Continuous Time Programming

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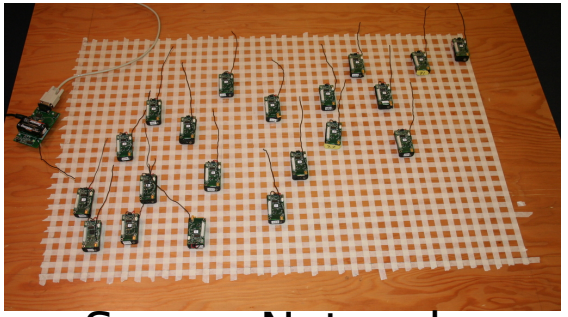
Spatial Computing



Sensor Networks

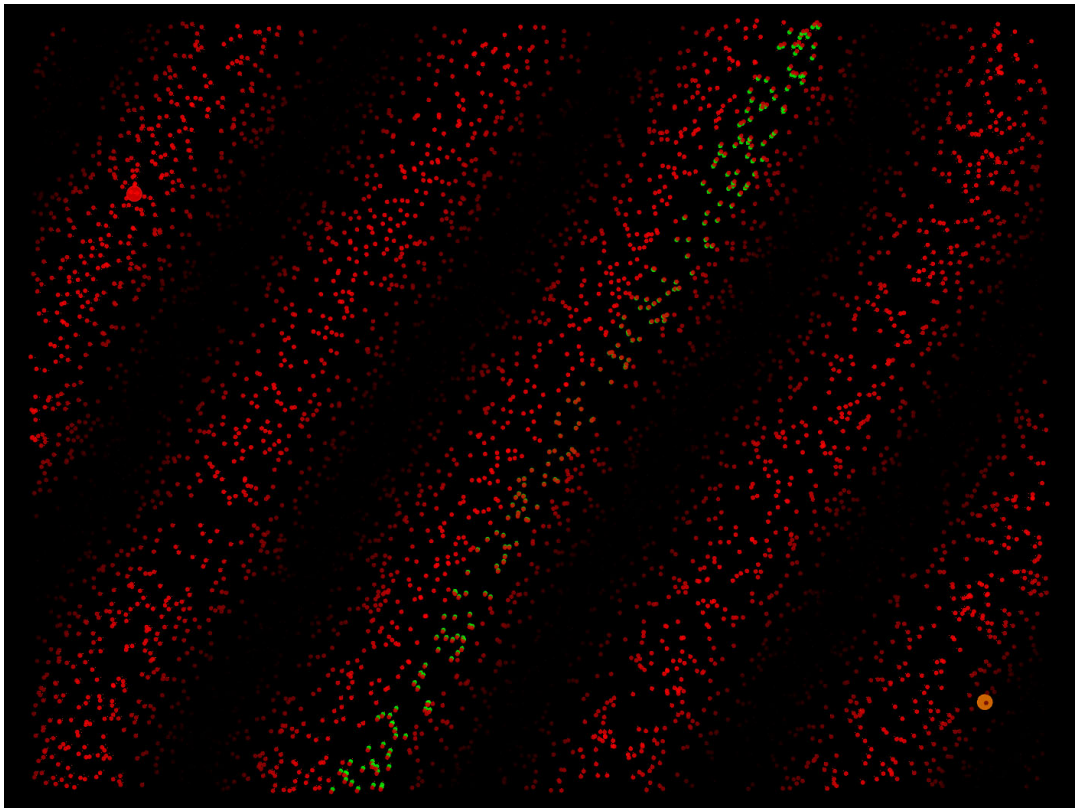
Modular Robotics

Biological Computing

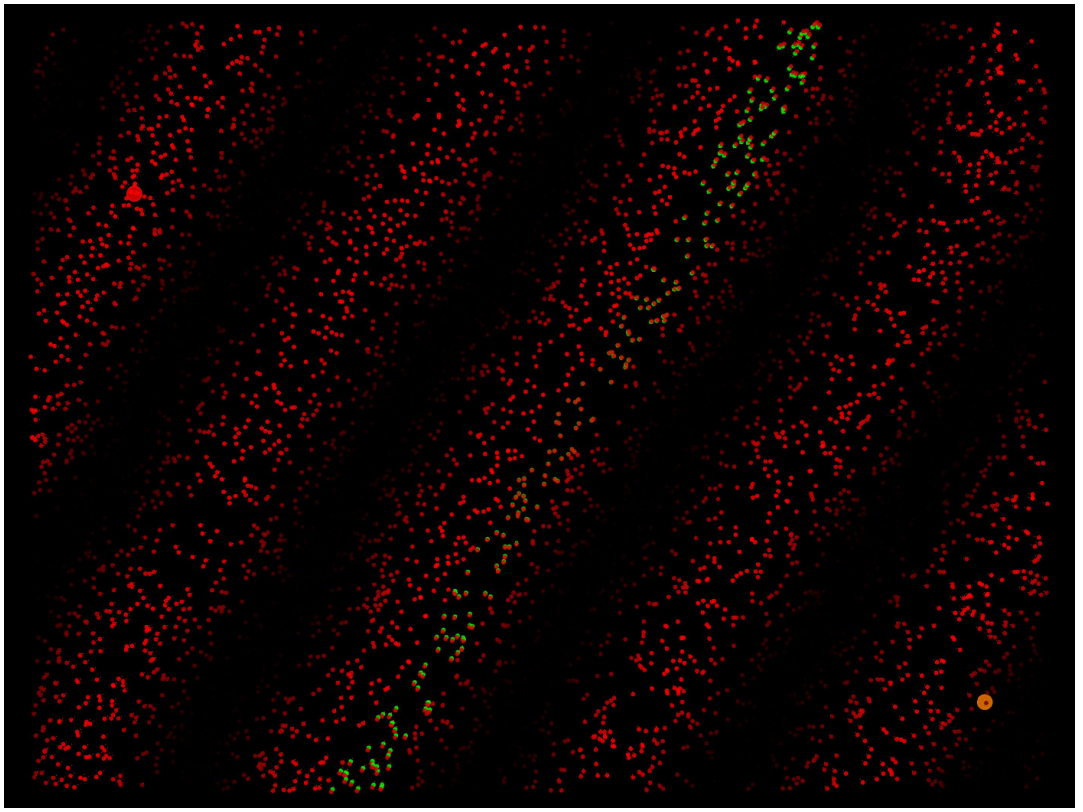
Robot Swarms

Programmability is the main challenge

Example: Directable Plane Wave



Example: Directable Plane Wave



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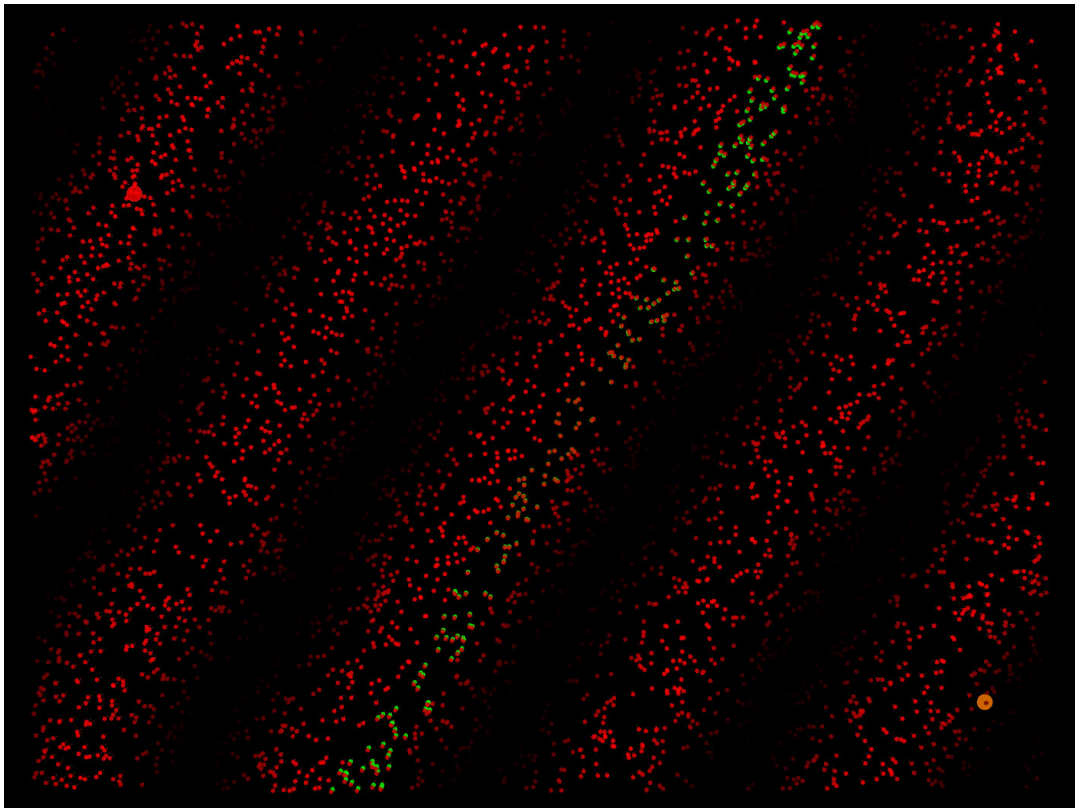

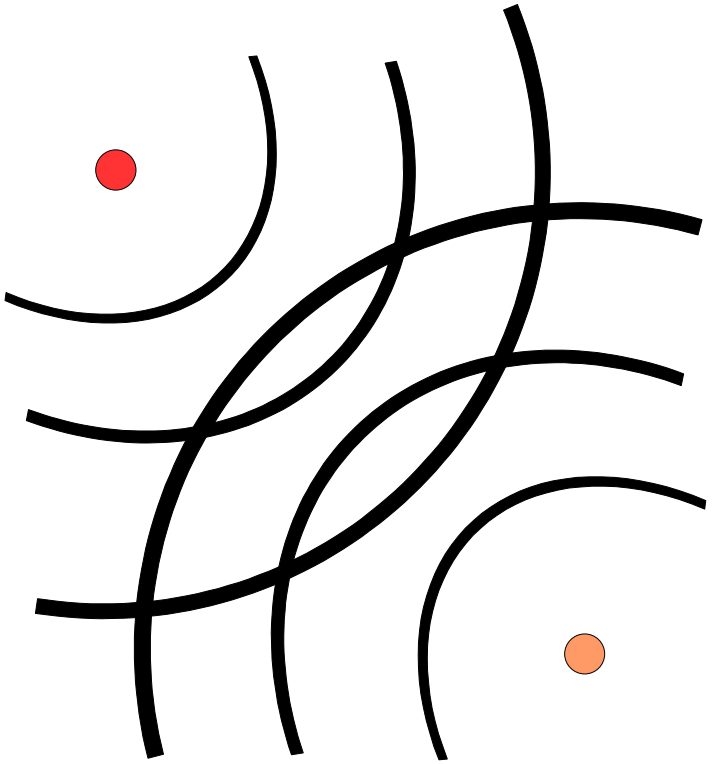

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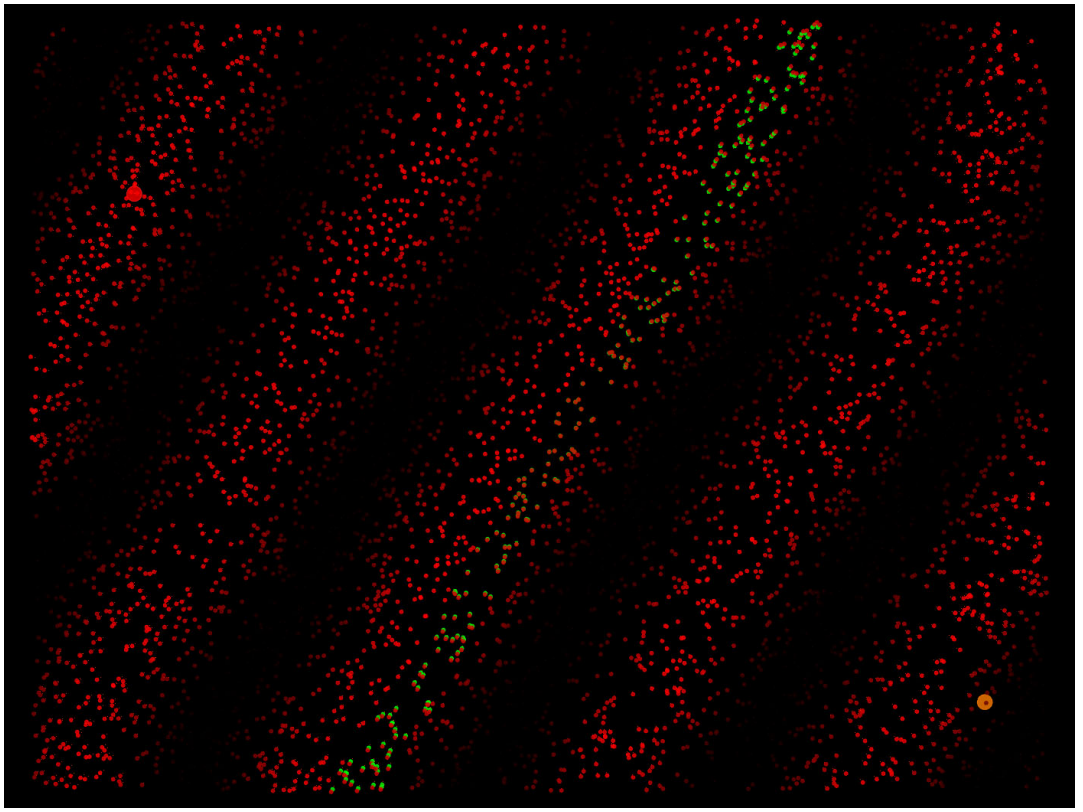

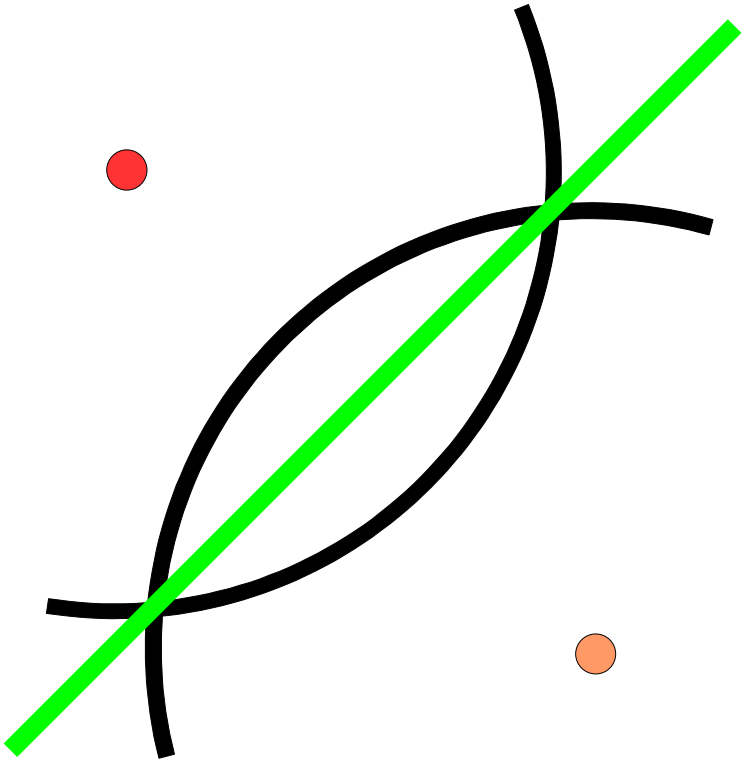

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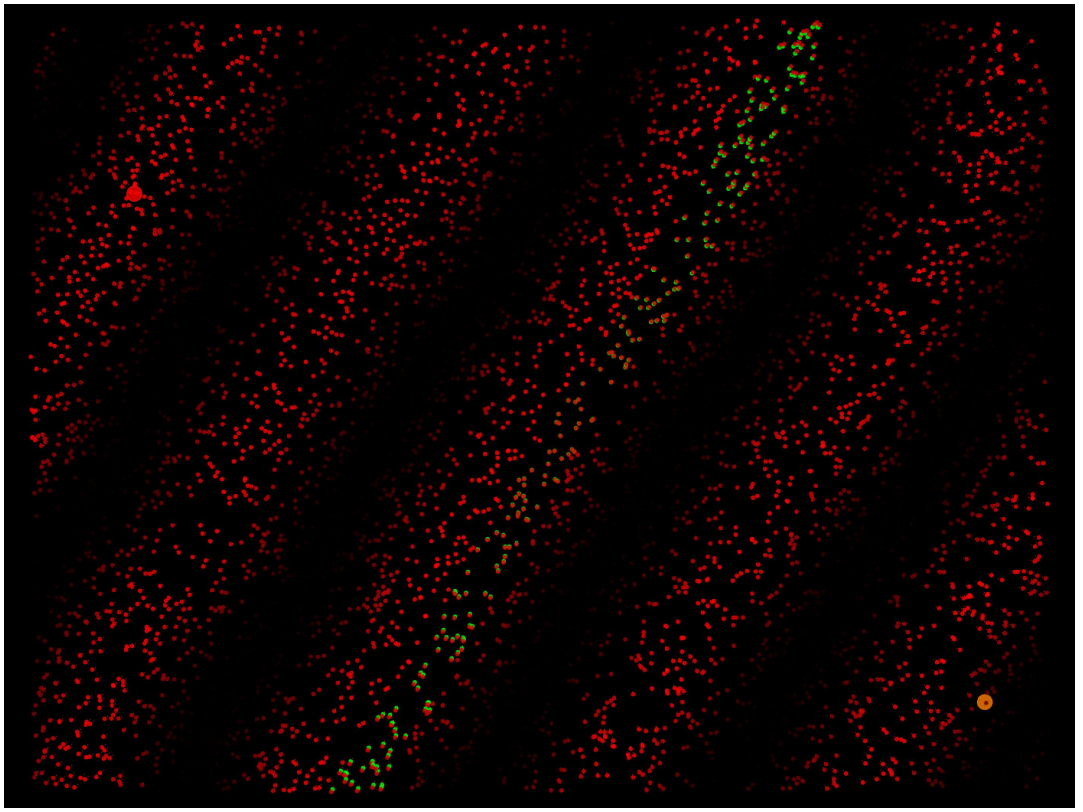

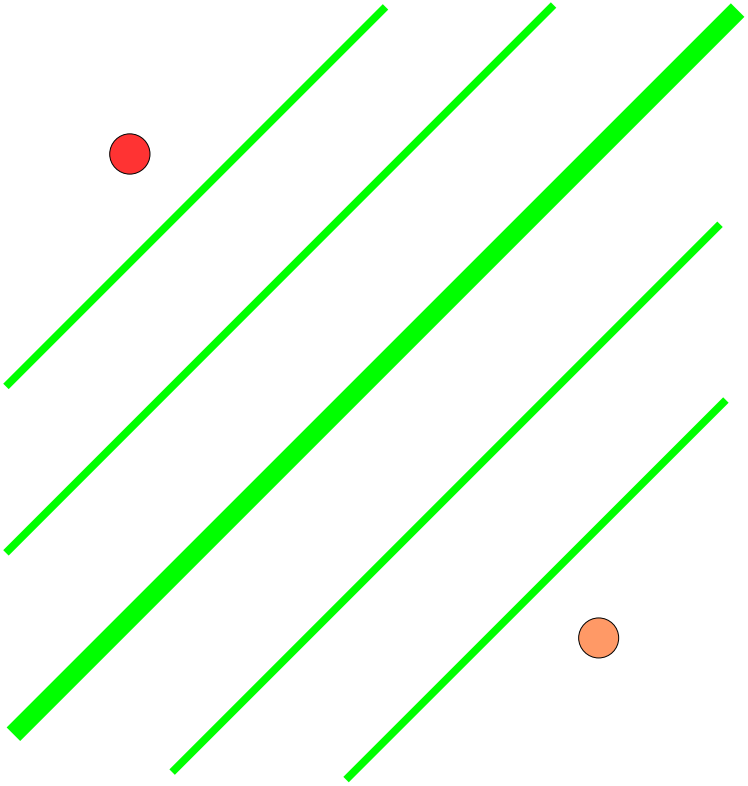

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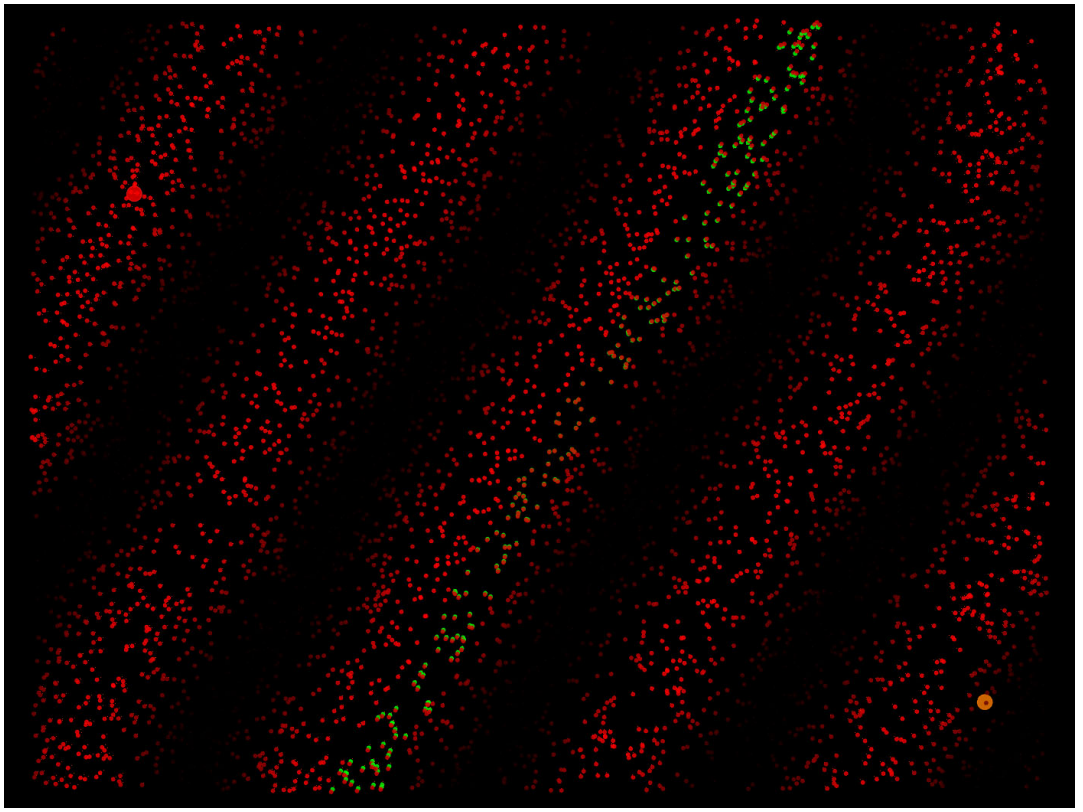

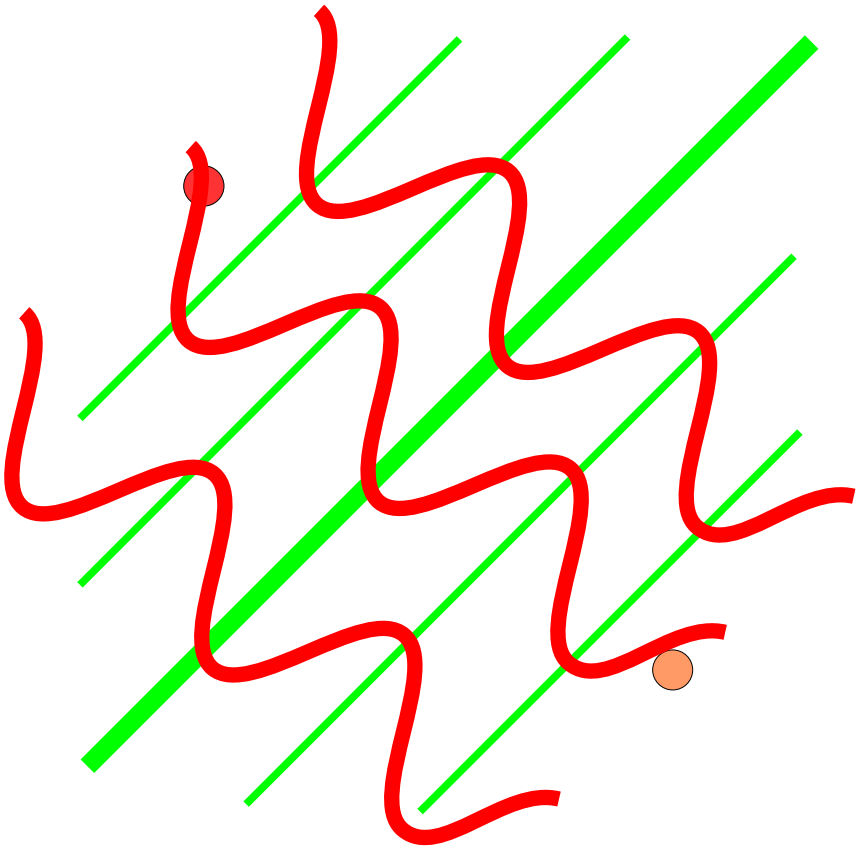

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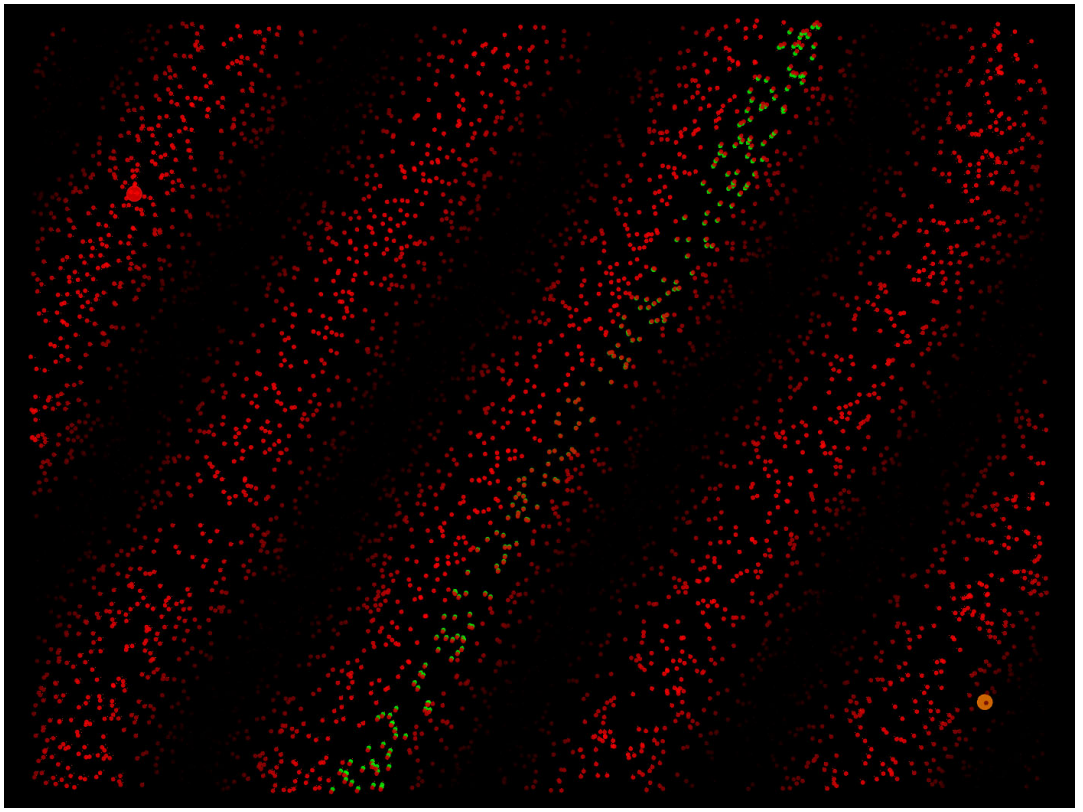

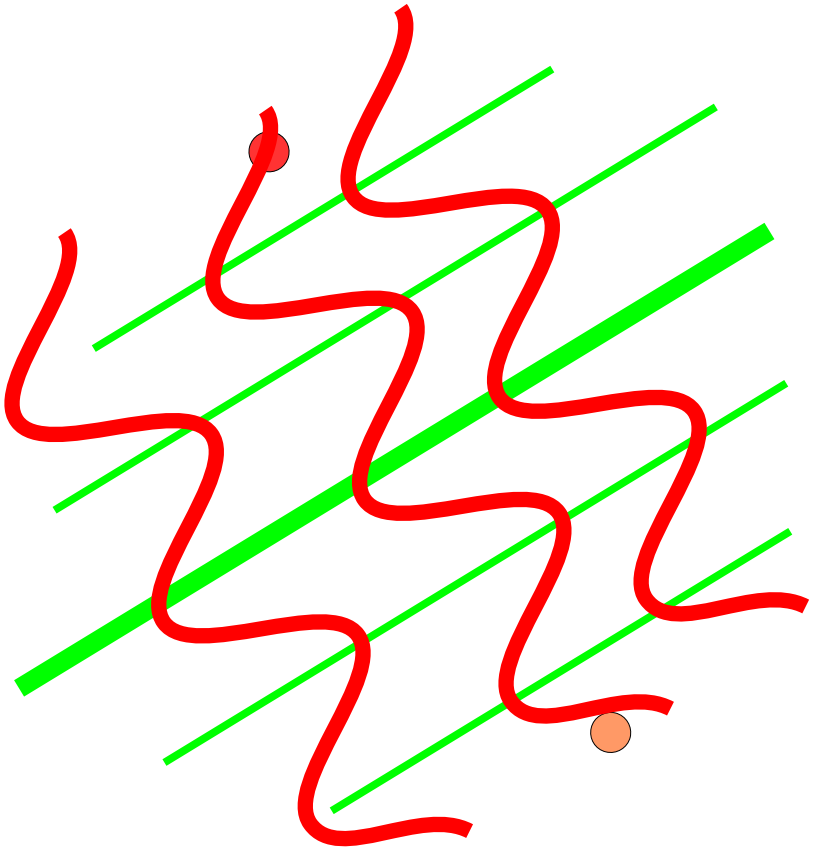

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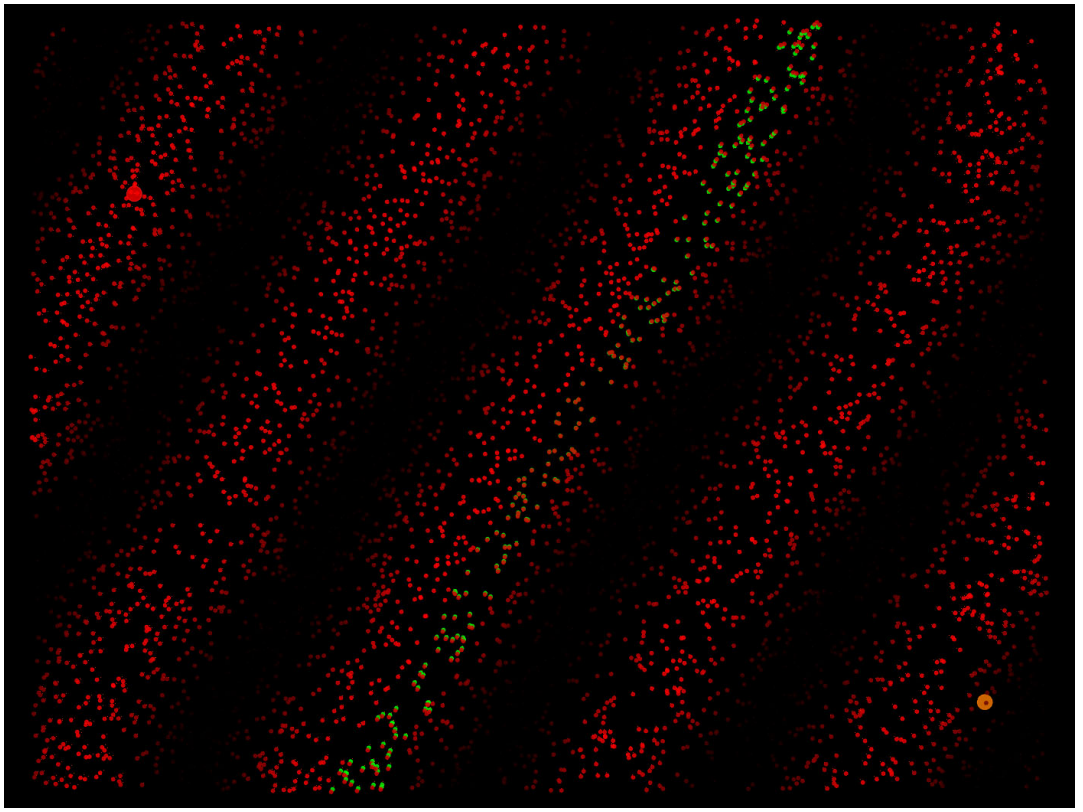

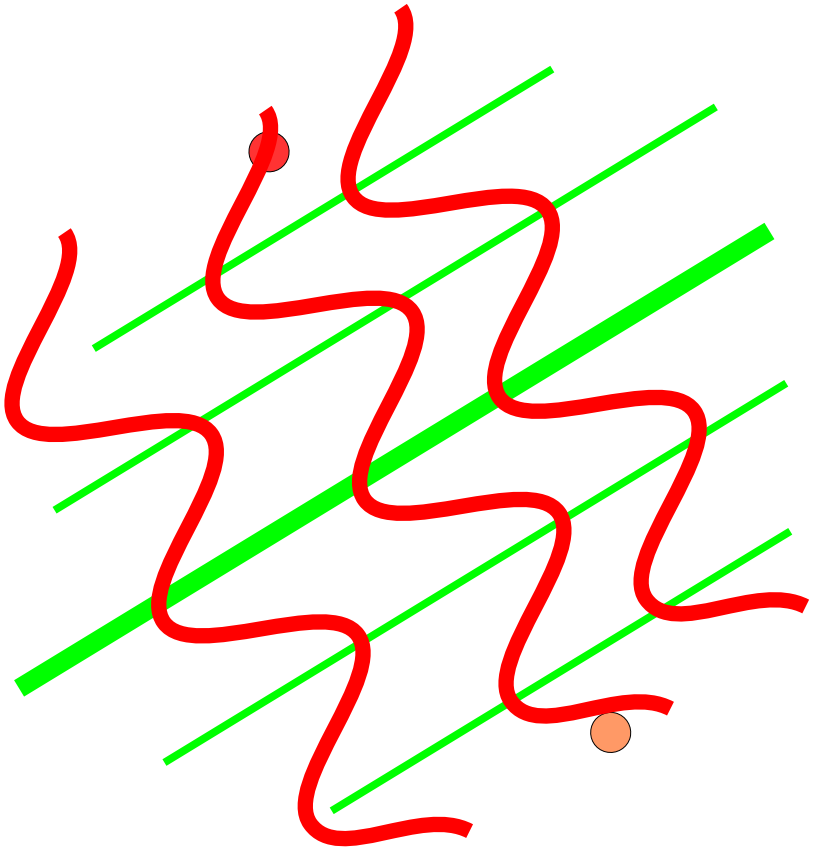

How can we write this program succinctly?

Many aspects of time...

- How behavior evolves
- Organization of computation
- Network delay and errors
- Platform differences

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- Organization of computation
- Network delay and errors
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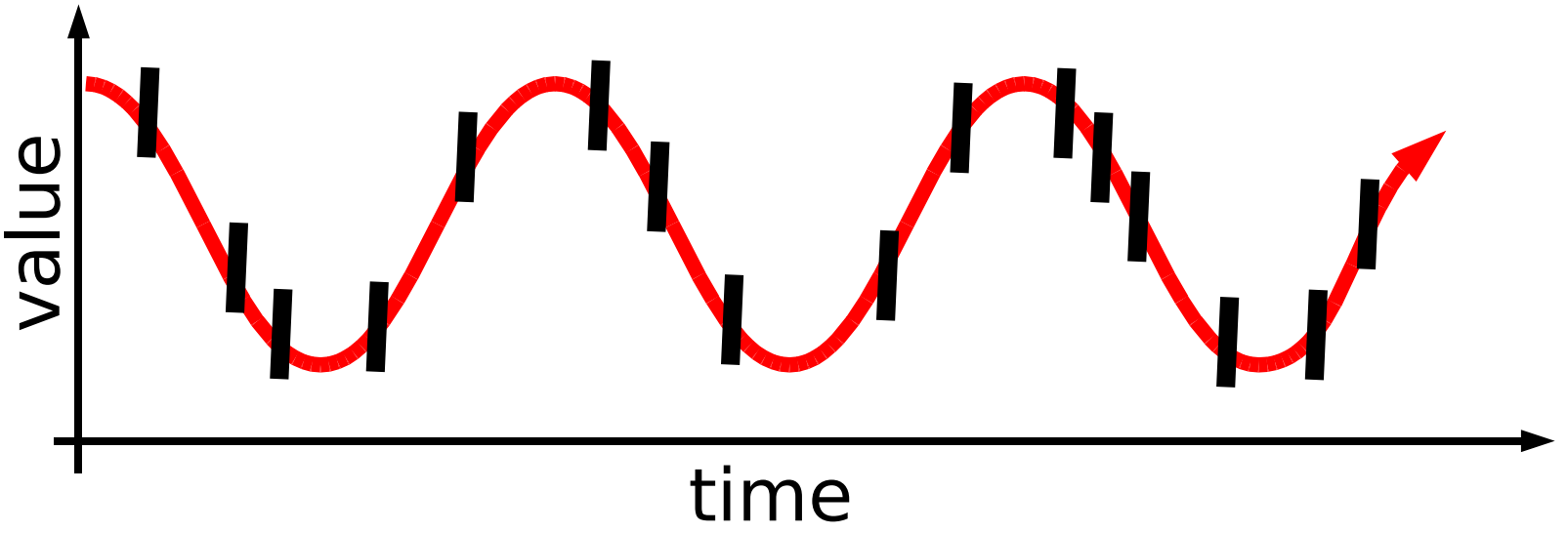
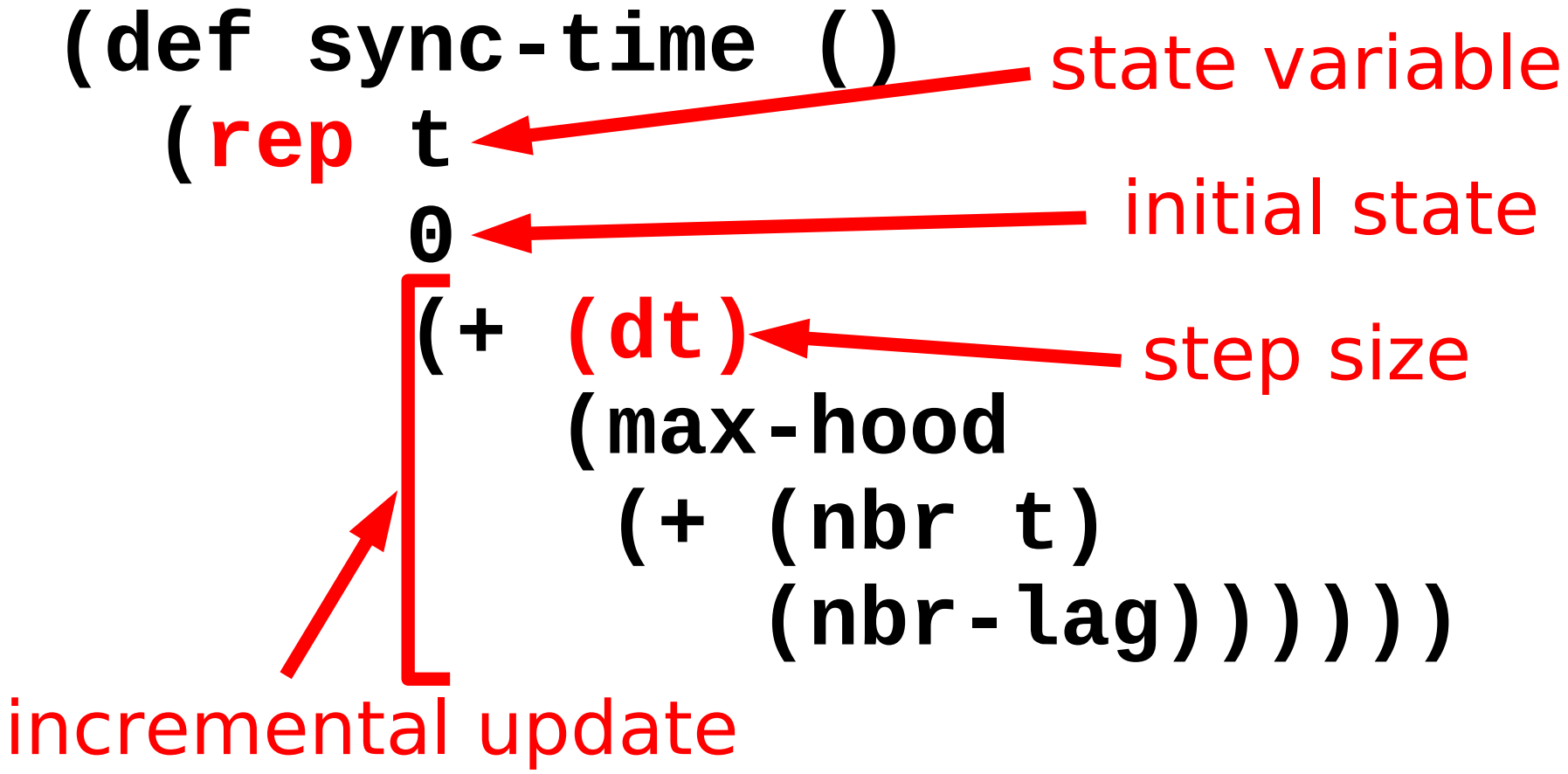
Can continuous time decouple them?

Configuration Path

- **s(t+dt) = f(s(t),dt)**
  - Function can leap from value to value (unlike derivative, CT-feedback approaches)
  - Steps can be irregular
  - Smaller steps = better approximation



Incremental Evolution



Path Combination

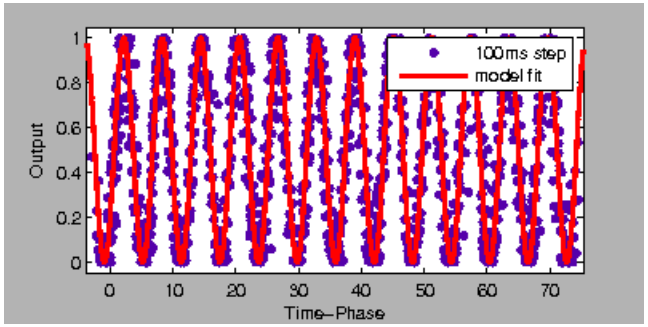
```
(sin (+ (/ (sync-time) t-period)
        (/ phase s-period)))))
```

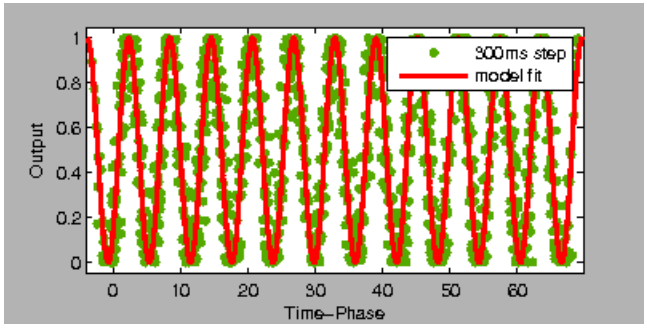
Plane Wave

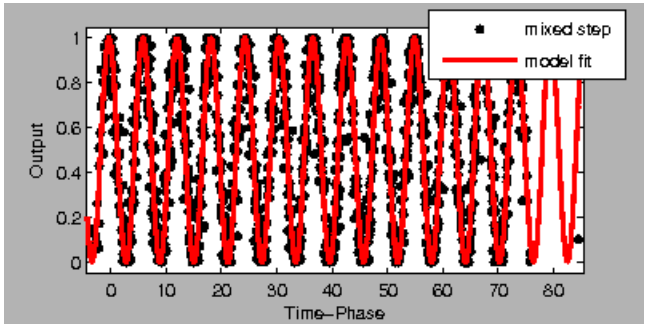
```
(def v 1)
(def diameter () 200)
(def sync-time ()
  (rep t 0 (max-hood (+ (nbr t) (nbr-lag)))))
(def distance-to (src)
  (rep d (inf) (mux src 0 (+ (min-hood (+ (nbr d) (nbr-range)))
                             (* v (dt))))))
(def bisector (a b)
  (min-freq (<= (abs (- (distance-to a) (distance-to b)))
                (+ v (radio-range)))
            (/ 1 v)))
(def dilate (src n) (<= (distance-to src) n))
(def bound (src lim boundary)
  (if boundary 0 (dilate src lim)))
(def abs-to-signed (sign val)
  (if (bound sign (diameter) (= val 0)) (neg val) val))
(def ct-plane-wave (src dst s-period t-period)
  (let* ((b (green (bisector src dst)))
         (phase (abs-to-signed dst (distance-to b))))
    (sin (+ (/ (sync-time) t-period) (/ phase s-period)))))
```

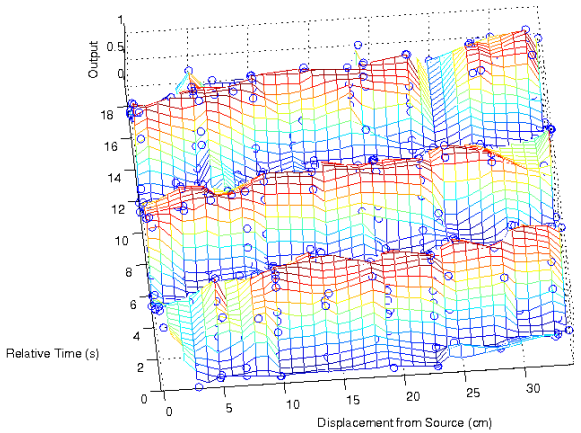
Invariance to Execution Rate

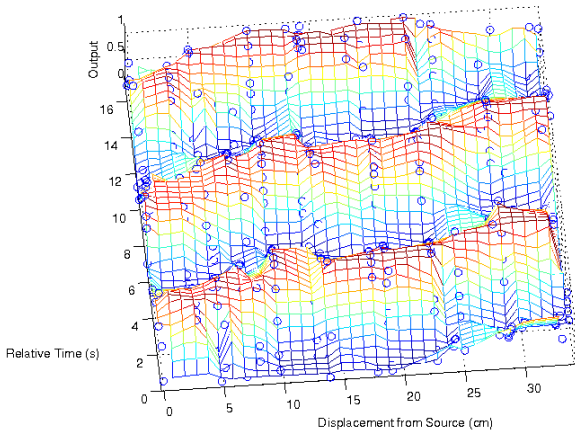
- Plane wave on 24 Mica2 Motes:

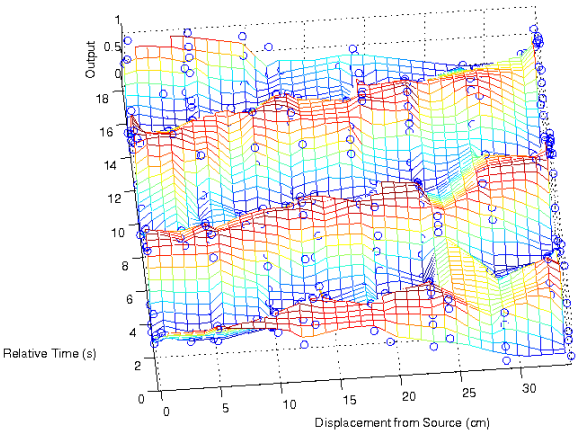












100ms step 300ms step mixed step

Contributions

- Configuration path semantics
- Application to spatial computing
- Experiment demonstrating invariance to execution rate

Open Questions

- Where else can config. paths be applied?
- What are useful ways to describe paths?
- How much precision information can be automatically deduced?