

RIPPLE

Effective Programming for Large Distributed Ensembles

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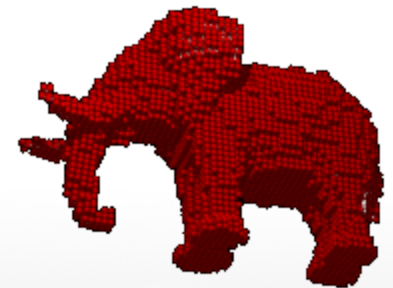
<http://www.qatar.cmu.edu/~iliano/projects/ripple/>

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





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 ...



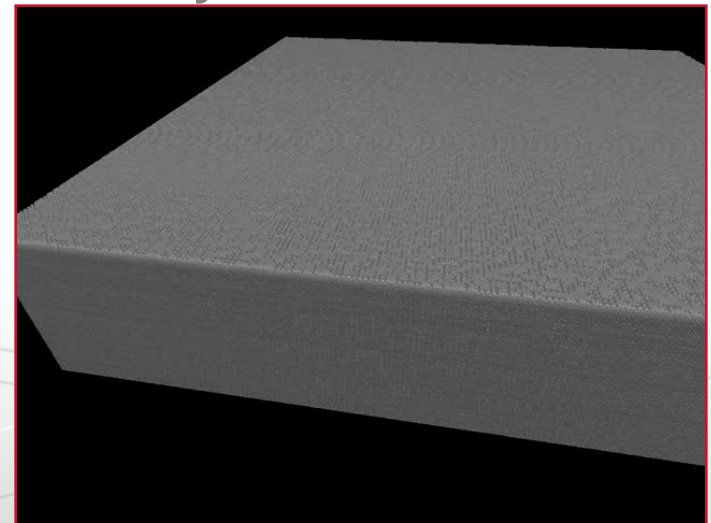
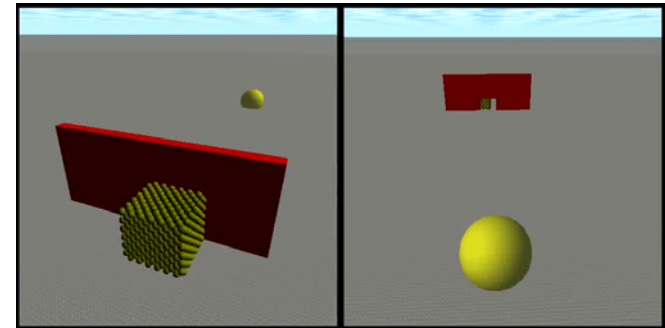
Programming Claytronics

➤ 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



- 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

Directions

➤ Develop MSR for Claytronics

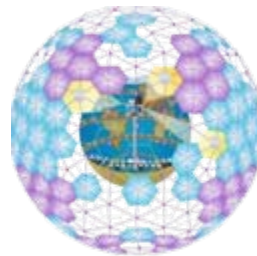
- Strongly-typed language
- Declarative
- Powerful

➤ 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
- ...

