Planar Catoms
Modular Robots using Magnetic Force Effectors

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Motivation

• Investigated as part of the Claytronics Project
• How can robotic modules be scaled down in size and up in quantity?

Ensemble Axiom

Each module contains the minimum functionality necessary to contribute to the ensemble as a whole.
Hardware Design Criteria

• Cylinders on a plane
  – Try 2D before 3D
• No moving parts
• Onboard control
  – Actuation
  – Planning
  – Communication
• As small as feasible
Ensemble Motion

(Actual Speed)
Planar Catom Modules

- Electromagnets
  - No moving “parts”
  - Relative motion only
- Two rings of 12 magnets, 24 total
  - Lattice flexibility
  - Intermediate configurations
- Torque
  - 12 mN-m at motion start
  - 200+ mN-m at motion end
- 100g 45mm diameter modules
Engineering Challenges

**Typical Stepper Motor**
- Concentric
- Simple
- Negligible
- Negligible
- Hard

**Stator/Rotor**
- Switching
- Friction
- Misalignment
- Motion Constraints

**Planar Catoms**
- Adjacent
- Complex
- Plane Surface
- Potentially Fatal
- Soft
Controlling Magnet Arrays

- Electromagnets require up to 30W in brief bursts
- Onboard power switching must fit 45mm diameter
- PWM control for torque/heat management
  - High power for actuation, low power for “locking”
  - Limiting factor is heat dissipation in coils
- Packing limitation allows simpler 1-of-4 muxing

Packed modules

12 magnet driver array, top / bottom
Sensing and Communications

• Key for coordinating all actuation
• IR emitter/detector array
  – localization
  – local communications
• 802.15.4 wireless serial
  – Basic module maintenance
  – Ties into DPRsim to drive hardware

…but what about the magnets?
Electromagnetism Revisited

• Not only actuation – a multipurpose effector
• Inductive Coupling Allows:
  – Local Communication
  – Neighbor Sensing
  – Power Transfer

Most of our ensemble contributions can be made with an array of identical features

Holds true for Electrostatics as well
Conclusions

• Modules with no inherent movement capability capable of ensemble motion

  Possible

• An array of identical magnetic effectors can contribute most ensemble functionality

  Scalable
Acknowledgements

Darpa
NSF
Intel Research Pittsburgh

Questions?