*f*unctional 3D **game design**

James Reeves

boolean·knot

why a **game?**

why **clojure?**

You cannot correctly represent change without immutability

Rich Hickey

concurrency
concurrency
concurrency

can **functional programming** be performant?

Performance

Brute Force

Caching

Mutability

Reliability

Brute Force

Caching

Mutability

When in doubt, use brute force.

Ken Thompson

Performance

assoc on 1000 element map

Brute Force	PersistentArrayMap	4600ns
Caching	PersistentHashMap	180ns
Mutability	TransientHashMap	85ns

caching is often good enough

16ms per frame

...is actually a sizable chunk of time

caveats

- performance can't be eyeballed
- I/O typically too costly
- hard time limit

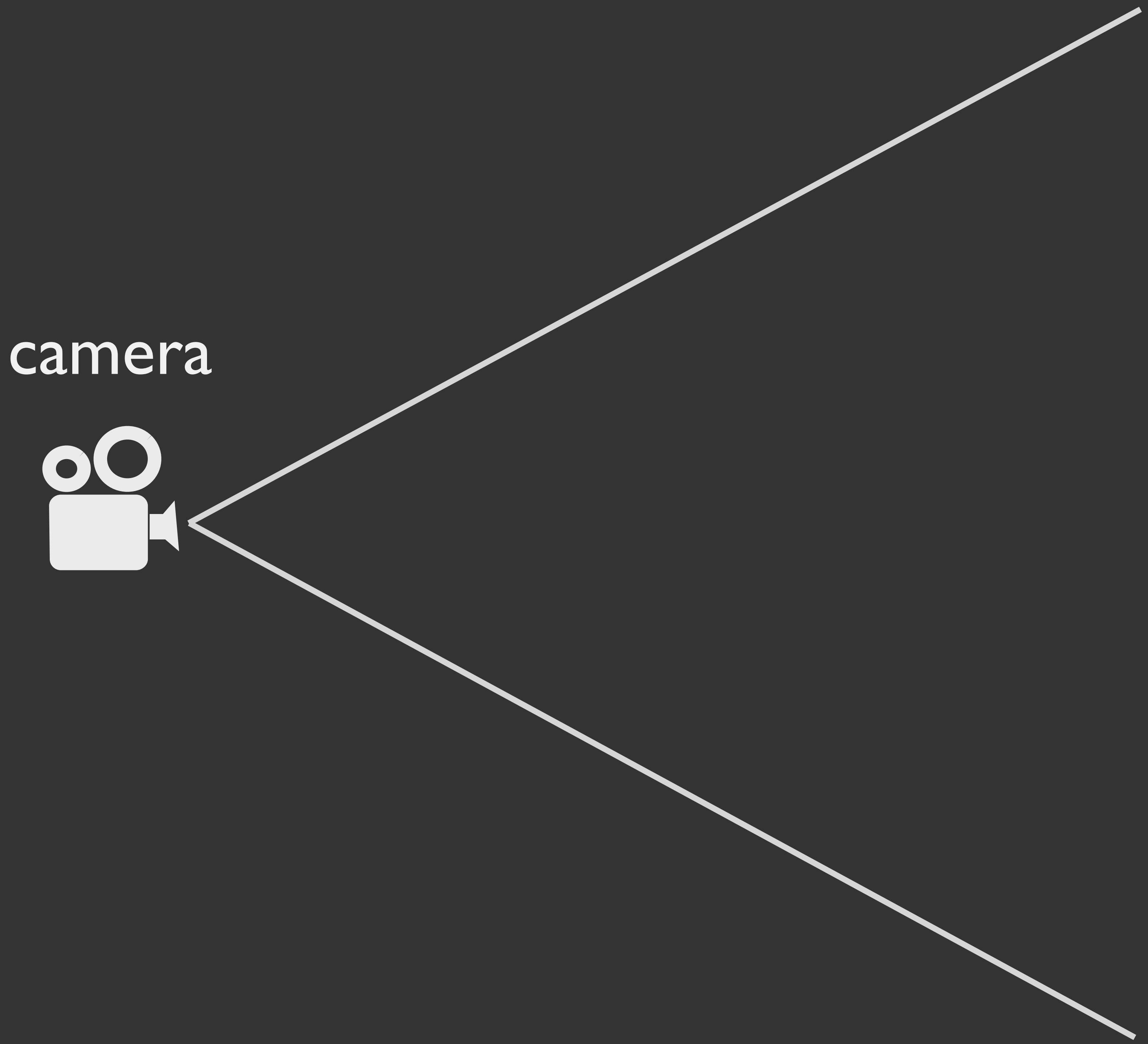
3D **space**

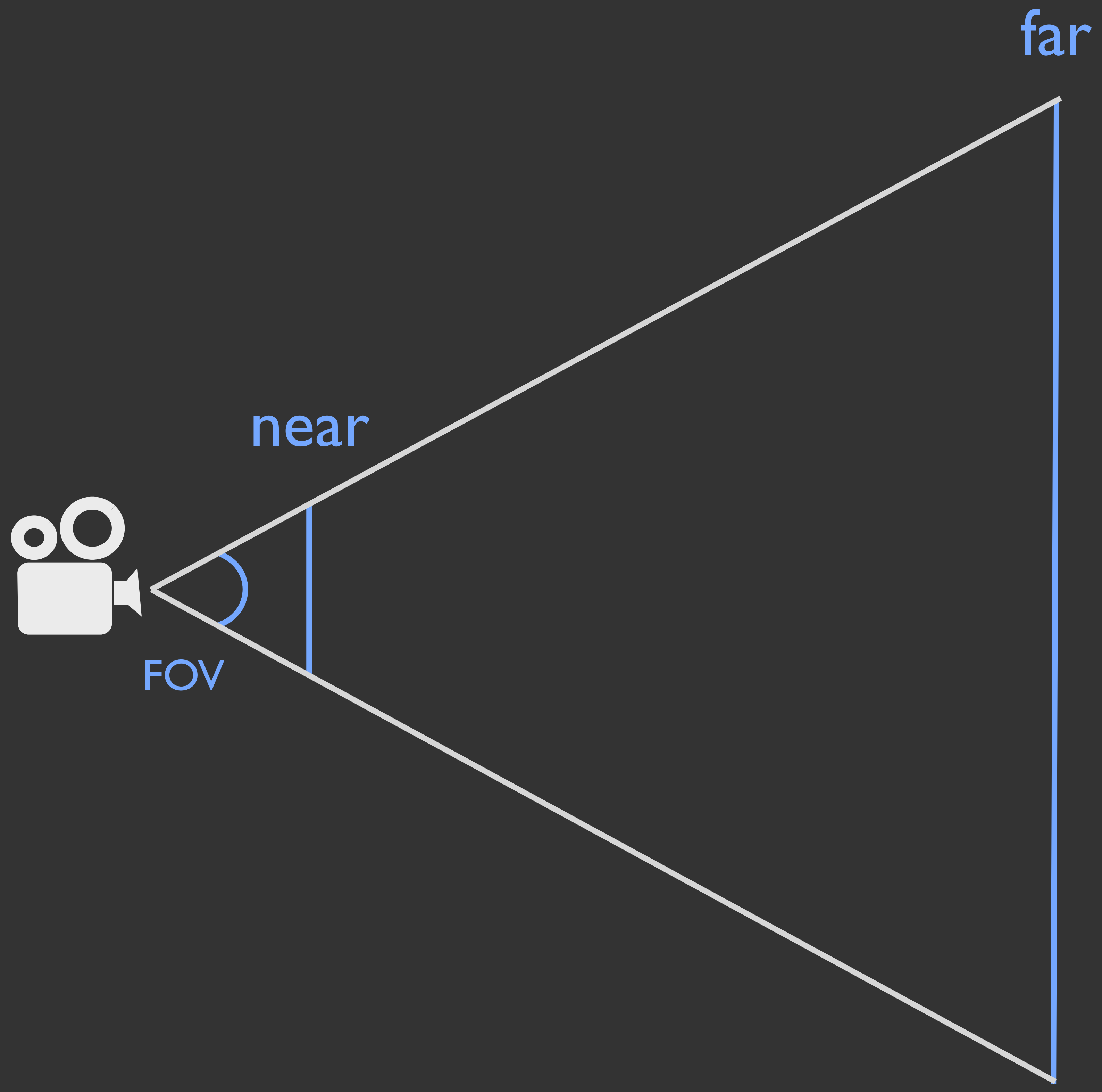
vector translation in space

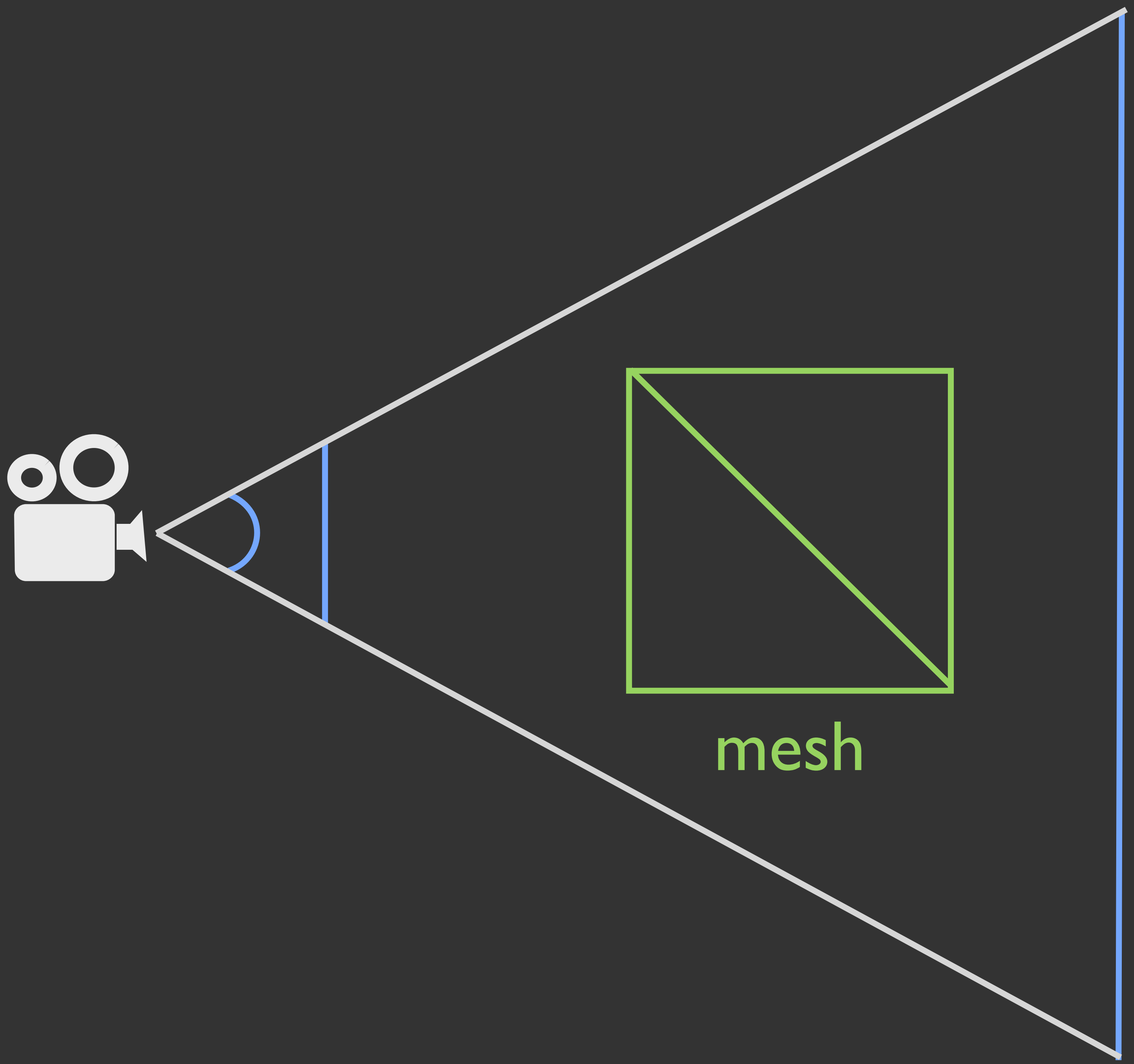
```
#math/vector [0 0 0]
```

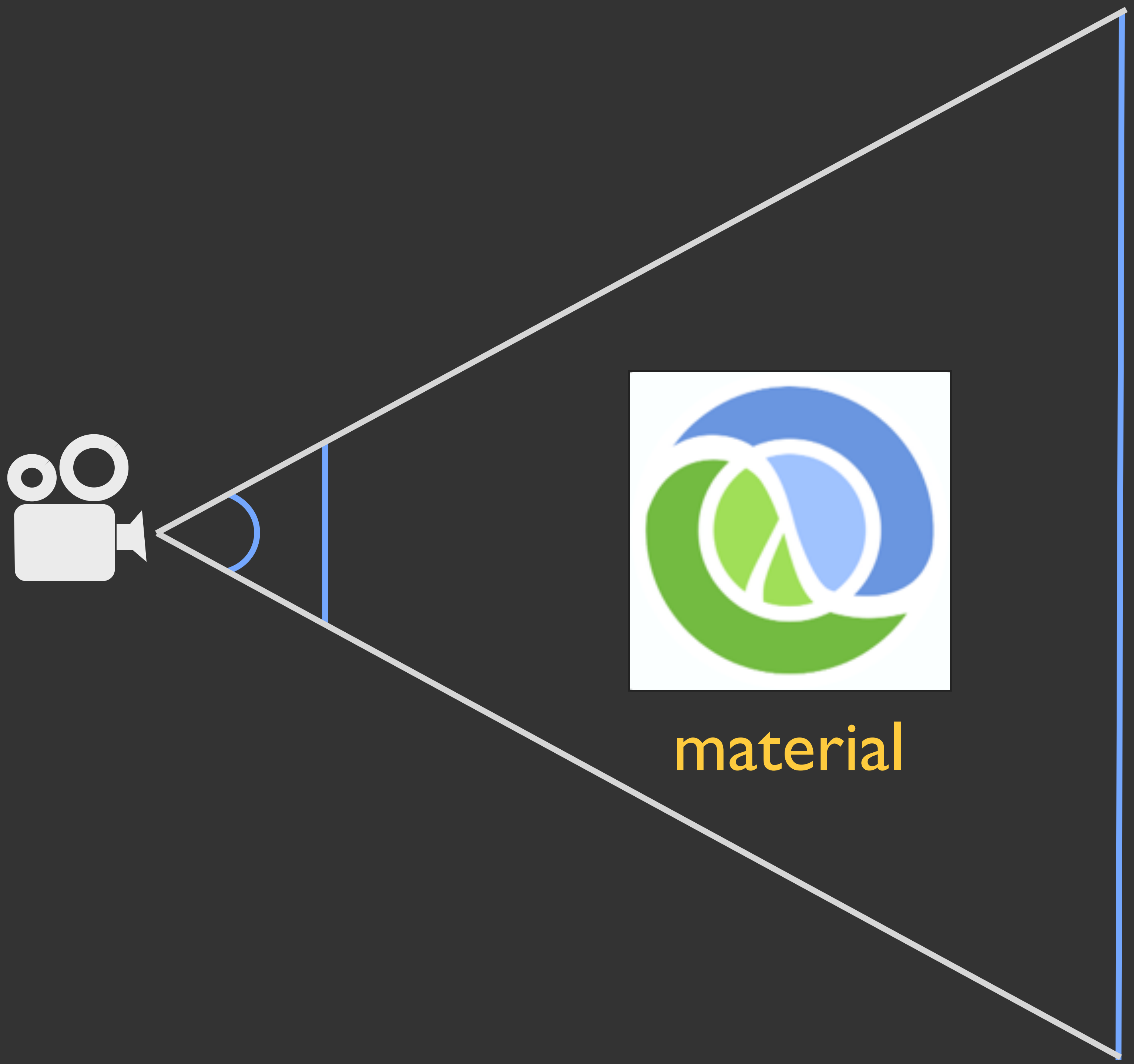
quaternion rotation in space

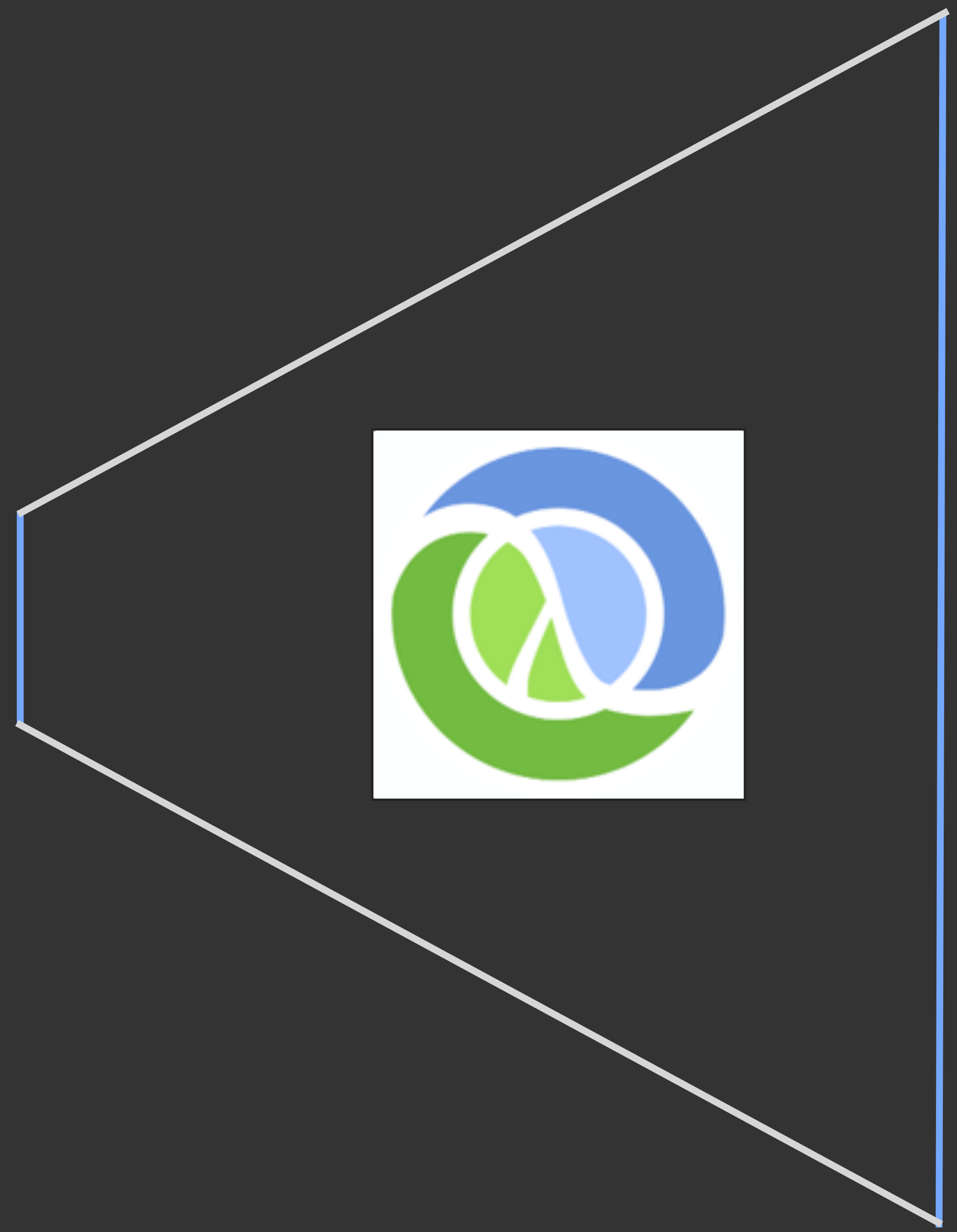
```
#math/quaternion [0 0 0 1]
```


camera


far
near
FOV


mesh


material

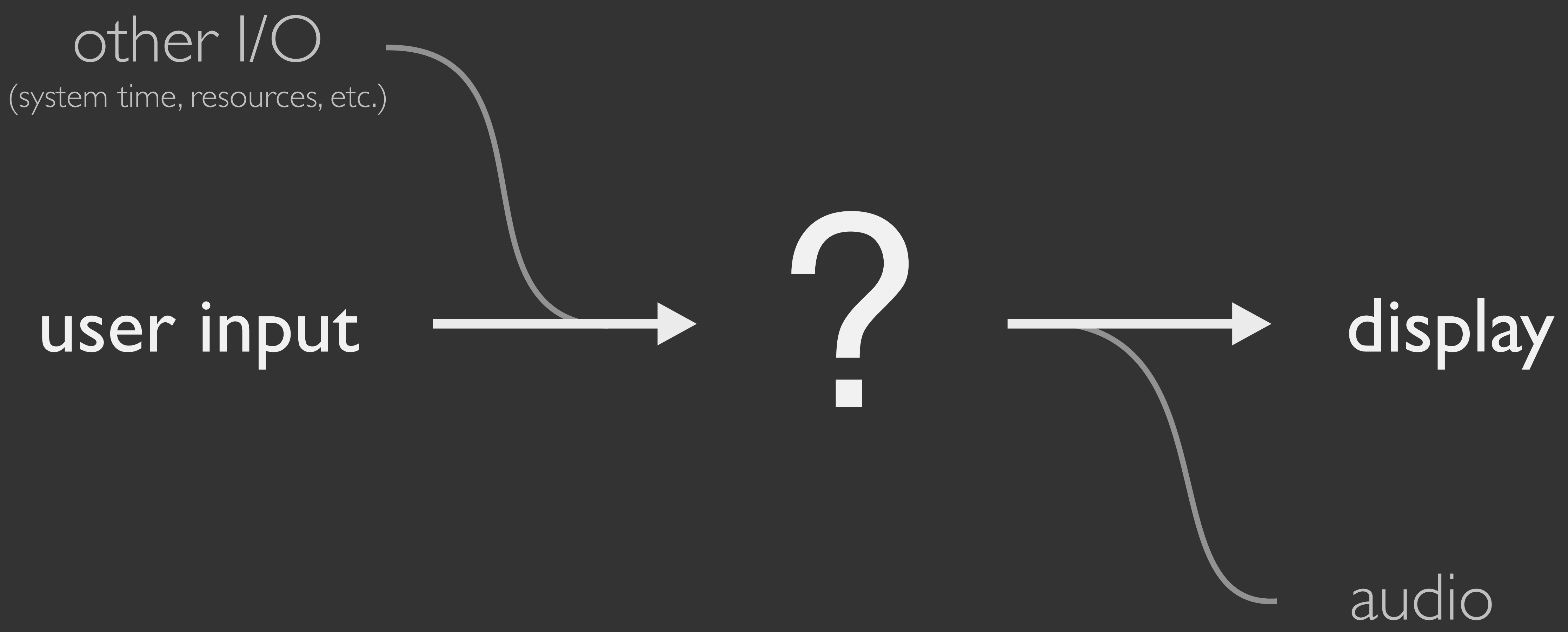


projection

data

camera	`:location :rotation`
frustum	`:fov :near :far`
mesh	`:location :rotation :scale` `:vertices :tex-coords :indexes`
material	`:definition :color-map`

game loop


other I/O
(system time, resources, etc.)
user input
?
display
audio

abstractions

display series of frames over time

frame snapshot of a changing value

➠ **reference**

```
(defn display []
  (loop []
    (render @scene)
    (recur)))
```

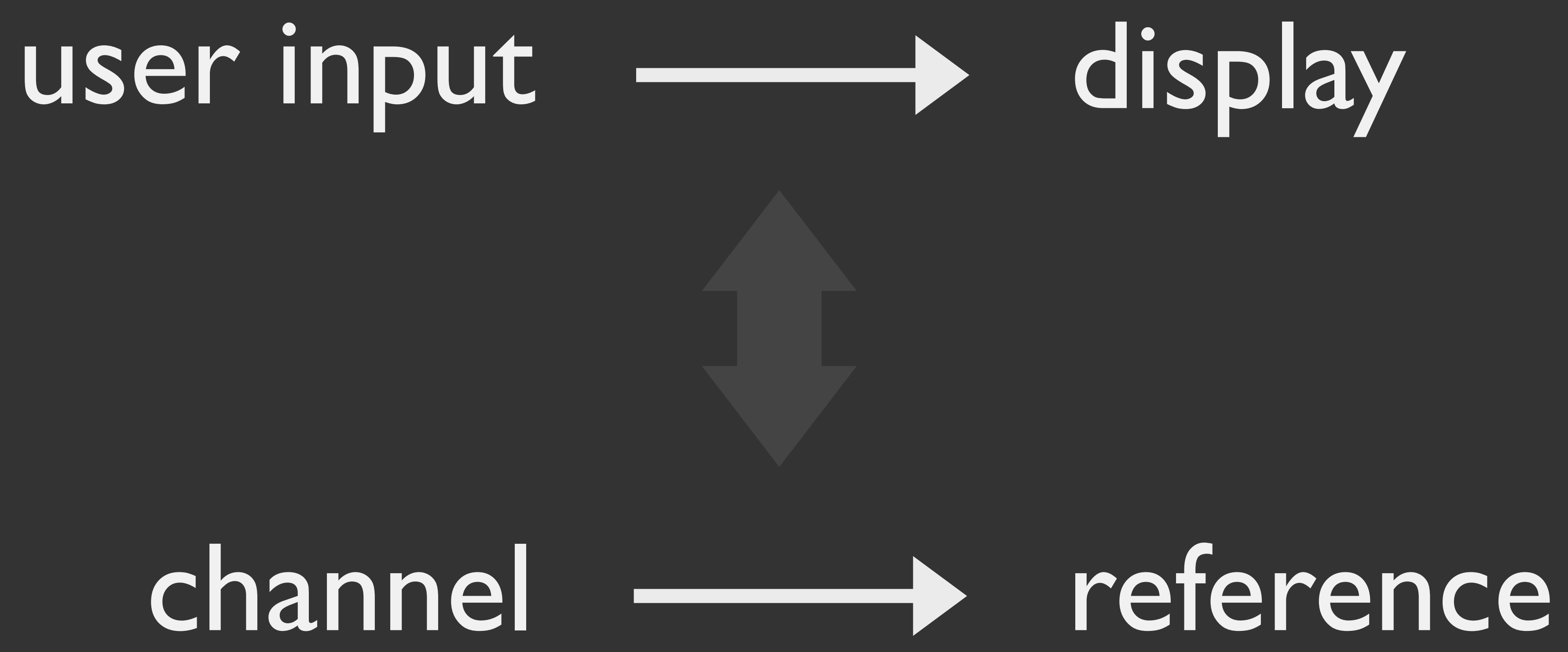
abstractions

user input series of discrete events

event immutable value

➠ **channel**

```
(def events (chan))
```


user input
display
channel
reference

channel → ? → reference

option 1

callbacks + mutable state

mutable state

```
(def events (chan))

(def world (atom {}))

(def callbacks (atom #{}))
```

callbacks

```
(go (loop []
      (when-let [evt (<! events)]
        (doseq [cb callbacks]
          (swap! world cb evt)))
        (recur))))
```

so what's the **problem?**

it's complex

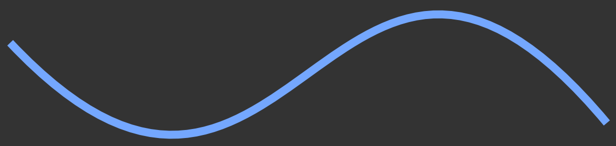
it's complex

- any callback can change any part of the world
- few constraints on mutation
- no isolation between components

option II

functional
reactive programming

reagi introduces two new reference types



behavior continuous change

events discrete changes

behavior

wraps a zero argument function

```
(r/behavior-call #(+ 1 1))

(r/behavior (+ 1 1))
```

behavior

most useful when dependent on time

```clojure
(def time
  (behavior (/ (System/nanoTime) 1e9)

(defn delta []
  (let [t0 @time]
    (behavior (- @time t0))))
```

events

wraps an asynchronous channel

```
(def nums (r/events))

(r/push! evts 1)

@evts ;; => 1
```

events

seq-like transform functions

```
(def nums (r/events))

(def incs (r/map inc nums))

(r/push! evts 2)

@incs ;; => 3
```

single value		multiple values
delay	⟷	behavior
promise	⟷	events

feedback

```
(r/reduce
  (fn [pos v] (+ pos v))
  init-position
  velocities)
```

feedback

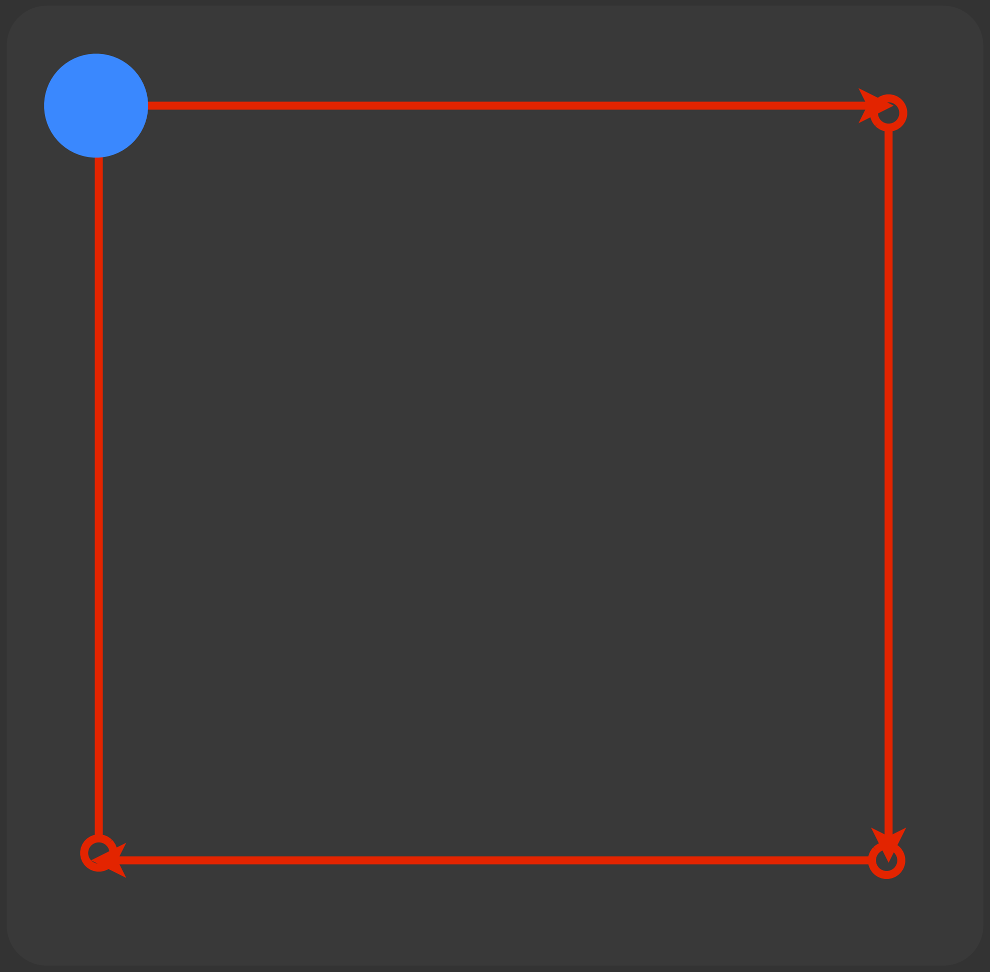
```
(r/reduce
  (fn [pos v]
    (let [p @pos]
      (r/behavior (+ p v))))
  (r/behavior init-position)
  velocities)
```

feedback

```
(r/reduce
  (fn [pos v]
    (let [p @pos, t (r/delta)]
      (r/behavior (+ p (* v t)))))
  (r/behavior init-position)
  velocities)
```

example

position



velocities

→ [1 0]

↓ [0 1]

← [-1 0]

↑ [0 -1]

refactor

```
(r/reduce
  (fn [pos v]
    (let [p @pos, t (r/delta)]
      (r/behavior (+ p (* v t)))))
  (r/behavior init-position)
  velocities)
```

refactor

```
(defn graph [f & args]
  (fn [pos]
    (let [p @pos, t (r/delta)]
      (r/behavior (apply f @t p args)))))

(defn linear [t p v]
  (+ p (* v t)))
```

refactor

```
(->> velocities
     (r/map (fn [v] (graph linear v)))
     (r/accum (r/behavior init-pos))
```

live coding

libraries

reagi	FRP for clojure
euclidean	vector and quaternion math
crumpets	color representation
criterium	benchmarking

questions?