St. Louis Clojure

Clojure Generators

Christopher Mark Gore

cgore.com

Tuesday, August 25, AD 2015

We Write Clojure at The Climate Corporation, And We're Hiring!

Add Stuff to Your `project.clj`

```
1  (defproject your-project "1.2.3"
2    :description "It's␣like␣totally␣awesome␣and␣stuff"
3    ;; ...
4    :dependencies [;;...
5                   [prismatic/schema "0.4.3"]
6                   [org.clojure/test.check "0.7.0"]
7                   ;; ...
8                   ]
9    ;; ...
10   )
```

Prismatic Schema

Schemata[a] are sort of like types, but only as strict as you want them to be at that specific moment, so no type hell.

```
1 (ns schema-stuff
2   (:require [schema.core :as s]))
3
4 (s/validate s/Num 42)
5 (s/validate s/Str "howza")
6 (s/validate s/Keyword :hey)
```

[a]The plural of *schema* is *schemata*, not *schemas*.

Clojure `test.check` and Generators

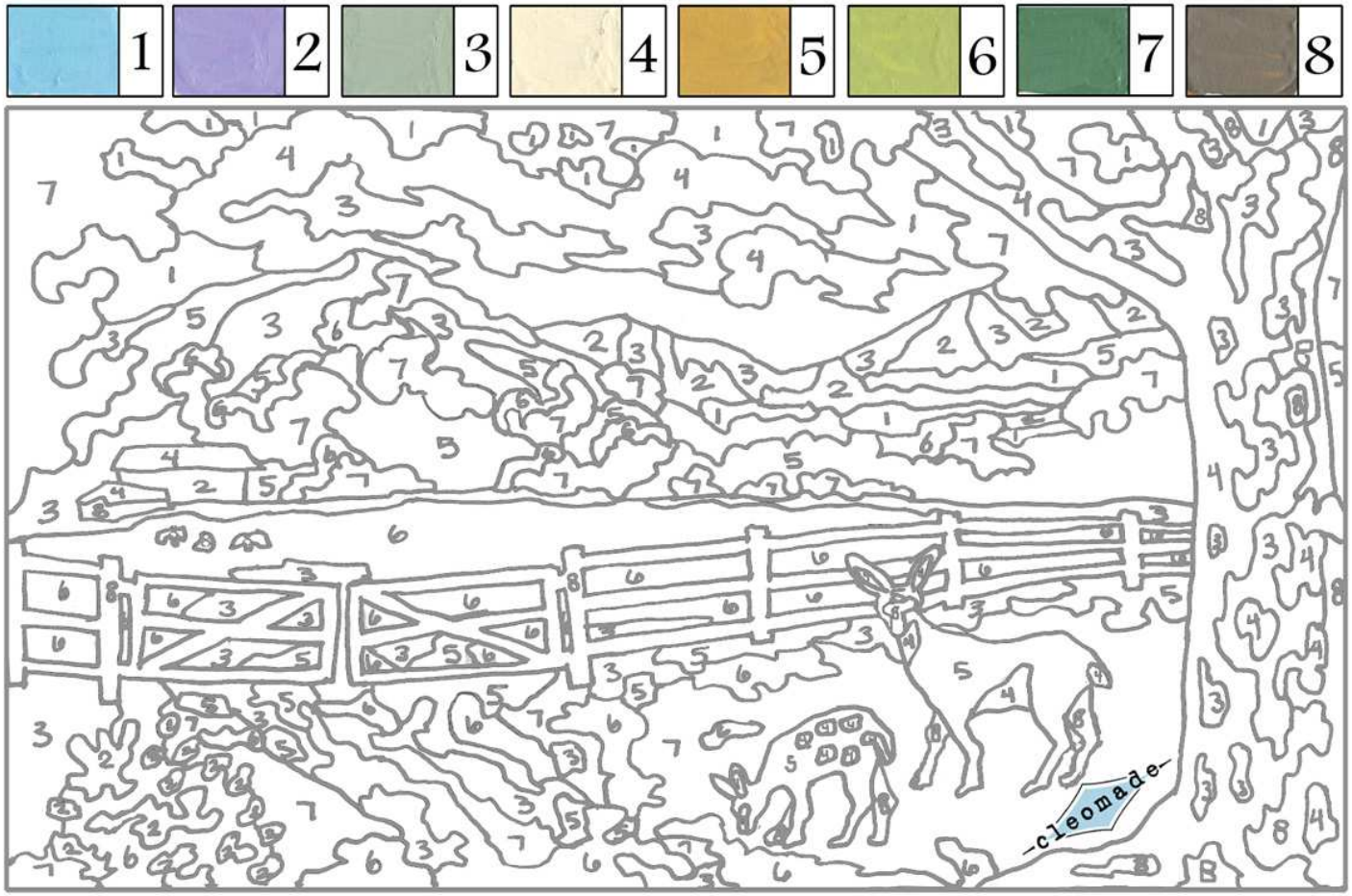
Generators make random examples according to a definition. It's a great way to make test data without brittle hand-rolled examples.

```
1 (ns gen-stuff
2   (:require [clojure.test.check :as tc]
3             [clojure.test.check.generators :as gen]
4             [clojure.test.check.properties :as prop]
5
6 (gen/sample gen/int)
7 ;; => (0 1 -1 0 -1 4 4 2 7 1)
8 (gen/sample gen/int 20)
9 ;; => (0 1 1 0 2 -4 0 5 -7 -8 4 5 3 11 -9 -4 6 -5 -3 0)
```

Schemata + Generators = Awesome!

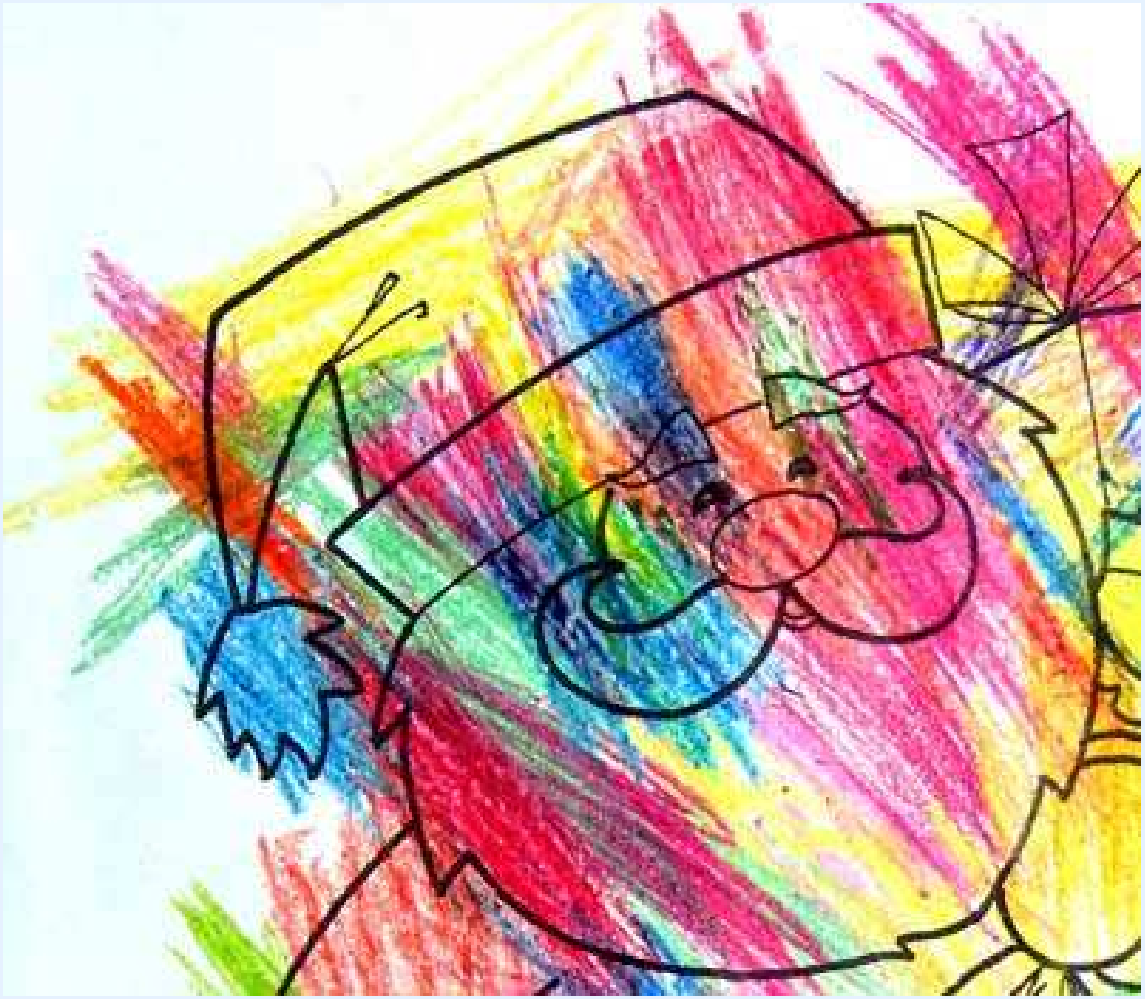
- Schemata to validate function input
  - Definitely in tests.
  - Maybe even in production.
- Generators to fuzz the function in tests.
- Feed the generators into the schemata.
  - Check the generator against the schema.
  - Check the schema with the generator.

Schemata are These



Generators are These

Used Together, We Catch When Our Code Does This



Schema: `validate` versus `check`

The two most important functions for schema checks are `validate` and `check`, the only real difference being that `validate` raises an error and check does not.

```
1 ;; A schema for integers.
2 (s/validate s/Int 42) ; passes, returns 42
3 (try (s/validate s/Int "nope") ; fails, throws an error.
4      (catch Exception e))
5
6 (s/check s/Int 42) ; => nil
7 (s/check s/Int "nope") ; => (not (integer? "nope"))
```

Test Check Properties

We define properties we expect to always hold, and assert those properties.

```
1  (def prop-addition-increments
2    (prop/for-all [a gen/int
3                   b gen/int]
4                  (>= (+ a b) a))) ; This is always true.
5  ;; Check 100 times
6  (tc/quick-check 100 prop-addition-increments)
7  ;; FAIL!  We forgot negatives!
8  {:result false, :seed 1434746134125, :failing-size 2,
9   :num-tests 3, :fail [1 -2],
10  :shrunk {:total-nodes-visited 4, :depth 2, :result false,
11           :smallest [0 -1]}}
```

Test Check Properties

We discover the *real properties* of our system this way, not just what we *think* they are.

$$[a + b \geq a] \forall a, b \in \mathbb{N} = \mathbb{Z} \cap [0, \infty)$$

```
1 ;; We meant for natural numbers [0,...)[a]
2 (def prop-addition-increments-for-nat
3   (prop/for-all [a gen/nat
4                  b gen/nat]
5                 (>= (+ a b) a))) ; This is REALLY true
6 ;; Check 100 times
7 (tc/quick-check 100 prop-addition-increments-for-nat)
8 ;; => {:result true, :num-tests 100, :seed 1434746600412}
```

[a] Somebody with a Ph.D. in mathematics might have told you that 0 isn't a natural number: they are wrong.

Our Schemata are Our Properties

Our schema must accept *all* instances, if not, it's not a valid schema, therefore we can state that the schema is a property *for all* of our generated examples.

```
(def Person {:name s/Str
             :age s/Int}) ; We'll make s/Nat in a bit.
(def person (gen/hash-map :name gen/string
                          :age gen/nat))
(def prop-person-generates-Person
  (prop/for-all [p person]
                (s/validate Person p)))
(tc/quick-check 100 prop-person-generates-Person)
```

Integrating `test.check` and `clojure.test`

There is a `defspec` macro to parallel `deftest` at `clojure.test.check.clojure-test/defspec`.

```
1 (defspec first-element-is-min-after-sorting
2           100 ; the number of iterations
3           (prop/for-all [v (gen/not-empty
4                             (gen/vector gen/int))]
5             (= (apply min v)
6                (first (sort v)))))
```

Names are Great, Two Are Better!

What is it	Schema	Generator
strings	`s/Str`	`gen/string`
real numbers	`s/Num`	*missing*
$\mathbb{Z} = \{\ldots, -2, -1, 0, 1, 2, \ldots\}$	`s/Int`	`gen/int`
$\mathbb{N} = \{0, 1, 2, \ldots\}$	*missing*	`gen/nat` or `gen/pos-int`
$\mathbb{Z}^+ = \mathbb{N} \setminus \{0\}$	*missing*	`gen/s-pos-int`
$\mathbb{Z}^-$	*missing*	`gen/s-neg-int`
$\mathbb{Z}^- \cup \{0\}$	*missing*	`gen/neg-int`

That's a Lot of Missing Things!

Existing Generators: Bits and Bytes

`gen/boolean` Either `true` or `false`.

```
(gen/sample gen/boolean)
;; => (false true false true true
;;      false false false false true)
```

`gen/byte` A single `java.lang.Byte`.

```
(gen/sample gen/byte)
;; => (-88 101 101 104 24 -37 -36 9 20 107)
```

`gen/bytes` A `byte-array`.

Existing Generators: Numbers

`gen/int` Any integer.

```
(gen/sample gen/int)
;; => (0 -1 1 2 3 -2 -3 3 5 -2)
```

`gen/choose` Numbers in the specified range.

```
(gen/sample (gen/choose 18 45)
;; => (24 34 33 37 27 29 29 32 44 18)
```

`gen/nat` Natural numbers: positive integers and 0.

`gen/pos-int` **and** `gen/neg-int` Postive-only or negative-only integers, allowing for 0.

`gen/s-pos-int` **and** `gen/s-neg-int` Postive-only or negative-only integers, **not** allowing for 0.

Existing Generators: Characters and Strings

`gen/char` Any character.

`gen/char-ascii` ASCII-only characters.

`gen/char-alphanumeric` Alphanumeric characters, a–z, A–Z and 0–9.

`gen/char-alpha` Alpha-only characters, a–z and A–Z.

`gen/string` Any string.

`gen/string-ascii` ASCII-only strings.

```
1  (gen/sample gen/string-ascii)
2  ;; => ("" "" "qc" "I-k" "F" ""
3  ;;      ", Ou" "6kT]<" "}`!" "5ZH=v75")
```

`gen/string-alphanumeric` Alphanumeric strings.

`gen/string-alpha` *Doesn't exist?*

Existing Generators: Collections

```
gen/tuple

gen/vector

gen/list

gen/shuffle

gen/map

gen/hash-map
```

Modifying Existing Generators

```
gen/not-empty

gen/no-shrink

gen/such-that

gen/sized

gen/resize
```

Making New Generators

`gen/return` Always the same thing.

```
1        (gen/sample (gen/return 42))
2        ;; => (42 42 42 42 42 42 42 42 42 42)
```

`gen/one-of`

`gen/frequency`

`gen/bind`

Using `gen/elements`

Randomly pick (without exhaustion) from a collection.

```
1 (gen/sample
2   (gen/elements [:spades :diamonds :hearts :clubs]))
3 ;; => (:diamonds :clubs :spades :clubs :hearts
4 ;;      :spades :spades :hearts :hearts :hearts)
```

Making New Generators With `gen/fmap`

If nothing makes sense to generate your stuff, there's always `gen/fmap`, and then you can use any function you want. Huzzah, Clojure!

```
1  (def even-and-positive (gen/fmap #(* 2 %) gen/pos-int))
2  (gen/sample even-and-positive 20)
3  ;; => (0 0 2 0 8 6 4 12 4 18 10 0 8 2 16 16 6 4 10 4)
4  (def gen-double (gen/fmap rand gen/int)
5  (gen/sample gen-double)
6  ;; => (0.0                    0.0
7  ;;      0.8433531349313175 -0.5407298249526976
8  ;;      0.7282154724842486 -0.5111220285736056
9  ;;     -1.699829459918618   1.4744104363479704
10 ;;      2.09462108198167   -1.7704991357273019)
```

Questions?