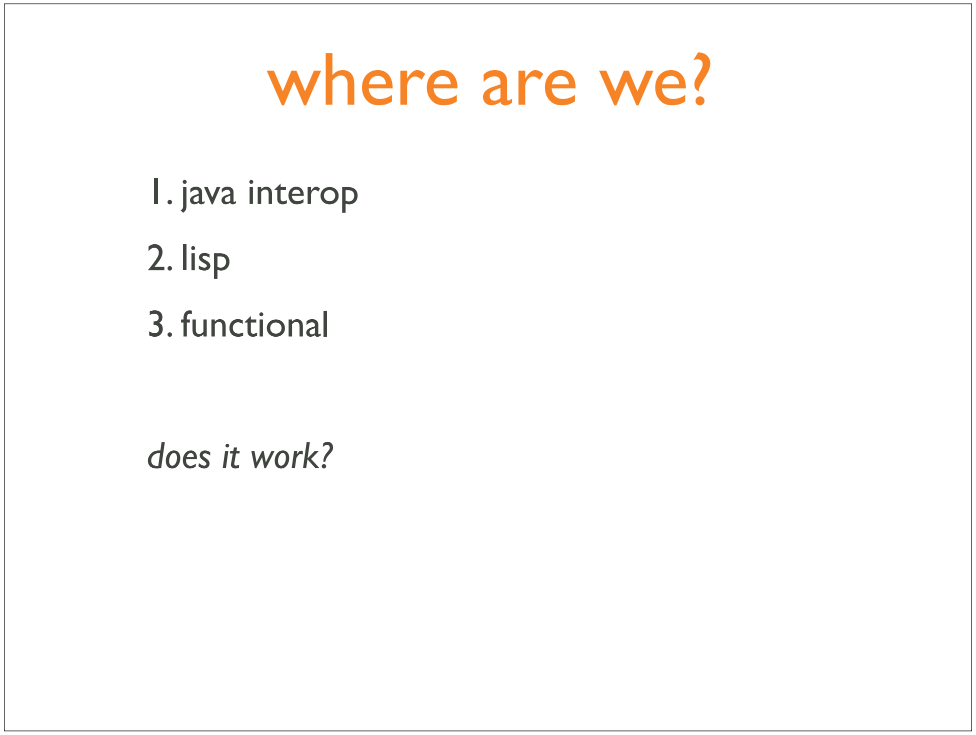
predicates

```
(every? odd? [1 3 5])
-> true

(not-every? even? [2 3 4])
-> true

(not-any? zero? [1 2 3])
-> true

(some nil? [1 nil 2])
-> true
```

nested ops

```
(def jdoe {:name "John Doe",
           :address {:zip 27705, ...}})

(get-in jdoe [:address :zip])
-> 27705

(assoc-in jdoe [:address :zip] 27514)
-> {:name "John Doe", :address {:zip 27514}}

(update-in jdoe [:address :zip] inc)
-> {:name "John Doe", :address {:zip 27706}}
```

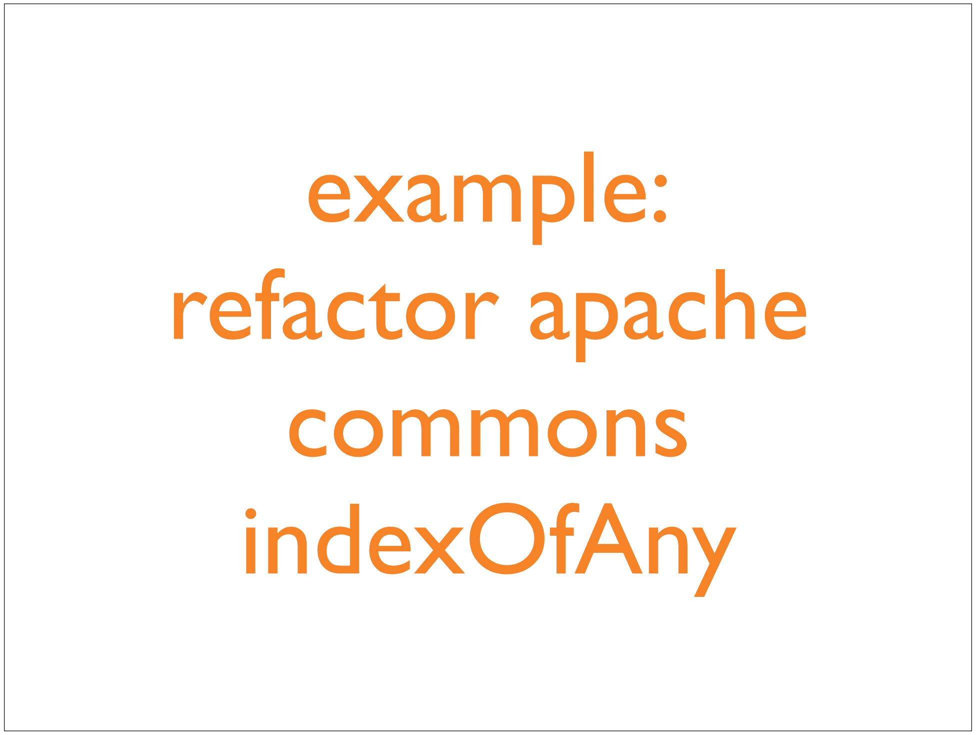
Ash zna durbatulûk,
ash zna gimbatul,
ash zna thrakatulûk
agh burzum-ishi
krimpatul.



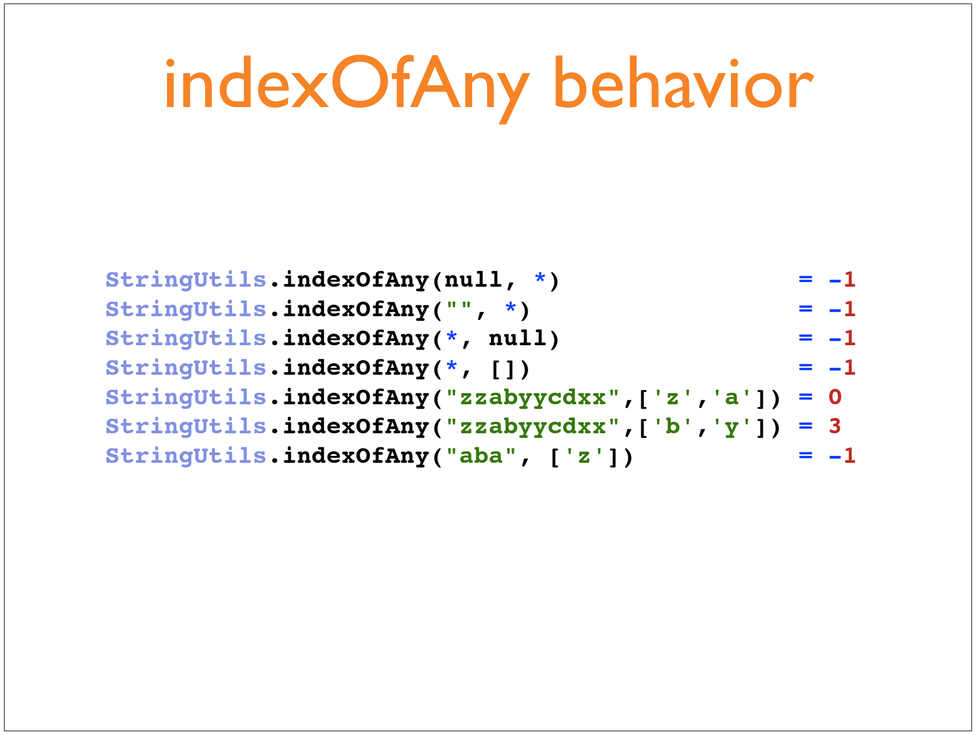
where are we?

1. java interop
2. lisp
3. functional

does it work?

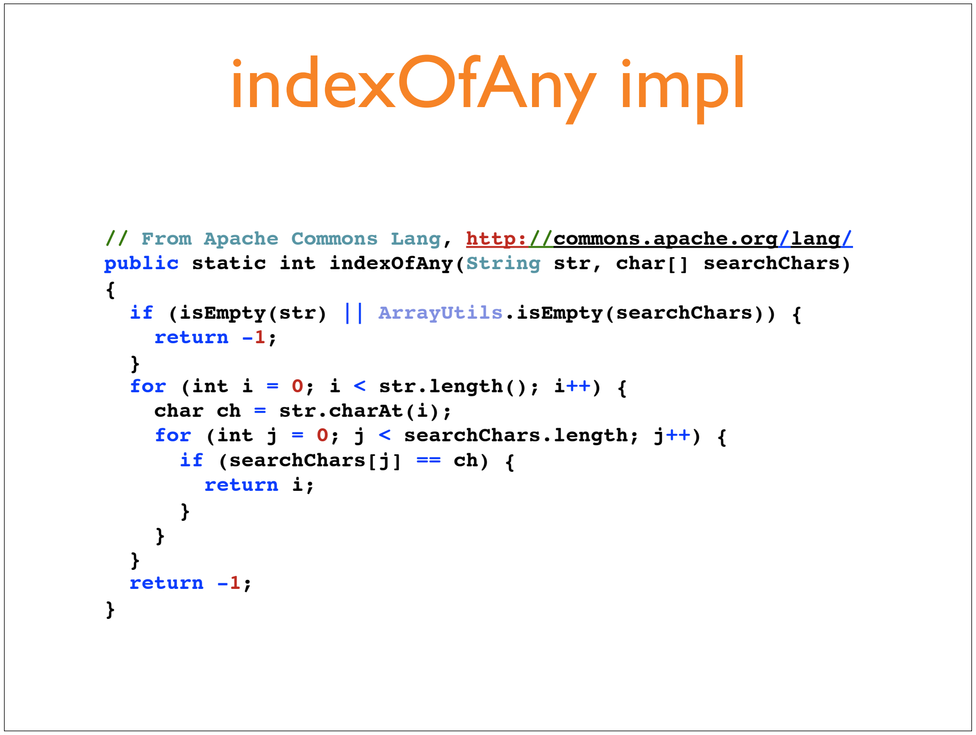


example: refactor apache commons indexOfAny



indexOfAny behavior

```
StringUtils.indexOfAny(null, *)                   = -1
StringUtils.indexOfAny("", *)                     = -1
StringUtils.indexOfAny(*, null)                   = -1
StringUtils.indexOfAny(*, [])                     = -1
StringUtils.indexOfAny("zzabyycdxx",['z','a']) = 0
StringUtils.indexOfAny("zzabyycdxx",['b','y']) = 3
StringUtils.indexOfAny("aba", ['z'])              = -1
```



indexOfAny impl

```
// From Apache Commons Lang, http://commons.apache.org/lang/
public static int indexOfAny(String str, char[] searchChars)
{
  if (isEmpty(str) || ArrayUtils.isEmpty(searchChars)) {
    return -1;
  }
  for (int i = 0; i < str.length(); i++) {
    char ch = str.charAt(i);
    for (int j = 0; j < searchChars.length; j++) {
      if (searchChars[j] == ch) {
        return i;
      }
    }
  }
  return -1;
}
```

simplify corner cases

```
public static int indexOfAny(String str, char[] searchChars)
{
  when (searchChars)
    for (int i = 0; i < str.length(); i++) {
      char ch = str.charAt(i);
      for (int j = 0; j < searchChars.length; j++) {
        if (searchChars[j] == ch) {
          return i;
        }
      }
    }
  }
}
```

- type decls

```
indexOfAny(str, searchChars) {
  when (searchChars)
    for (i = 0; i < str.length(); i++) {
      ch = str.charAt(i);
      for (j = 0; j < searchChars.length; j++) {
        if (searchChars[j] == ch) {
          return i;
        }
      }
    }
  }
}
```

+ when clause

```
indexOfAny(str, searchChars) {
  when (searchChars)
    for (i = 0; i < str.length(); i++) {
      ch = str.charAt(i);
      when searchChars(ch) i;
    }
  }
}
```

+ comprehension

```
indexOfAny(str, searchChars) {
  when (searchChars)
    for ([i, ch] in indexed(str)) {
      when searchChars(ch) i;
    }
  }
}
```

lispify!

```
(defn index-filter [pred coll]
  (when pred
    (for [[idx elt] (indexed coll) :when (pred elt)] idx)))
```

functional
is
simpler

	imperative	functional
functions	1	1
classes	1	0
internal exit points	2	0
variables	3	0
branches	4	0
boolean ops	1	0
function calls*	6	3
total	***18***	***4***

functional
is
more general!

reusing index-filter

```
; idxs of heads in stream of coin flips
(index-filter #{:h}
[:t :t :h :t :h :t :t :t :h :h])
-> (2 4 8 9)

; Fibonaccis pass 1000 at n=17
(first
  (index-filter #(> % 1000) (fibo)))
-> 17
```

imperative	functional
searches strings	searches *any sequence*
matches characters	matches *any predicate*
returns first match	returns *lazy seq of all matches*

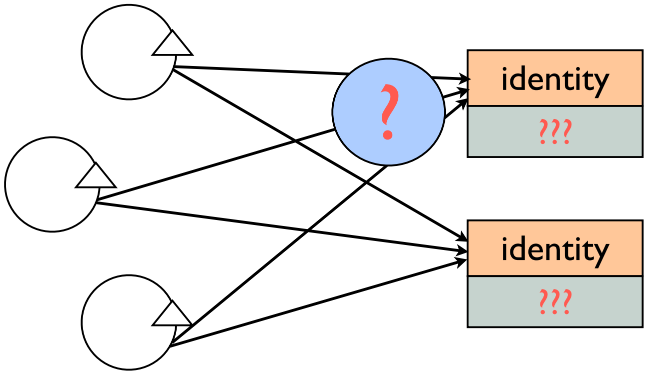
fp reduces incidental complexity by an order of magnitude

4. concurrency

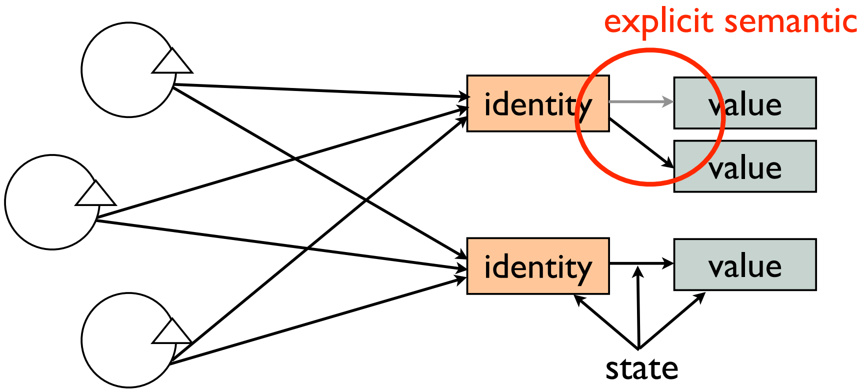
4. state

~~concurrency~~

oo is incoherent



clojure



terms

1. **value:** immutable data in a persistent data structure

2. **identity:** series of causally related values over time

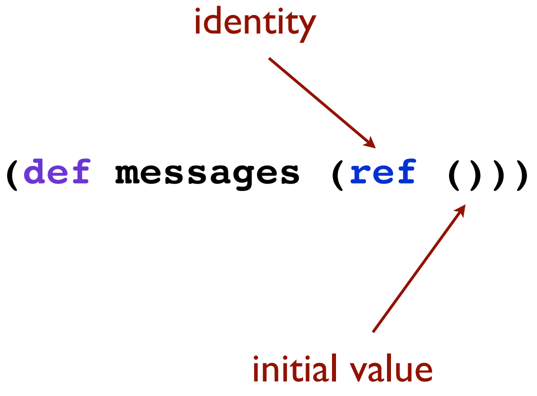
3. **state:** identity at a point in time

identity types (references)

	shared	isolated
synchronous/ coordinated	**refs/stm**	-
synchronous/ autonomous	**atoms**	**vars**
asynchronous/ autonomous	**agents**	-

identity 1: refs and stm

ref example: chat



identity

```
(def messages (ref ()))
```

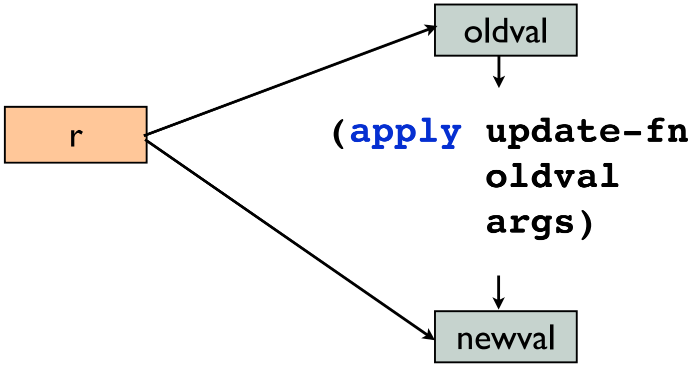
initial value

reading value

```
(deref messages)
=> ()

@messages
=> ()
```

alter

```
(alter r update-fn & args)
```



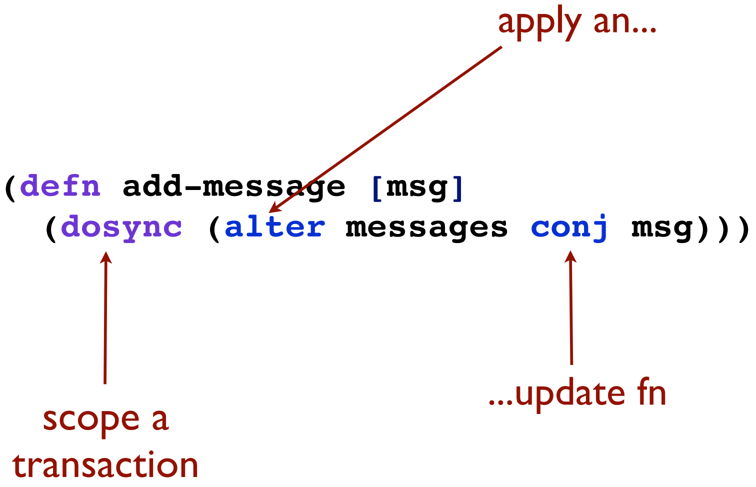
r

oldval

```
(apply update-fn
       oldval
       args)
```

newval

updating



apply an...

```
(defn add-message [msg]
  (dosync (alter messages conj msg)))
```

scope a transaction

...update fn

unified update model

update by function application

readers require no coordination

readers never block anybody

writers never block readers

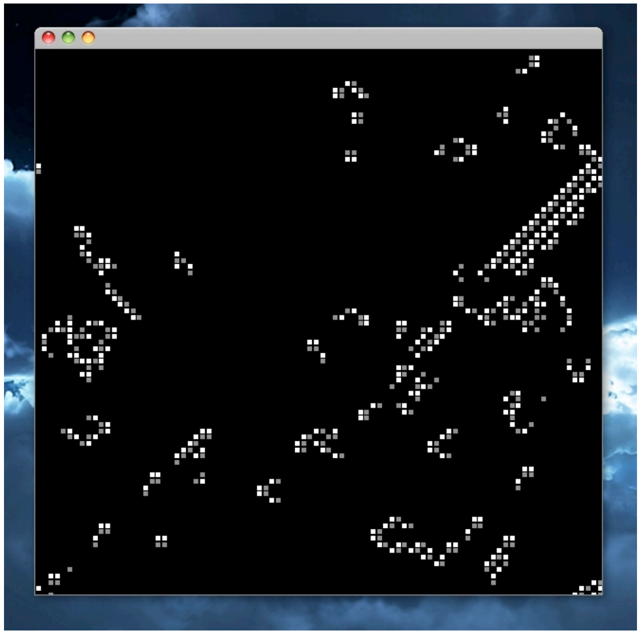
a sane approach to local state permits coordination, but does not require it

unified update model

	ref	atom	agent	var
create	ref	atom	agent	def
deref	deref/@	deref/@	deref/@	deref/@
update	alter	swap!	send	alter-var-root

identity 2: atoms

http://blog.bestinclass.dk/index.php/2009/10/brians-functional-brain/

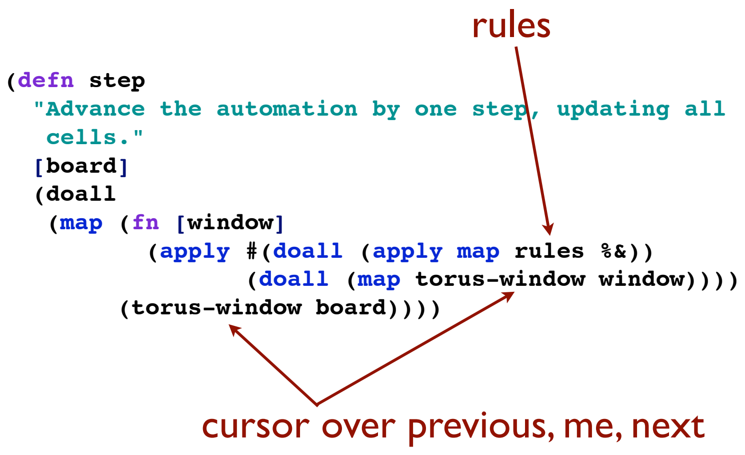


board is just a value

```
(defn new-board
  "Create a new board with about half the cells set
   to :on."
  ([] (apply new-board dim-board))
  ([dim-x dim-y]
     (for [x (range dim-x)]
       (for [y (range dim-y)]
         (if (< 50 (rand-int 100)) :on :off)))))
```

distinct bodies by arity

update is just a function

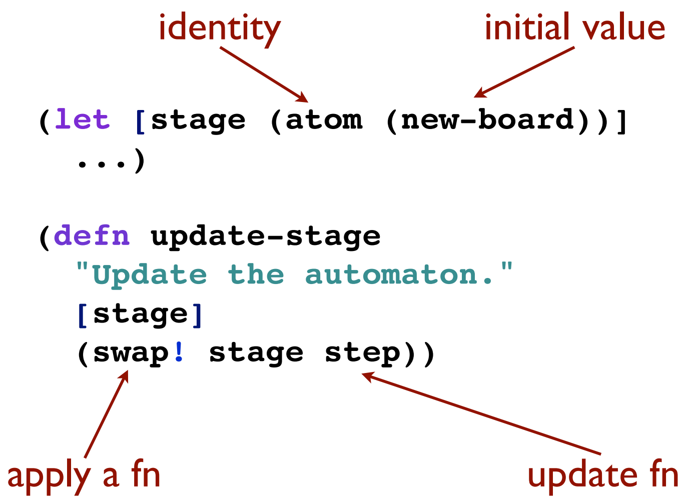


rules

```
(defn step
  "Advance the automation by one step, updating all
   cells."
  [board]
  (doall
   (map (fn [window]
          (apply #(doall (apply map rules %&))
                 (doall (map torus-window window))))
        (torus-window board))))
```

cursor over previous, me, next

state is trivial



identity

initial value

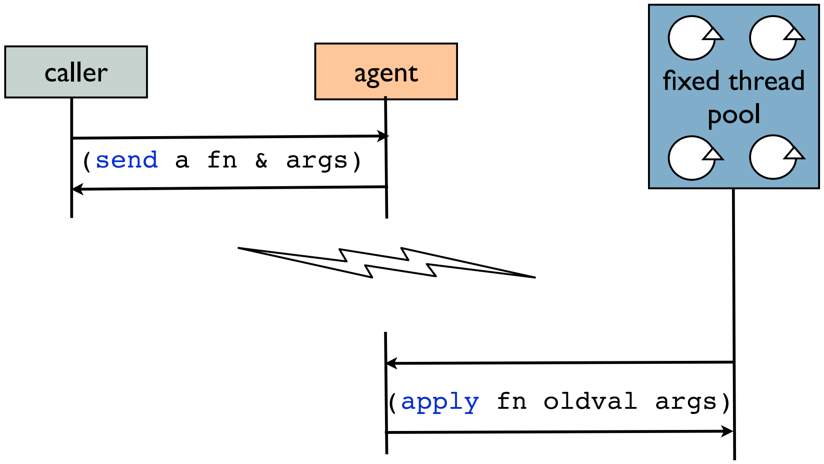
```
(let [stage (atom (new-board))]
  ...)

(defn update-stage
  "Update the automaton."
  [stage]
  (swap! stage step))
```

apply a fn

update fn

identity 3: agents

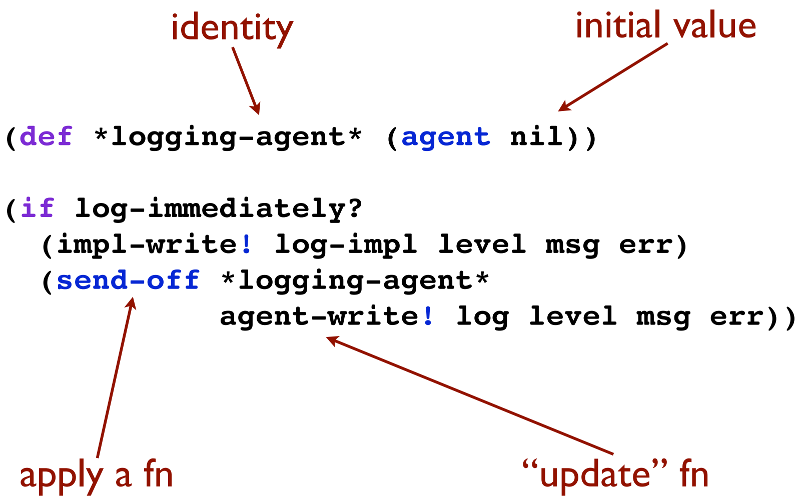
send



```
(send a fn & args)
```

```
(apply fn oldval args)
```

state is trivial



```
(def *logging-agent* (agent nil))

(if log-immediately?
  (impl-write! log-impl level msg err)
  (send-off *logging-agent*
            agent-write! log level msg err))
```

identity 4:
vars

def forms create vars

```
(def greeting "hello")

(defn make-greeting [n]
  (str "hello, " n))
```

vars can be rebound

api	scope
`alter-var-root`	root binding
`set!`	thread-local, permanent
`binding`	thread-local, dynamic

system settings

```
(set! *print-length* 20)
=> 20

primes
=> (2 3 5 7 11 13 17 19 23 29 31 37 41
    43 47 53 59 61 67 71 ...)

(set! *print-length* 5)
=> 5

primes
=>(2 3 5 7 11 ...)
```

var	usage
`*in*`, `*out*`, `*err*`	standard streams
`*print-length*`, `*print-depth*`	structure printing
`*warn-on-reflection*`	performance tuning
`*ns*`	current namespace
`*file*`	file being evaluated
`*command-line-args*`	*guess*

with-... helper macros

```
(def bar 10)
-> #'user/bar

(with-ns 'foo (def bar 20))
-> #'foo/bar

user/bar
-> 10

foo/bar
-> 20
```

bind a var
for a dynamic
scope

other def forms

form	usage
defonce	set root binding once
defvar	var plus docstring
defunbound	no initial binding
defstruct	map with slots
defalias	same metadata as original
defhinted	infer type from initial binding
defmemo	defn + memoize

many of these are in clojure.contrib.def...

identity: more options

use commute when update can happen anytime

not safe for commute

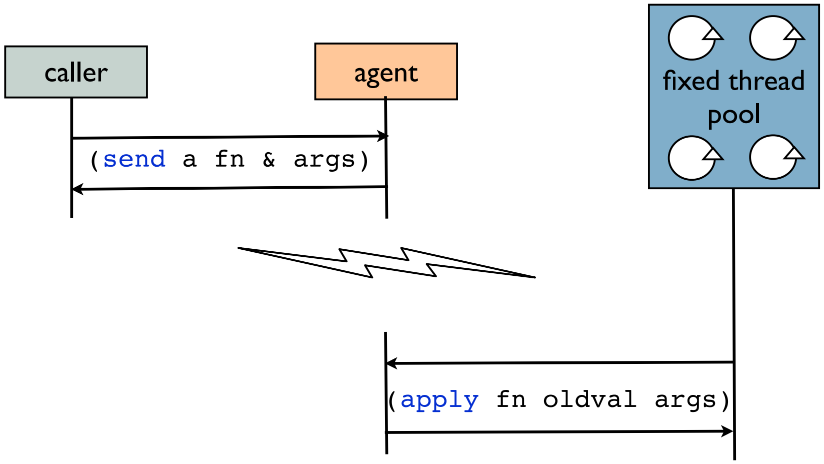
```
(defn next-id
  "Get the next available id."
  []
  (dosync
   (alter ids inc)))
```

safe!

```
(defn increment-counter
  "Bump the internal count."
  []
  (dosync
   (alter ids inc))
  nil)
```

prefer send-off if agent ops might block

send



caller

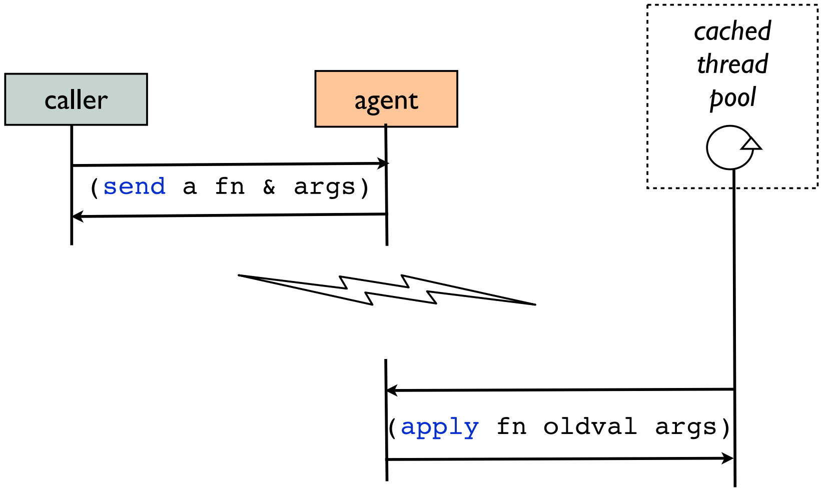
agent

fixed thread pool

(send a fn & args)

(apply fn oldval args)

send-off



caller

agent

cached thread pool

(send a fn & args)

(apply fn oldval args)

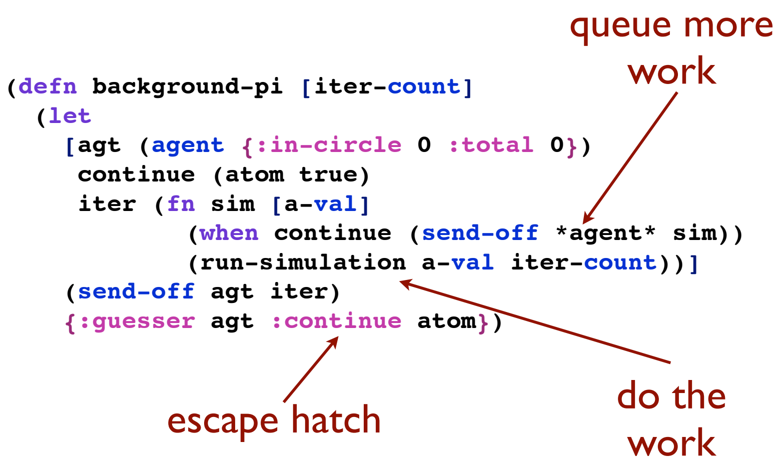
use ref-set to set initial/base state

unified update, revisited

update mechanism	ref	atom	agent
pure function application	`alter`	`swap!`	`send`
pure function (commutative)	`commute`	-	-
pure function (blocking)	-	-	`send-off`
setter	`ref-set`	`reset!`	-

send-off to *agent* for background iteration

monte carlo via ongoing agent



queue more work

```
(defn background-pi [iter-count]
  (let
    [agt (agent {:in-circle 0 :total 0})
     continue (atom true)
     iter (fn sim [a-val]
            (when continue (send-off *agent* sim))
            (run-simulation a-val iter-count))]
    (send-off agt iter)
    {:guesser agt :continue atom}))
```

escape hatch

do the work

(not= agents actors)

agents	actors
in-process only	oop
no copying	copying
no deadlock	can deadlock
no coordination	can coordinate

validation

create a function

that checks every item...

```
(def validate-message-list
  (partial
    every?
    #(and (:sender %) (:text %))))
```

for some criteria

```
(def messages
  (ref
    ()
    :validator validate-message-list))
```

and associate fn with updates to a ref

agent error handling

```
(def counter (agent 0 :validator integer?))
-> #'user/counter

(send counter (constantly :fail))
-> #<Agent 0>
```

will fail soon

```
(agent-errors counter)
-> (#<IllegalStateException
     java.lang.IllegalStateException:
     Invalid reference state>)
```

list of errors

```
(clear-agent-errors counter)
-> nil
```

reset and move on

```
@counter
-> 0
```

agents and transactions

tying agent to a tx

```
(defn add-message-with-backup [msg]
  (dosync
   (let [snapshot (alter messages conj msg)]
     (send-off backup-agent (fn [filename]
            (spit filename snapshot)
            filename))
     snapshot)))
```

exactly once if tx succeeds

where are we?

1. java interop
2. lisp
3. functional
4. value/identity/state

does it work?

a workable approach to state

good values: persistent data structures

good identities: references

mostly functional?

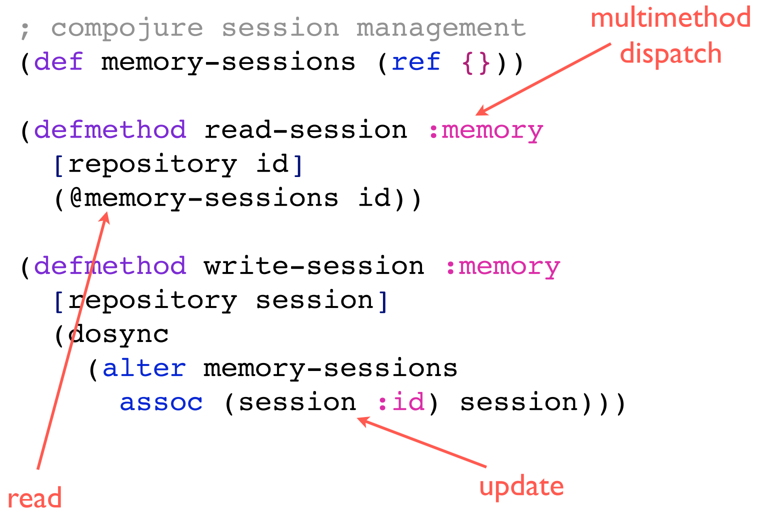
usable by mortals?

mostly functional?

1 line in 1000 creates a reference

project	loc	calls to ref	calls to agent	calls to atom
clojure	7232	3	1	2
clojure-contrib	17032	22	2	12
compojure	1966	1	0	0
incanter	6248	1	0	0

usable by mortals?



```
; compojure session management
(def memory-sessions (ref {}))

(defmethod read-session :memory
  [repository id]
  (@memory-sessions id))

(defmethod write-session :memory
  [repository session]
  (dosync
    (alter memory-sessions
      assoc (session :id) session)))
```

multimethod dispatch

read

update

cache previous results

```
; from clojure core
(defn memoize [f]
  (let [mem (atom {})]
    (fn [& args]
      (if-let [e (find @mem args)]
        (val e)
        (let [ret (apply f args)]
          (swap! mem assoc args ret)
          ret)))))
```

cache hit

cache miss: call f, add to cache

clojure

values are

immutable, persistent

identities are

well-specified, consistent

state is

mostly functional

usable by mortals

languages that emphasize immutability are *better at mutation*

time management

prepare to parallelize

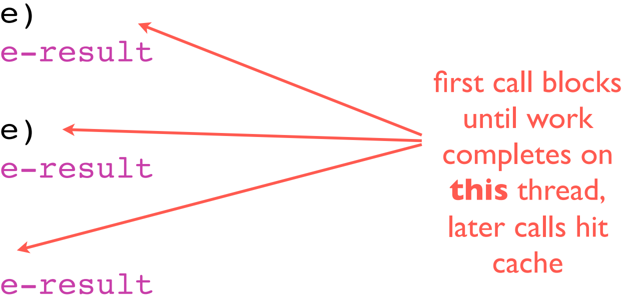
```
(defn step
  "Advance the automation by one step, updating all
   cells."
  [board]
  (doall
   (map (fn [window]
          (apply #(doall (apply map rules %&))
                 (doall (map torus-window window))))
        (torus-window board))))
```

done

```
(defn step
  "Advance the automation by one step, updating all
   cells."
  [board]
  (doall
   (pmap (fn [window]
          (apply #(doall (apply map rules %&))
                 (doall (map torus-window window))))
        (torus-window board))))
```

delay

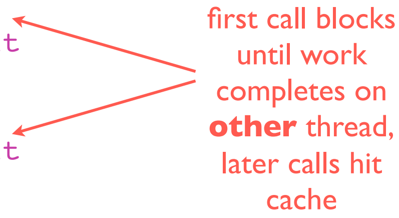
```
(def e (delay (expensive-calculation)))
-> #'demo.delay/e

(delay? e)
-> true

(force e)
-> :some-result

(deref e)
-> :some-result

@e
-> :some-result
```



first call blocks until work completes on **this** thread, later calls hit cache

future

```
(def e1 (future (expensive-calculation)))
-> #'demo.future/e1

(deref e1)
-> :some-result

@e1
-> :some-result
```



first call blocks until work completes on **other** thread, later calls hit cache

cancelling a future

```
(def e2 (future (expensive-calculation)))
-> #'demo.future/e2

(future-cancel e2)
-> true

(future-cancelled? e2)
-> true

(deref e2)
-> java.util.concurrent.CancellationException
```

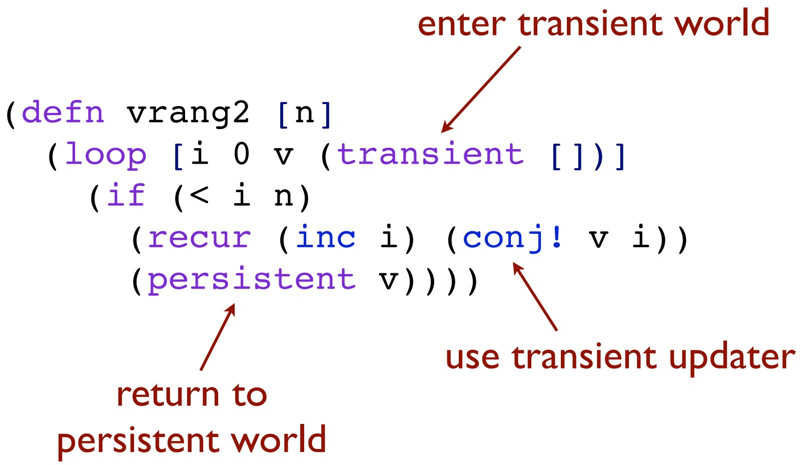
transients

build structure on one thread, then release into the wild

persistent...

```
(defn vrange [n]
  (loop [i 0 v []]
    (if (< i n)
      (recur (inc i) (conj v i))
      v)))
```

...to transient



enter transient world

```
(defn vrang2 [n]
  (loop [i 0 v (transient [])]
    (if (< i n)
      (recur (inc i) (conj! v i))
      (persistent v))))
```

use transient updater

return to
persistent world

fast!

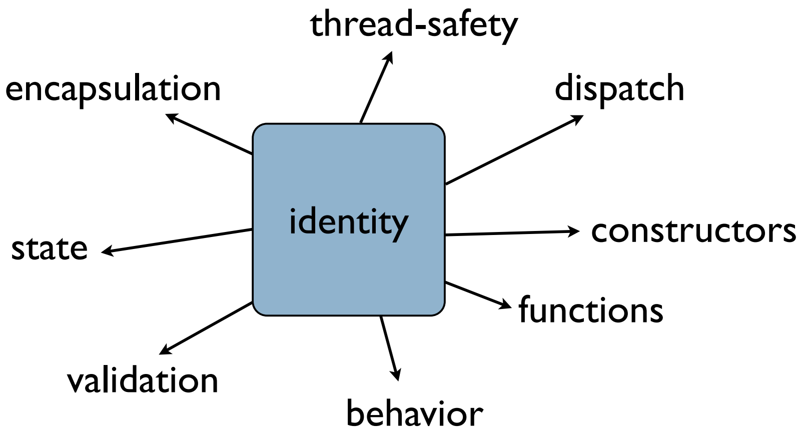
```
(time (def v (vrange 1000000)))
"Elapsed time: 1130.721 msecs"

(time (def v2 (vrange2 1000000)))
"Elapsed time: 82.191 msecs"
```

transients

- usage:
  - **`transient`**
  - bang updates: **`assoc!`** **`conj!`** etc.
  - **`persistent!`**
- optimization, not coordination
  - O(1) creation from persistent object
  - fast, isolated updates
  - O(1) conversion back to persistent object

what about objects?

oo: one identity fits all



clojure: bespoke code in an off-the-rack world

clojure's four elevators

java interop

lisp

functional

state

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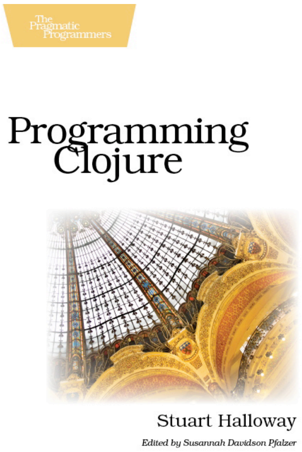
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