CS492: Probabilistic Programming

Basics of Clojure and tiny bit of Anglican

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Does anyone use Clojure, Scheme, or Lisp?

Does anyone use Clojure, Scheme, or Lisp?

What are the cons and pros of such a lang.?

Clojure

- Re-design of Scheme for Java virtual machine, with concurrency in mind.
- Untyped.
- Highly expressive.
- Cousin language for Anglican, the probabilistic programming language used in this course.

Learning outcome

- Can write simple Clojure programs with recursion, loop, list, and map.
- Can write simple Anglican programs with no conditioning, and perform inference.
- All by copy-paste-modify programming.

Clojure in a nutshell

1. Prefix instead of infix notation:

   `(+ 3 3)`, not 3+3

2. Use let to bind variables to values.

```
(let [x (* 3 3) y (* 4 4)] (+ x y))
```

3. Anonymous function using fn:

```
(let [f (fn [x] (* x x))] (+ (f 3) (f 4)))
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(let [f (fn [x] (* x x))]
  (+ (f 1)
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     (f 3)
     (f 4)
     (f 5)))
```

2. Use ... s.

```
(le ... x y))
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(let [f (fn [x] (* x x))] (+ (f 3) (f 4)))
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[Q] Write a program that computes $1^2 + 2^2 + \ldots + \cancel{5^2}$ n^2.

Clojure in a nutshell

4. Separate function definition:

```
(defn f [n] …)
```

E.g.

```
(defn f [n]
  (if (= n 0)
    0
    (+ n (f (- n 1)))))

(println (f 10))
```

n^2

[Q] Write a program that computes $1^2 + 2^2 + \dots + 5^2$.

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Recursion allowed

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Clojure in a nutshell

Lecture2 — vi sum.clj — 55×14

...me/Work/Teaching/2017-18/ProbProg18/Lectures/Lecture2 — vi sum.clj | ...k/Teaching/2017-18/ProbProg18/Lectures/Lecture2 — java ◂ lein repl

```
(ns lecture2)

(defn sq [x] (* x x))

(defn g [n]
  (if (= n 0)
    0
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~
~
~
sum.clj                                  1,1          All
"sum.clj" 9L, 101C written
```

[Q] Write a program that computes $1^2 + 2^2 + \dots + \cancel{5^2}\ n^2$.

NB: I installed leiningen. Then, I ran “lein repl”. You can install Clojure and run “clj” instead.

```
user=> (load-file "sum.clj")
#'lecture2/g
user=> (lecture2/g 100)
338350
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333833500
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StackOverflowError   clojure.lang.Numbers$LongOps.combi
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user=>


user=> 
```

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```

No StackOverflow.

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Clojure in a nutshell

5. Tail recursion.

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Clojure in

No further work after recursive call.

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No further work
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Not tail recursive

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(defn g [n r]
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5. Tail recursion. 1) Use accumulator.

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(defn f [N] (g N 0))
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Tail recursive. Acc. r

[Q] Write a program that computes $1^2 + 2^2 + \ldots + \cancel{5^2}\; n^2$.

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5. Tail recursion. 1) Use accumulator. 2) Inform the compiler using loop and recur.

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Tail recursive. Acc. r

[Q] Write a program that computes $1^2 + 2^2 + \ldots + \overset{n^2}{\cancel{5^2}}$.

```clojure
(ns lecture2b)

(defn sq [x] (* x x))

(defn g [n]
  (loop [i n r 0]
    (if (= i 0)
      r
      (recur (- i 1) (+ (sq i) r)))))
```

sum_loop.clj [+]   11,0-1   All

[Q] Write a program that computes $1^2 + 2^2 + \ldots + \cancel{5^2}\ n^2$.

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Lecture2 — java ◂ lein repl — 55×14
...Work/Teaching/2017-18/ProbProg18/Lectures/Lecture2 — java ◂ lein repl    .../Teaching/2017-18/ProbProg18/Lectures/Lecture2 — vi sum_loop.clj

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333338333350000
user=> (lecture2b/g 1000000)
333333833333500000
user=>
```

n^2

[Q] Write a program that computes $1^2 + 2^2 + \ldots + \cancel{5^2}$.

Exercise 1: Fibonacci sequence

[Q] Write a Clojure function that takes $n \geq 2$ and computes the n-th Fibonacci number F_n:

$$F_1 = 1, \quad F_2 = 1, \quad F_{n+2} = F_n + F_{n+1}$$

Exercise 1: Fibonacci sequence

[Q] Write a Clojure function that takes n≥2 and computes the n-th Fibonacci number F_n:

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[Hint]

```
(defn fib [n]
  (loop [i . . . . .  ]
    (if (= i n)
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             . . . .
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```

Exercise 2: Random Fibonacci sequence R_n

$$R_1 = 1, \quad R_2 = 1,$$

$$R_{n+2} = R_n + R_{n+1} \text{ or } R_{n+1} - R_n, \text{ each with prob. } 1/2$$

[Q] What does the distribution of R_n look like?

Anglican in a nutshell

1. Define an Anglican query using defquery.

```
(defquery baby-rfib [n]
  (let [b (sample (flip 0.5))
        new-n (if b n (+ n 1))]
    (loop [i 2 r0 1 r1 1]
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query body

Anglican in a nutshell

Creating and sampling from distribution object

ery using defquery.

query name

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[Q] Write an Anglican query for generating R_n for given n.

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                                                   ]
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```

```
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[Q] Write an Anglican query for generating R_n for given n.

Anglican in a nutshell

2. Perform inference using doquery.

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Clojure keyword.
Chooses an inference algorithm.

Anglican in a nutshell

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Anglican in a nutshell

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Clojure keyword.
Chooses an inference algorithm.

Returns a lazy infinite list
of samples.
Only a finite prefix used.

Anglican in a nutshell

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( {:log-weight 0.0,
   :result 1,
   :predict []}

  {:log-weight 0.0,
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   :predict []} )
```

Anglican in a nutshell

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List

Anglican in a nutshell

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List

of maps

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List
of maps
with three keys

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- To move on, we need to understand map and list datatypes of Clojure.

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- Two key questions:

1. How to construct a datatype?

2. How to destruct (or decompose) it?

Map in Clojure

1. Constructed using {..} or assoc typically.

```
{:a 0, :b 1, 3 10},
(assoc {:a 0, :b 1} 3 10)
```

2. Accessed (or destructed) by get & keyword.

```
(get {:a 0, :b 1, 3 10} 3)
(get {:a 0, :b 1, 3 10} :a)
(:a {:a 0, :b 1, 3 10})
```

List in Clojure

1. Created using list and conj typically.

   `(list 1 2 3), (conj (list 2 3) 1)`

2. Destructed by first, rest, and take.

```
(first (list 1 2 3)),
(rest (list 1 2 3)),
(take 2 (list 1 2 3))
```

List in Clojure

3. Changed using map and filter.

```
(map inc (list 1 2 3)),
(map + (list 1 2 3) (list 10 11 12))
(filter (fn [x] (>= x 2)) (list 1 2 3))
```

4. reduce.

```
(reduce + 0.0 (list 1 2 3 4))
```

5. drop, empty?, many other functions. Google.

Summary

- Map: {..}, assoc, get, and access by keyword.
- List: list, conj, first, rest, take, map, filter, reduce, drop, empty?, etc.

Summary

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Core functions

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Masters' tools.

Core functions

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[Q1] Write a fun. `rev` that reverses a list.

[Q2] Write a fun. `conc` that concatenates two lists.

```
(defn rev [l]
  (reduce conj (list) l))
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y

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(defn rev [l]
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(defn conc [l1 l2]
  (reduce conj l2 (rev l1))
```

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Anglican in a nutshell

1. Define an Anglican query using defquery.
2. Perform inference using doquery.

```
(let [s (doquery :importance rfib [20])]
  (take 2 s))
```

```
( {:log-weight 0.0,
   :result 1,
   :predict []}
 {:log-weight 0.0,
   :result -17,
   :predict []} )
```

List
of maps
with three keys

Anglican in a nutshell

3. Pick :result entries and analyse them.

```
(doquery :importance rfib [20])
```

Anglican in a nutshell

3. Pick :result entries and analyse them.

```
(let [s (doquery :importance rfib [20])
      r (map :result (take 1000 s))]



                                                         )
```

Anglican in a nutshell

3. Pick :result entries and analyse them.

```
(let [s (doquery :importance rfib [20])
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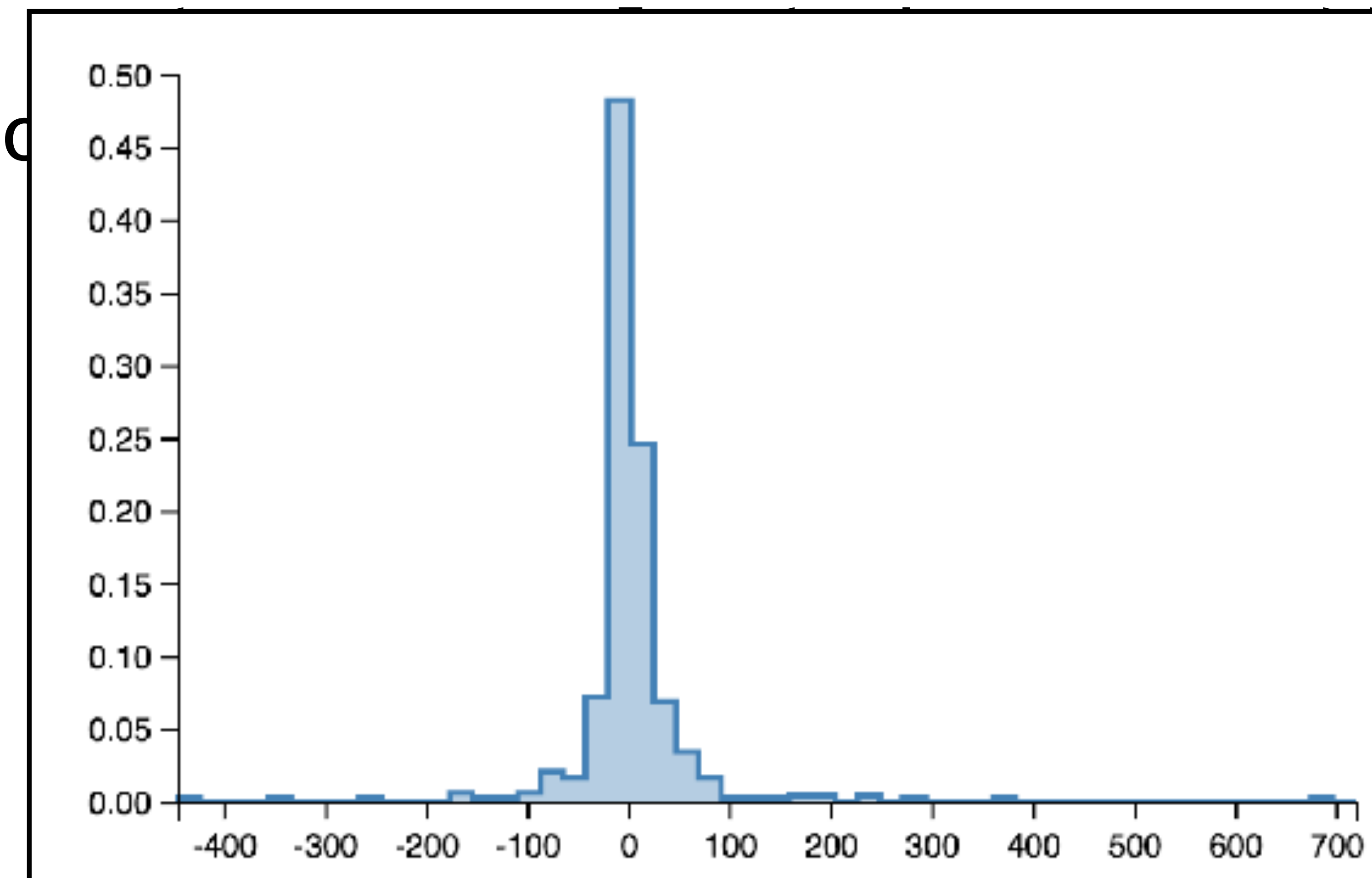
  (plot/histogram r
                  :bins 50
                  :normalize :probability))
```

Anglican in a nutshell

3. Pick :result entries and analyse them.

```
(let [s (doquery :importance rfib [20])
                                        )]
  (plo
                                       ability))
```



Anglican in a nutshell

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[Q1] Compute the average of generated R_{20} using 1000 samples. This is called empirical mean.

Anglican in a nutshell

3. Pick :result entries and analyse them.

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Anglican in a nutshell

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[Q1] Compute the average of generated R_{20} using 1000 samples. This is called empirical mean.
[Q2] Compute the variance of generated R_{20}.

Anglican in a nutshell

3. Pick :result entries and analyse them.

```
(let [s (doquery :importance rfib [20])
      r (map :result (take 1000 s))
      m (/ (reduce + 0.0 r) 1000.0)
      f (fn [x] (Math/pow (- x m) 2))]
  (/ (reduce + 0.0 (map f r)) 1000.0))
```

[Q1] Compute the average of generated R_{20} using 1000 samples. This is called empirical mean.

[Q2] Compute the variance of generated R_{20}.

Exercise 3:

[Part 1] Generate a list of Fibonacci numbers (list F_1 F_2 … F_n) for a given n.

[Part 2] Generate a list of indices $0<i\leq 10000$ such that i is the sum of digits of F_i.

Assume get-digits for converting a number to a list of its digits. (get-digits 23)=(list 2 3).

Assume range. (range 1 6) = (list 1 2 3 4 5).

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Part 1

```
(defn fib [n]
  (loop [i 2 s (list 1 1)]
    (if (= i n)
      (rev s)
      (recur (+ i 1)
             (conj s (+ (first s)
                        (second s)))))))
```

Part 2

```
(defn ck [fibn-and-i]
  (let [fibn (first fibn-and-i)
        i    (second fibn-and-i)]
    (= (reduce + 0 (get-digits fibn))
       i)))

(def idx-fib-seq
  (map (fn [s i] (list s i))
       (fib 10000)
       (range 1 10001)))

(def indices
  (map second (filter ck idx-fib-seq)))
```

Topics covered

- Functions, recursion, loop, list, and map in Clojure.
- defquery, and doquery in Anglican.

Announcement

1. Homework 0 in the course webpage.
    - It will teach you how to use Gorilla and to try examples in the web browser.
2. Form a group and tell us by the midnight of 13 March 2018 (Tuesday).