RIPPLE

Effective Programming for Large Distributed Ensembles

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http://www.qatar.cmu.edu/~iliano/projects/ripple/
Claytronics

- Programmable Matter
  - A cyber-physical material…
  - …with actuation and sensing…
  - …that can change shape under software control…
  - …and in reaction to external stimuli
- A massively distributed system embedded in the physical world with a constantly changing network

http://www.cs.cmu.edu/~claytronics
Claytronics Today

- A multidisciplinary project
  - Robotics, nanotechnology, programming, logic, …
  - 7 years
  - 22 researchers, 4 PhD students, 19 undergrads

- Hardware
  - Design for sensing, actuation, communication, power
  - Several platforms
    - Silicon catoms, …
    - Blinky blocks

- Software …
Programming Claytronics

- The real challenge
  - Massively distributed computation
    - Manage computation and communication
    - Keep nodes in a coherent state
    - Be fault tolerant, …
  - Program the ensemble as a single entity
    - Let the compiler handle the details
    - Use logic programming
      - LDP
      - Meld
    - Correct by design
    - Work well on small examples
    - But to scale to larger programs
      - we need a more flexible paradigm
Higher-Order Multiset Rewriting

- Simple local rules to describe global changes
  \[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]
- Used successfully
  - Computer security
    - Foundations
    - Specification
    - Verification
  - Biomolecular systems
- QNRF support
  - Specialize to Claytronics

- Native support for
  - Concurrency
  - Synchronization
  - Mobile code
  - Non-determinism
  - Non-monotonicity
  - Atomicity
- Foundations in
  - Logic
  - Transition systems
  - Process algebra

http://www.qatar.cmu.edu/~iliano/projects/msr/
Directions

- Develop MSR for Claytronics
  - Strongly-typed language
  - Declarative
  - Powerful
- Build an implementation
  - Blinky block simulator and hw
- Program complex behaviors
  - Large library of examples
  - Beyond what is practical today

Further impact

- Micro-economic analysis
- Biomolecular simulation
- Flow dynamics
- Crowd rendering
- Sensor networks
- Internet routers
- Autonomous vehicles
- Smart power grid
- Cryptographic protocols
- ...