Continuous Time Programming

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Spatial Computing

Modular Robotics

Sensor Networks

Biological Computing

Robot Swarms

Programmability is the main challenge
Example: Directable Plane Wave
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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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- How behavior evolves
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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

\[
\text{(def sync-time () (rep t 0)} \\
\quad (\text{+ (dt)}} \\
\quad \text{(max-hood}} \\
\quad \quad (+ (nbr t) \\
\quad \quad (nbr-lag))))))
\]
Path Combination

\[
\sin \left( + \left( \frac{\text{sync-time}}{t\text{-period}} \right) \right) \left( \frac{\text{phase}}{s\text{-period}} \right)
\]
(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?