Simulation Testing with Simulant

@stuarthalloway

Example-Based Tests (EBT)

```
describe Bowling, "#score" do
  it "returns 0 for all gutter game" do
    bowling = Bowling.new
    20.times { bowling.hit(0) }
    bowling.score.should eq(0)
  end
end
```

EBT


```
describe Bowling, "#score" do
  it "returns 0 for all gutter game" do
    bowling = Bowling.new
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end
```

EBT

execution

```
describe Bowling, "#score" do
  it "returns 0 for all gutter game" do
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    bowling.score.should eq(0)
  end
end
```

EBT

```
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EBT

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    bowling = Bowling.new
    20.times { bowling.hit(0) }
    bowling.score.should eq(0)
  end
end
```

EBT

```
(are [x y] (= x y)
     (+) 0
     (+ 1) 1
     (+ 1 2) 3
     (+ 1 2 3) 6

     (+ -1) -1
     (+ -1 -2) -3
     (+ -1 +2 -3) -2

     (+ 2/3) 2/3
     (+ 2/3 1) 5/3
     (+ 2/3 1/3) 1 )
```

EBT

```
(are [x y] (= x y)
     (+) 0
     (+ 1) 1
     (+ 1 2) 3
     (+ 1 2 3) 6

     (+ -1) -1
     (+ -1 -2) -3
     (+ -1 +2 -3) -2

     (+ 2/3) 2/3
     (+ 2/3 1) 5/3
     (+ 2/3 1/3) 1 )
```

no setup

EBT

```
(are [x y] (= x y)
     (+)          0
     (+ 1)        1
     (+ 1 2)      3
     (+ 1 2 3)    6

     (+ -1)       -1
     (+ -1 -2)    -3
     (+ -1 +2 -3) -2

     (+ 2/3)      2/3
     (+ 2/3 1)    5/3
     (+ 2/3 1/3)  1 )
```

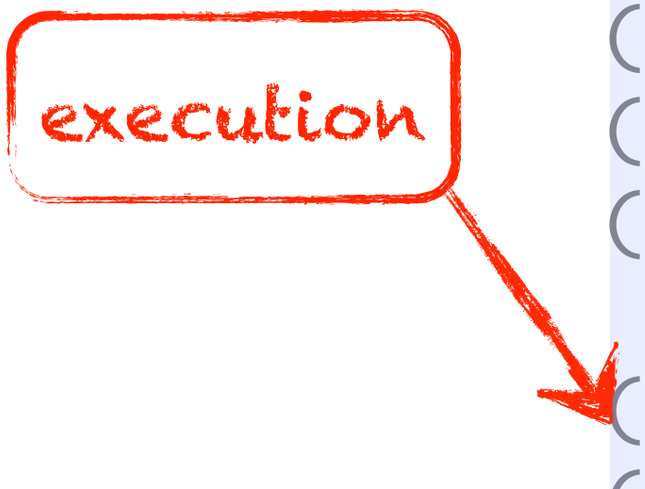
inputs

EBT

```
(are [x y] (= x y)
     (+)          0
     (+ 1)        1
     (+ 1 2)      3
     (+ 1 2 3)    6

     (+ -1)       -1
     (+ -1 -2)    -3
     (+ -1 +2 -3) -2

     (+ 2/3)      2/3
     (+ 2/3 1)    5/3
     (+ 2/3 1/3)  1 )
```



EBT

```
(are [x y] (= x y)
     (+)          0
     (+ 1)        1
     (+ 1 2)      3
     (+ 1 2 3)    6

     (+ -1)       -1
     (+ -1 -2)    -3
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     (+ 2/3)      2/3
     (+ 2/3 1)    5/3
     (+ 2/3 1/3)  1 )
```

EBT

```
(are [x y] (= x y)
     (+)          0
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     (+ -1 -2)    -3
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     (+ 2/3)      2/3
     (+ 2/3 1)    5/3
     (+ 2/3 1/3)  1 )
```

EBT in the Wild

Scales: Unit, Functional, Acceptance

Styles: Test-After, TDD, BDD

Common Idioms: Fixtures, Stubs, Mocks

Deconstructing EBT

Inputs

Execution

Outputs

Validation

Simulation

Model

Outputs

Execution

Inputs

Validation

Simulation

Model

Outputs

kinds of agents
interactions as distributions
stored in a database

Execution

Inputs

Validation

Simulation

Model

Outputs

agents
time-stamped action stream
stored in a database

Inputs

Validation

Simulation

Model

Outputs

Execution

driver program
coordinated through a database
maps agents to processes

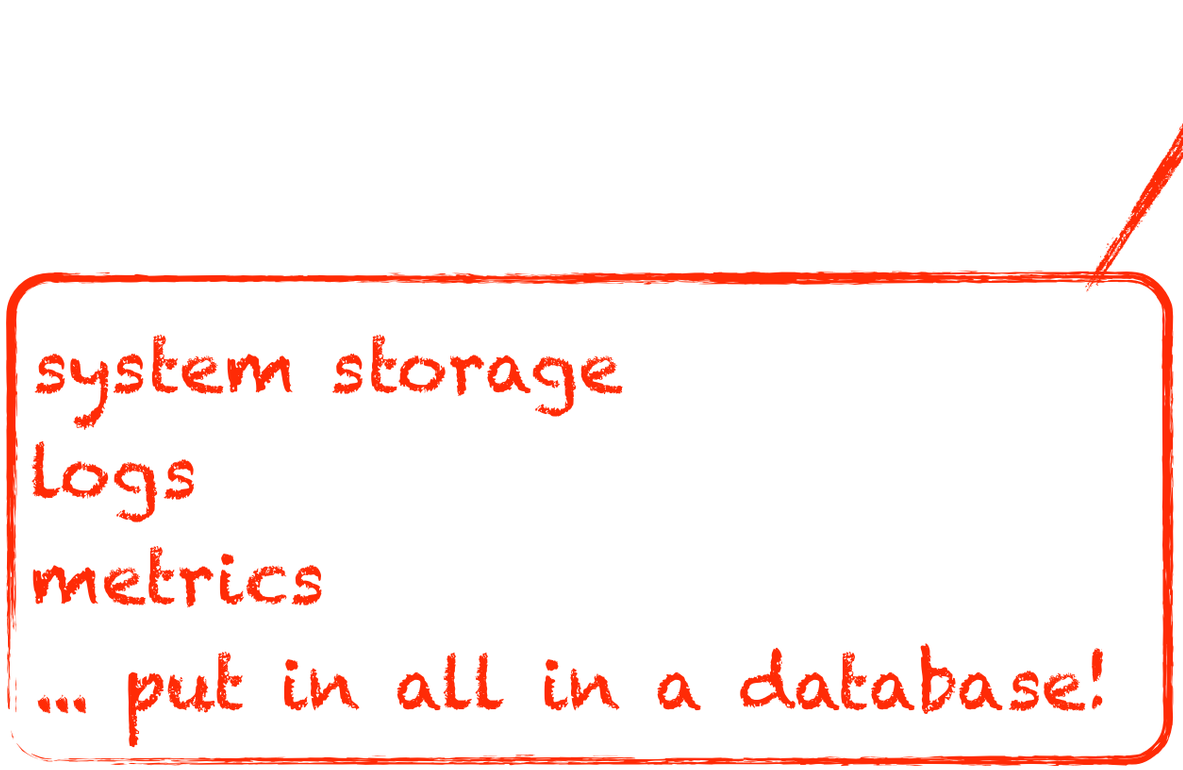
Inputs

lidation

Simulation

Model

Outputs



Inputs

Validation

Simulation

Model

Outputs

database queries
may be probabilistic

Inputs

Validation

Simulant

Datomic

Simulant Schema

:model partition

shared by
model, test, sim:

model
tests
type

1-N

The World

creates

1-N

codebase
git/uri
type
git/sha

:test partition

test
type
agents
sims
duration

1-N

agent
actions
type
errorDescription

1-N

action
atTime
type

creates

1-N

:sim partition

sim
clock
processes
services
type

1-1

clock
type

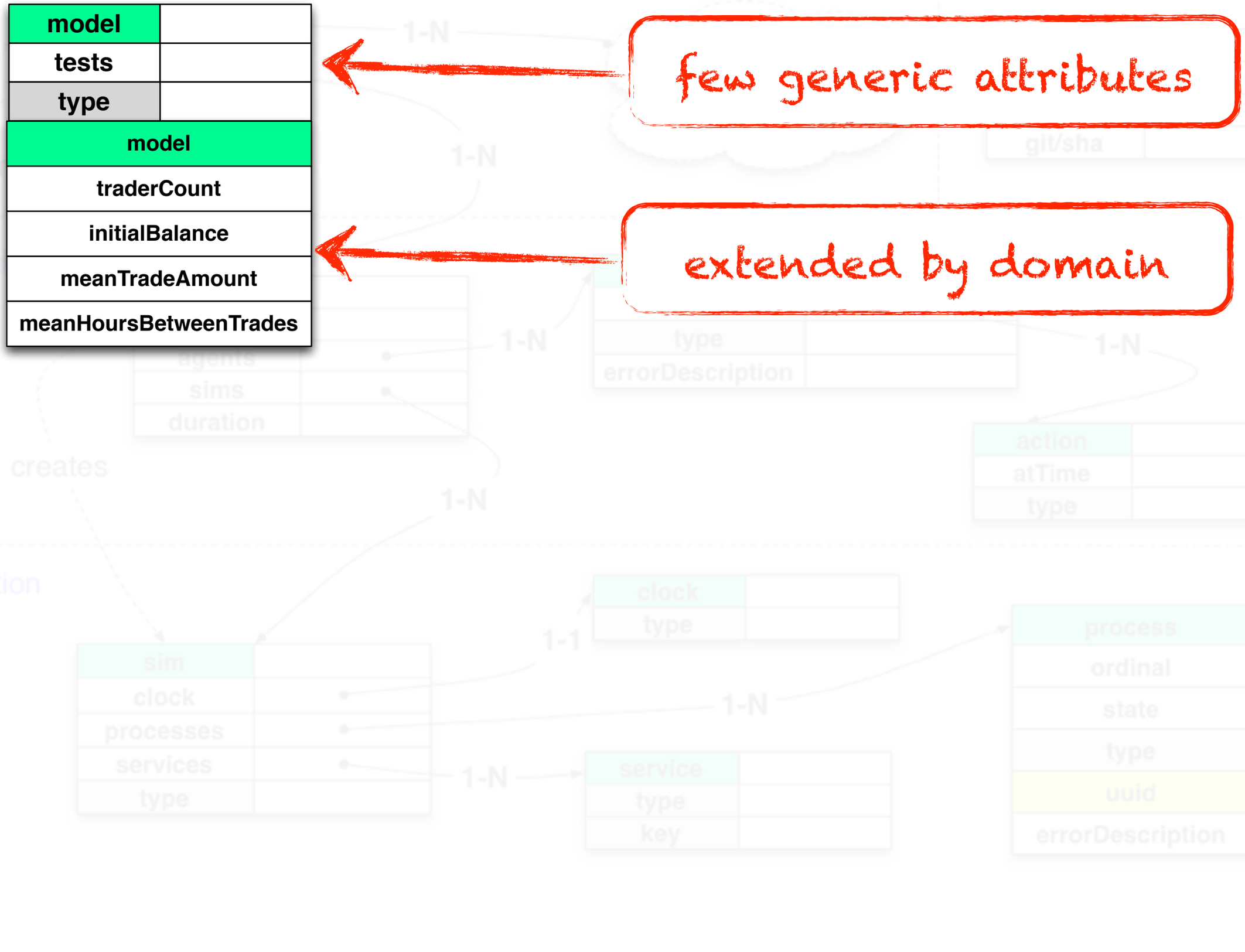
1-N

1-N

service
type
key

process
ordinal
state
type
uuid
errorDescription

Models


model
tests
type
model
traderCount
initialBalance
meanTradeAmount
meanHoursBetweenTrades
few generic attributes
extended by domain

Activity

:test partition

test	
type	
agents	
sims	
duration	

1-N

agent	
actions	
type	
errorDescription	

1-N

action	
atTime	
type	

creates

1-N

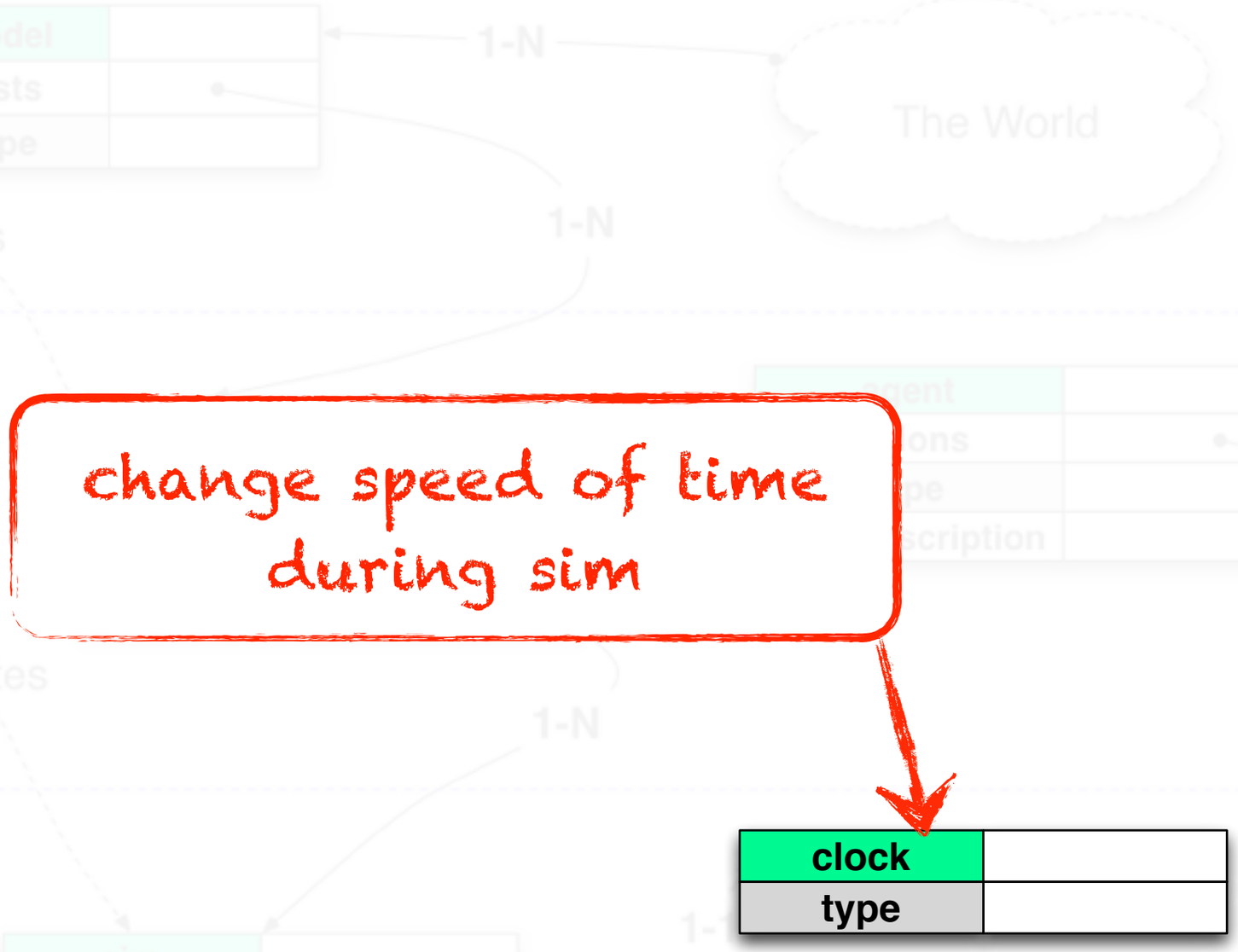
:sim partition

domain extension

action
transferFrom
transferTo
transferAmount

Clock

change speed of time during sim



Simulant Schema

:model partition

shared by
model, test, sim:

model
tests
type

1-N

The World

creates

1-N

codebase
git/uri
type
git/sha

:test partition

test
type
agents
sims
duration

1-N

agent
actions
type
errorDescription

1-N

action
ordinal
state
type
uuid
errorDescription

creates

1-N

:sim partition

sim
clock
processes
services
type

1-1

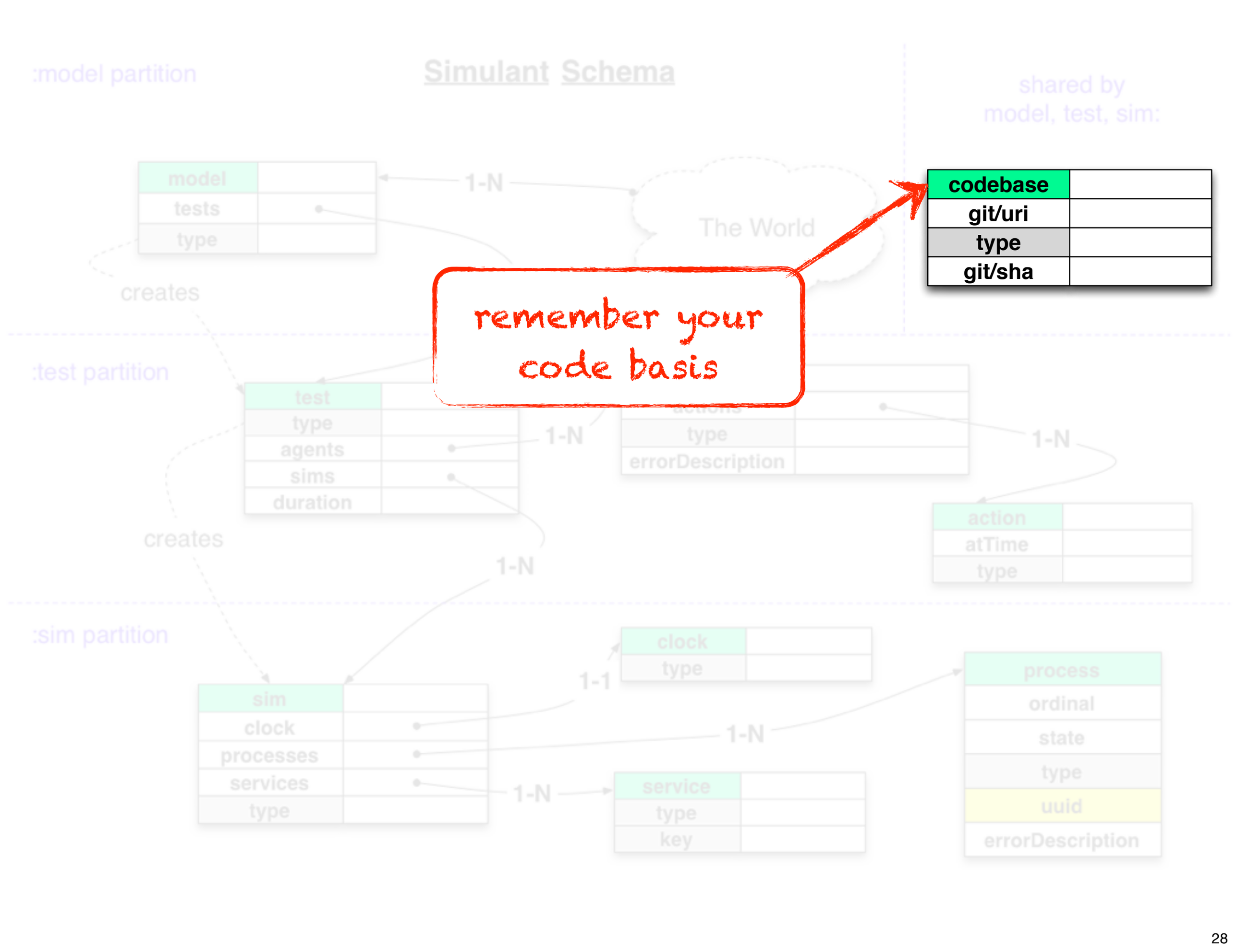
clock
type

1-N

1-N

service
type
key

manage lifecyle
for external systems


Simulant Schema
:model partition
shared by
model, test, sim:
model
tests
type
1-N
The World
creates
codebase
git/uri
type
git/sha
remember your
code basis
:test partition
test
type
agents
sims
duration
1-N
type
errorDescription
1-N
creates
action
atTime
type
1-N
:sim partition
clock
type
1-1
sim
clock
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services
type
1-N
1-N
service
type
key
process
ordinal
state
type
uuid
errorDescription

Demo

data.generators

Objectives

Generate all kinds of data

Various distributions

Predictable

Approach

Generator fns shadow related fns in clojure.core

Default integer distributions are uniform on range

Other defaults are arbitrary

Repeatable via dynamic binding of *rnd*

Scalar Generators

```
(require '[clojure.data.generators :as gen])

(gen/short)
=> 14913

(gen/uniform 0 10)
=> 6

(gen/rand-nth [:a :b :c])
=> :a
```

Scalar Generators

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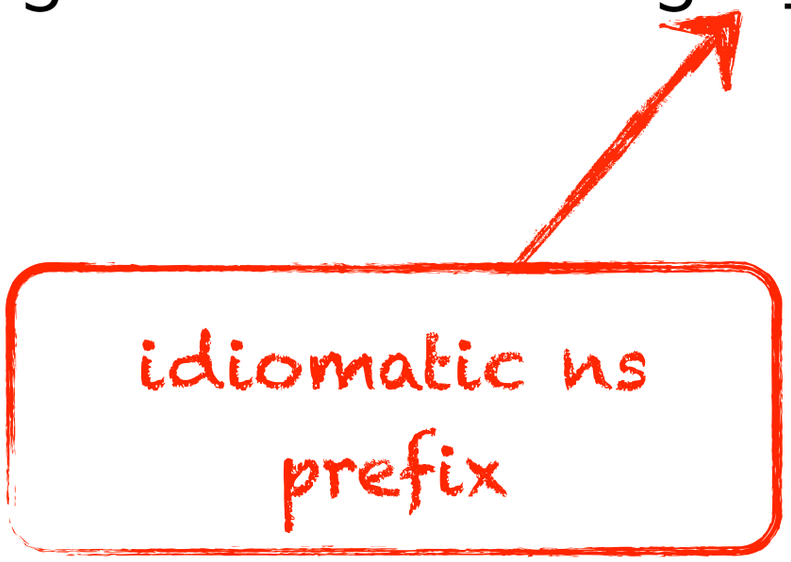

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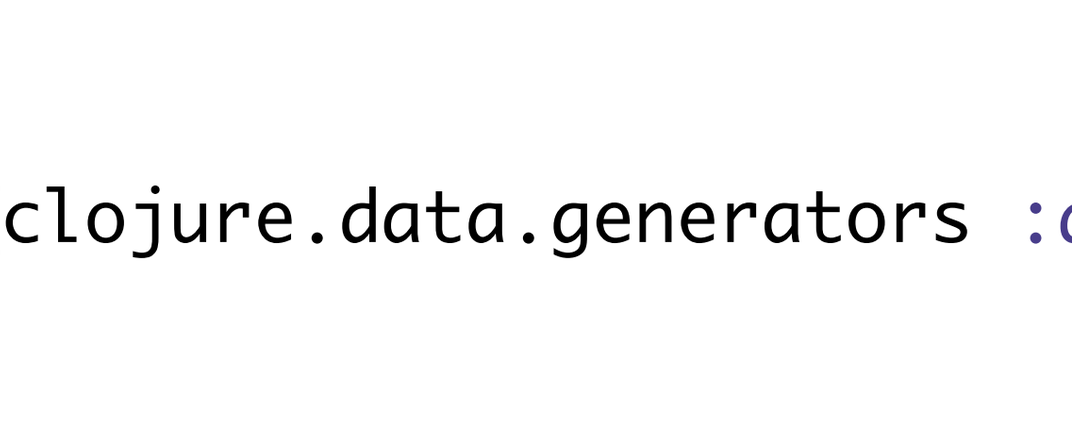
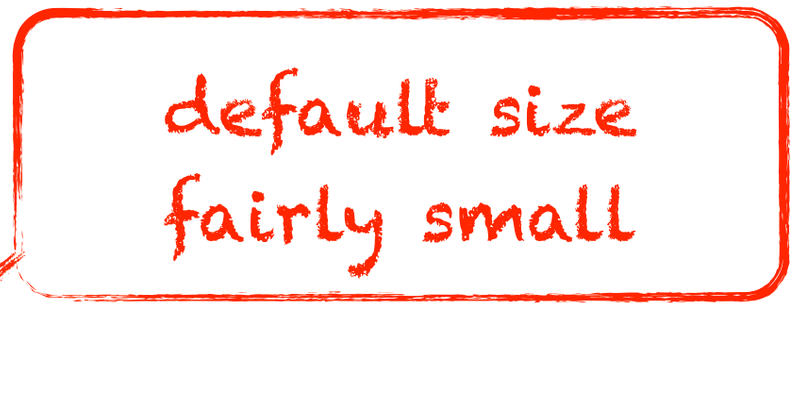


Collection Generators

```
(gen/list gen/short)
=> (-8600 -14697 -2382 18540 27481)
```

```
(gen/hash-map gen/short gen/string 2)
=> {-7110 "UBL)l",
    11472 "Q5|>^>rQNL9E..y#}IMpw>gnM']jD'<q"}
```

Collection Generators

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```

Composition

```
(gen/one-of gen/long gen/keyword)
=> :OBe0Mkc1g7eqqQnGvcXq0m-McRzl9areH0NwR1

(gen/weighted {gen/long 10 gen/keyword 1})
=> 47180317273564660 9
```

```
(gen/scalar)
=> -49

(gen/collection)
=> #{-3945240682015942560
     -490949758534279262 0
     ...}
```

Composition

```
(gen/one-of gen/long gen/keyword)
=> :OBe0MkcIgZeqqQnGvcXq0m-McRzl9areH0NwR1

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=> -49

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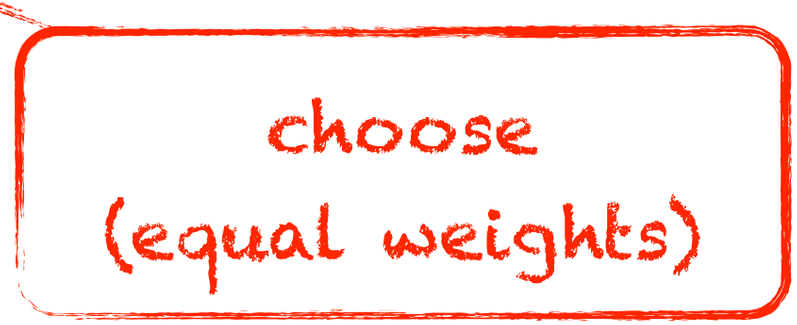

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(gen/weighted {gen/long 10 gen/keyword 1})
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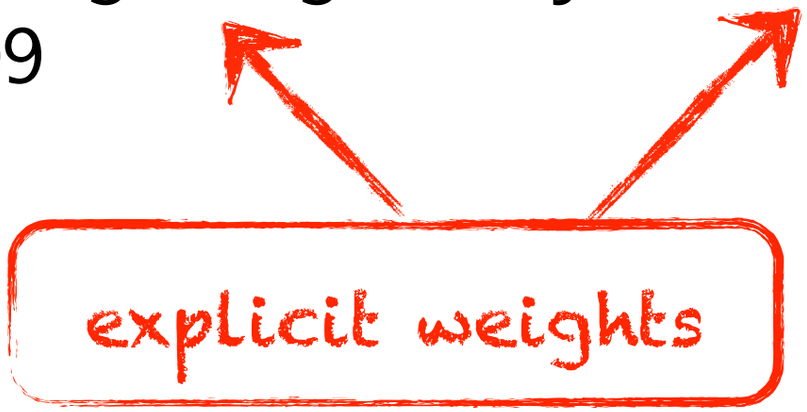
(gen/scalar)
=> -49

(gen/collection)
=> #{-3945240682015942560
     -490949758534279262O
     ...}
```



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(gen/scalar)
=> -49

(gen/collection)
=> #{-3945240682015942560
     -490949758534279262 0
     ...}
```

Datalog

Query Anatomy

```
q([:find ...
   :in ...
   :where ...],
  input1,
  ...
  inputN);
```

Query Anatomy

constraints

```
q([:find ...
   :in ...
   :where ...],
  input1,
  ...
  inputN);
```

Query Anatomy

```
q([:find ...
   :in ...
   :where ...],
  input1,
  ...
  inputN);
```

inputs

Query Anatomy

```
q([:find ...
   :in ...
   :where ...],
  input1,
  ...
  inputN);
```

names for inputs

Query Anatomy

```
q([:find ...
   :in ...
   :where ...],
  input1,
  ...
  inputN);
```

variables to return

Variables

?customer

?product

?orderId

?email

Constants

```
42                                  :email

                  "john"

:order/id

                        #inst "2012-02-29"
```

Extensible Reader

```
:email
42
"john"
:order/id
#inst "2012-02-29"
```

Example Database

entity	attribute	value
42	:email	jdoe@example.com
43	:email	jane@example.com
42	:orders	107
42	:orders	141

Data Pattern

Constrains the results returned,
binds variables

```
[?customer :email ?email]
```

Data Pattern

Constrains the results returned,
binds variables

```
[?customer :email ?email]
```

Data Pattern

Constrains the results returned,
binds variables

constant

```
[?customer :email ?email]
```

Data Pattern

Constrains the results returned,
binds variables

variable variable

```
[?customer :email ?email]
```

entity	attribute	value
42	:email	jdoe@example.com
43	:email	jane@example.com
42	:orders	107
42	:orders	141

```
[?customer :email ?email]
```

Constants Anywhere

"Find a particular customer's email"

```
[42 :email ?email]
```

entity	attribute	value
42	:email	jdoe@example.com
43	:email	jane@example.com
42	:orders	107
42	:orders	141

```
[42 :email ?email]
```

Variables Anywhere

"What attributes does
customer 42 have?

```
[42 ?attribute]
```

entity	attribute	value
42	:email	jdoe@example.com
43	:email	jane@example.com
42	:orders	107
42	:orders	141

```
[42 ?attribute]
```

Variables Anywhere

"What attributes and values does customer 42 have?

```
[42 ?attribute ?value]
```

entity	attribute	value
42	:email	jdoe@example.com
43	:email	jane@example.com
42	:orders	107
42	:orders	141

```
[42 ?attribute ?value]
```

Where Clause

data pattern

```
[:find ?customer
 :where [?customer :email]]
```

Find Clause

variable to return

```
[:find ?customer
 :where [?customer :email]]
```

Implicit Join

"Find all the customers who
have placed orders."

```
[:find ?customer
 :where [?customer :email]
        [?customer :orders]]
```

API

```
import static datomic.Peer.q;


q("[:find ?customer
  :where [?customer :id]
         [?customer :orders]]",
db);
```

q

```
import static datomic.Peer.q;

q("[:find ?customer
  :where [?customer :id]
         [?customer :orders]]",
db);
```

Query

```
import static datomic.Peer.q;


q("[:find ?customer
   :where [?customer :id]
          [?customer :orders]]",
  db);
```

Input(s)

```
import static datomic.Peer.q;


q("[:find ?customer
  :where [?customer :id]
         [?customer :orders]]",
db);
```

In Clause

Names inputs so you can refer to them elsewhere in the query

```
:in $database ?email
```

Parameterized Query

"Find a customer by email."

```
q([:find ?customer
   :in $database ?email
   :where [$database ?customer :email ?email]],
  db,
  "jdoe@example.com");
```

First Input

"Find a customer by email."

```
q([:find ?customer
   :in $database ?email
   :where [$database ?customer :email ?email]],
  db,
  "jdoe@example.com");
```

Second Input

"Find a customer by email."

```
q([:find ?customer
   :in $database ?email
   :where [$database ?customer :email ?email]],
  db,
  "jdoe@example.com");
```

Verbose?

"Find a customer by email."

```
q([:find ?customer
   :in $database ?email
   :where [$database ?customer :email ?email]],
  db,
  "jdoe@example.com");
```

Shortest Name Possible

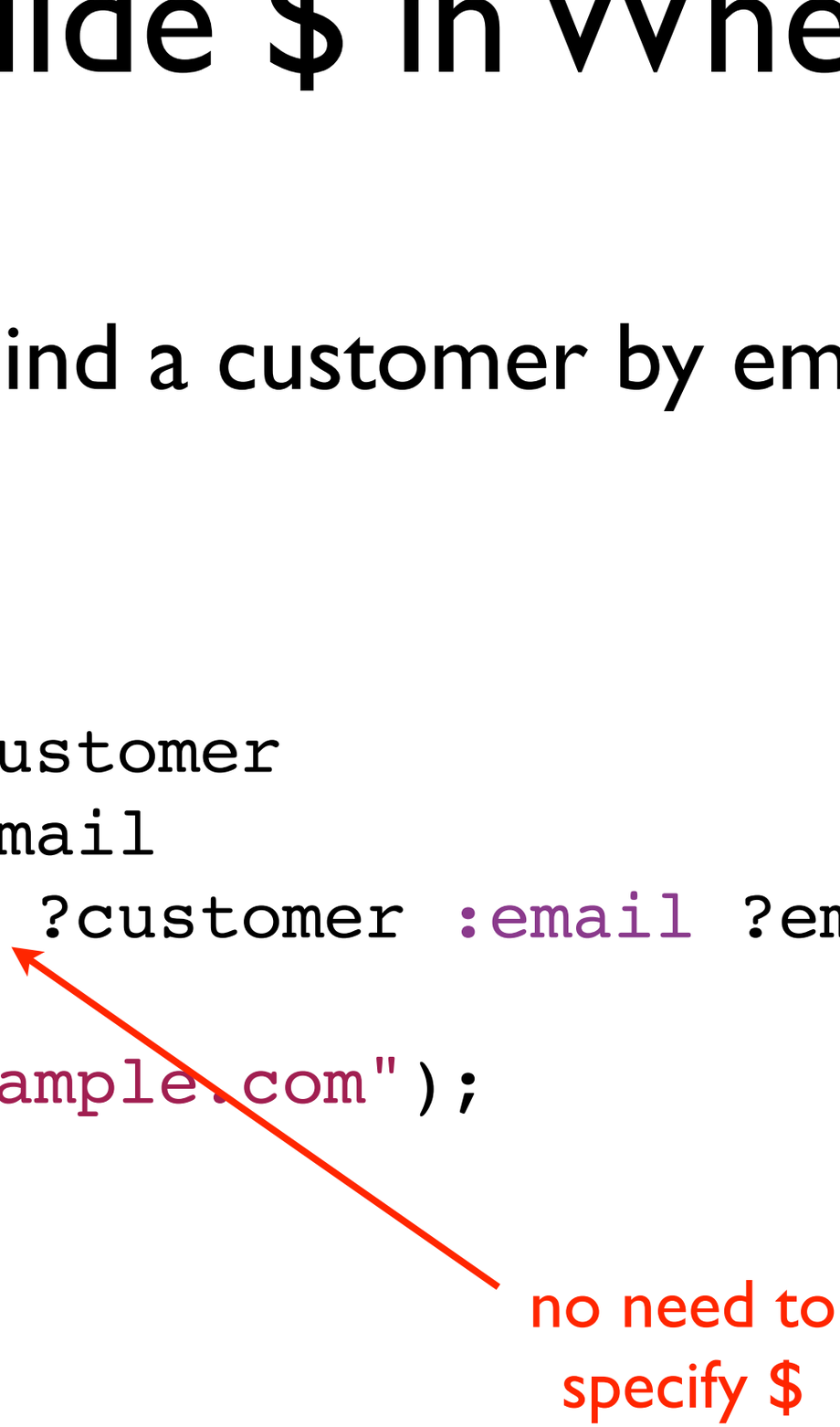
"Find a customer by email."

```
q([:find ?customer
   :in $ ?email
   :where [$ ?customer :email ?email]],
  db,
  "jdoe@example.com");
```

Elide $ in Where

"Find a customer by email."

```
q([:find ?customer
   :in $ ?email
   :where [ ?customer :email ?email]],
  db,
  "jdoe@example.com");
```



Predicates

Functional constraints that can appear in a :where clause

```
[(< 50 ?price)]
```

Adding a Predicate

"Find the expensive items"

```
[:find ?item
 :where [?item :item/price ?price]
        [(< 50 ?price)]]
```

Functions

Take bound variables as inputs
and bind variables with output

```
[(shipping ?zip ?weight) ?cost]
```

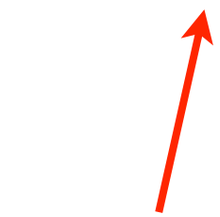
Function Args

```
[(shipping ?zip ?weight) ?cost]
```

bound inputs

Function Returns

```
[(shipping ?zip ?weight) ?cost]
```



bind return values

Calling a Function

"Find me the customer/product combinations where the shipping cost dominates the product cost."

```
[:find ?customer ?product
 :where [?customer :shipAddress ?addr]
        [?addr :zip ?zip]
        [?product :product/weight ?weight]
        [?product :product/price ?price]
        [(Shipping/estimate ?zip ?weight) ?shipCost]
        [(<= ?price ?shipCost)]]
```

Calling a Function

"Find me the customer/product combinations where the shipping cost dominates the product cost."

navigate from customer to zip

```
[:find ?customer ?product
 :where [?customer :shipAddress ?addr]
        [?addr :zip ?zip]
        [?product :product/weight ?weight]
        [?product :product/price ?price]
        [(Shipping/estimate ?zip ?weight) ?shipCost]
        [(<= ?price ?shipCost)]]
```

Calling a Function

"Find me the customer/product combinations where the shipping cost dominates the product cost."

```
[:find ?customer ?product
 :where [?customer :shipAddress ?addr]
        [?addr :zip ?zip]
        [?product :product/weight ?weight]
        [?product :product/price ?price]
        [(Shipping/estimate ?zip ?weight) ?shipCost]
        [(<= ?price ?shipCost)]]
```

get product facts needed *during query*

Calling a Function

"Find me the customer/product combinations where the shipping cost dominates the product cost."

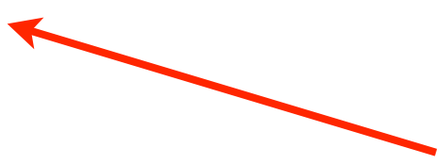
```
[:find ?customer ?product
 :where [?customer :shipAddress ?addr]
        [?addr :zip ?zip]
        [?product :product/weight ?weight]
        [?product :product/price ?price]
        [(Shipping/estimate ?zip ?weight) ?shipCost]
        [(<= ?price ?shipCost)]]
```

call web service to bind shipCost

Calling a Function

"Find me the customer/product combinations where the shipping cost dominates the product cost."

```
[:find ?customer ?product
 :where [?customer :shipAddress ?addr]
        [?addr :zip ?zip]
        [?product :product/weight ?weight]
        [?product :product/price ?price]
        [(Shipping/estimate ?zip ?weight) ?shipCost]
        [(<= ?price ?shipCost)]]
```



constrain price

Calling a Function

"Find me the customer/product combinations where the shipping cost dominates the product cost."

return customer, product pairs

```
[:find ?customer ?product
 :where [?customer :shipAddress ?addr]
        [?addr :zip ?zip]
        [?product :product/weight ?weight]
        [?product :product/price ?price]
        [(Shipping/estimate ?zip ?weight) ?shipCost]
        [(<= ?price ?shipCost)]]
```

Clojure Wins

700 LOC

Multimethods

Seqs

Laziness

Agents

Datomic Wins

Open schema

Datalog

Time model

Functional

Multi-db queries

Datomic

Adopting Simulation

Test any target system

Don’t throw our your example-based tests

Comfort with the model comes in ~1 week

Simulation requires time and thought

References

The Simulant open-source library,
https://github.com/datomic/simulant

Simulant Demo,
https://github.com/Datomic/simulant/blob/master/examples/repl/hello_world.clj

Datomic,
http://www.datomic.com/

Clojure,
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http://thinkrelevance.com/

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https://github.com/stuarthalloway/presentations

@stuarthalloway

https://github.com/stuarthalloway/presentations/wiki