

Planar Catoms

Modular Robots using Magnetic Force Effectors

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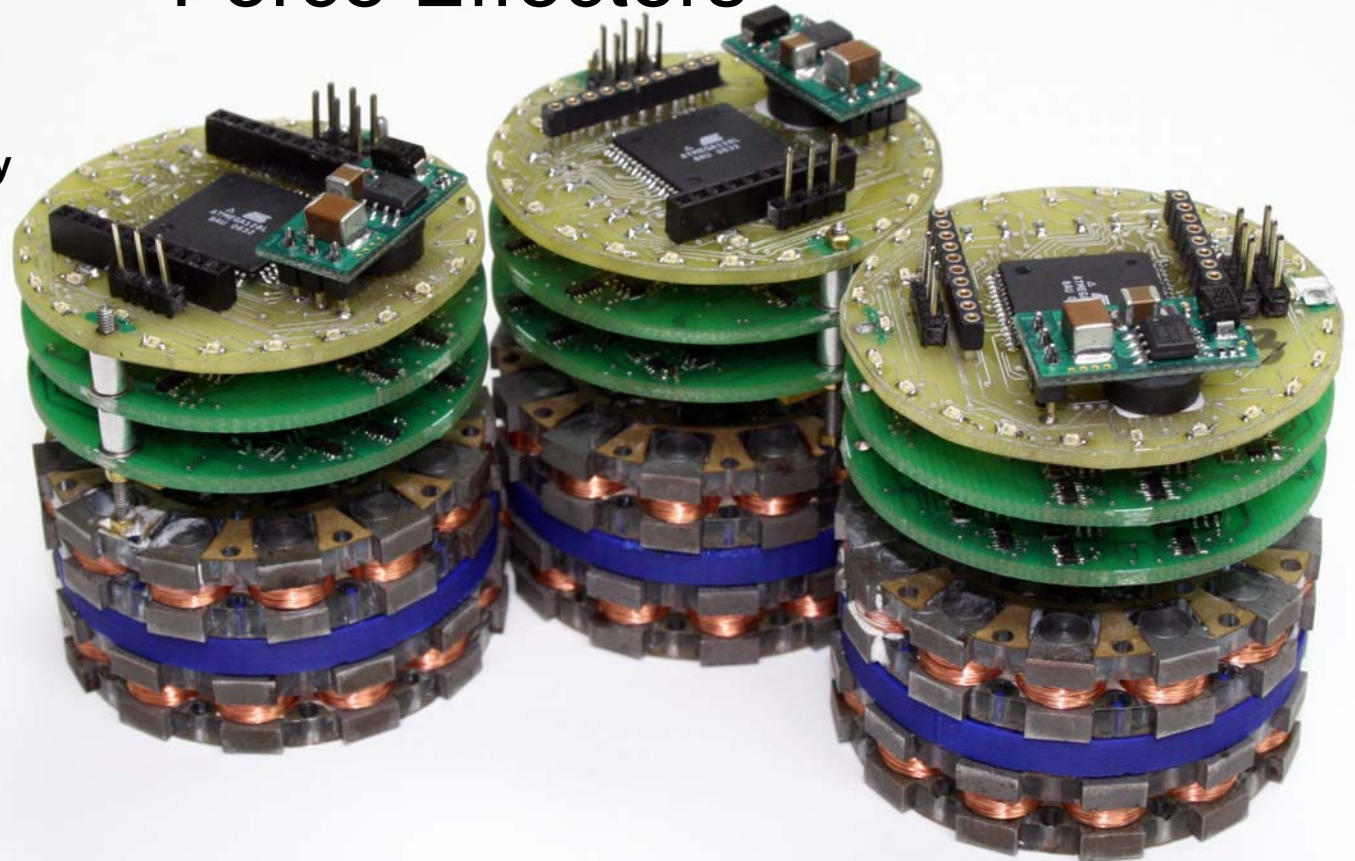
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Motivation

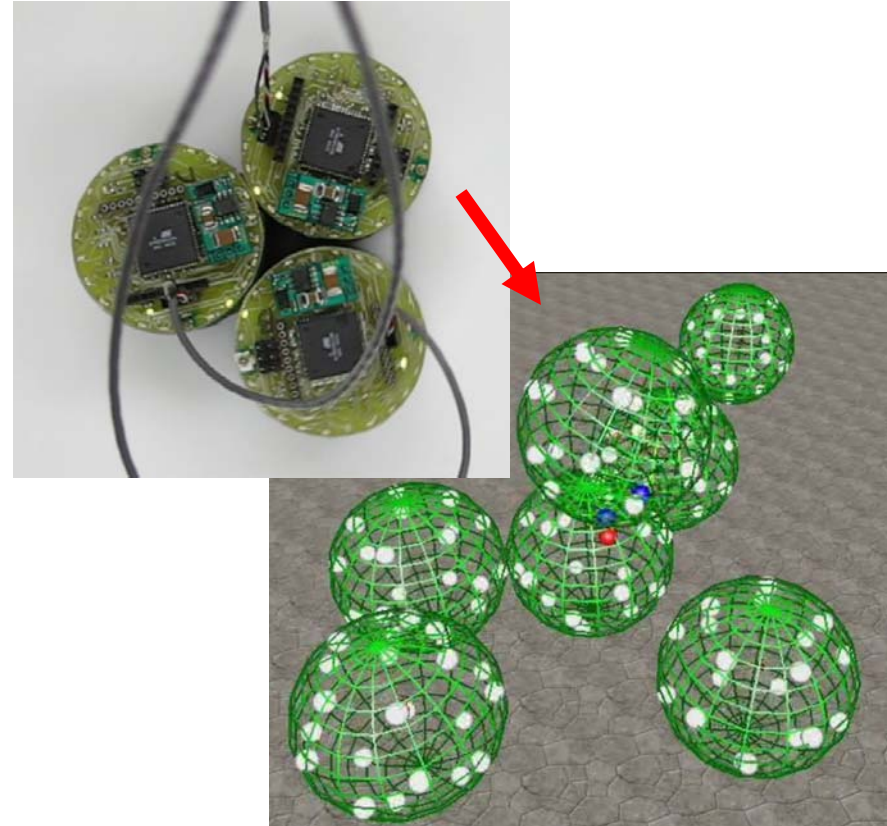
- Investigated as part of the Claytronics Project
- How can robotic modules be scaled down in size and up in quantity?

Ensemble Axiom

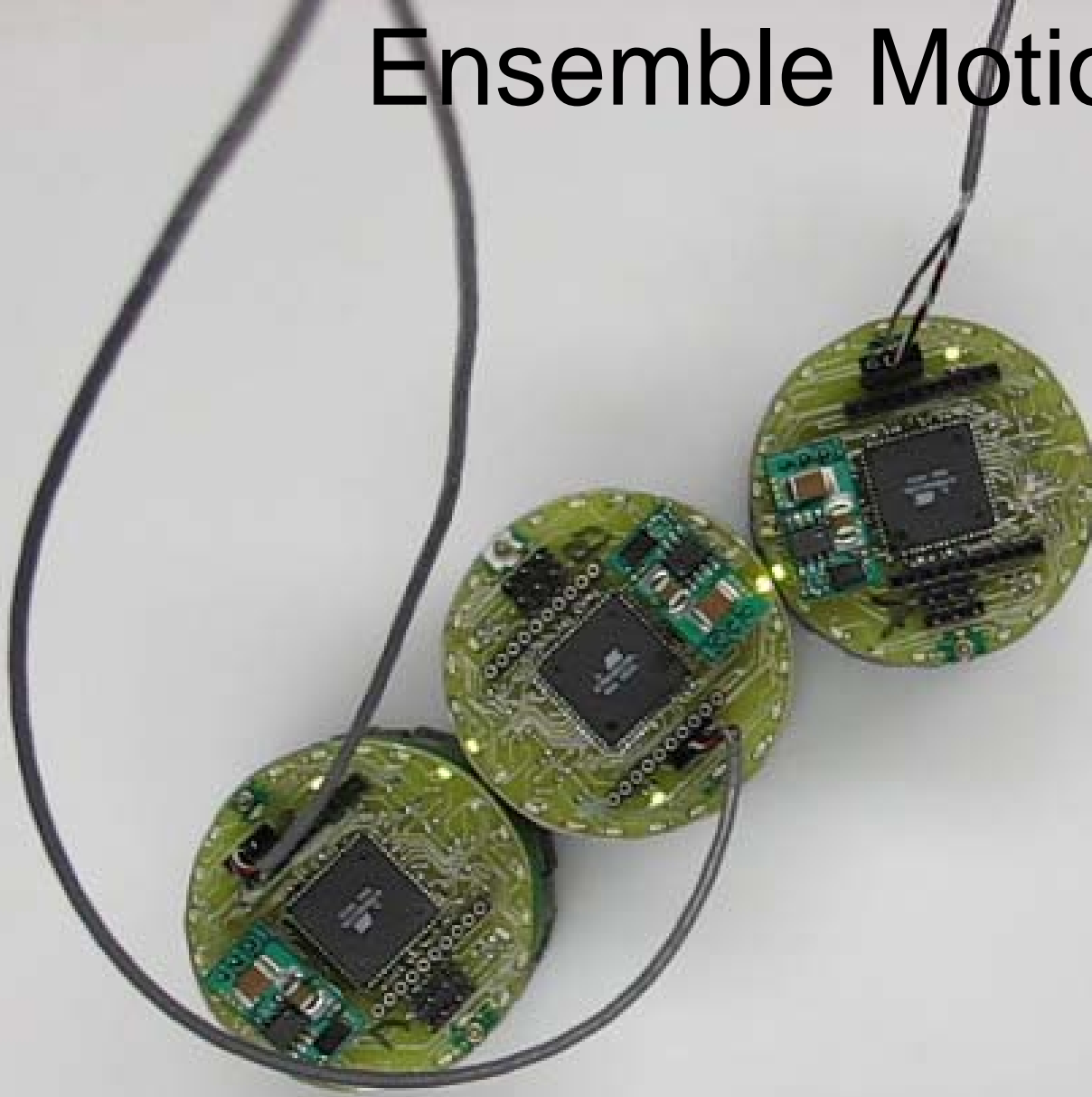
Each module contains the minimum functionality necessary to contribute to the ensemble as a whole.

Hardware Design Criteria

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

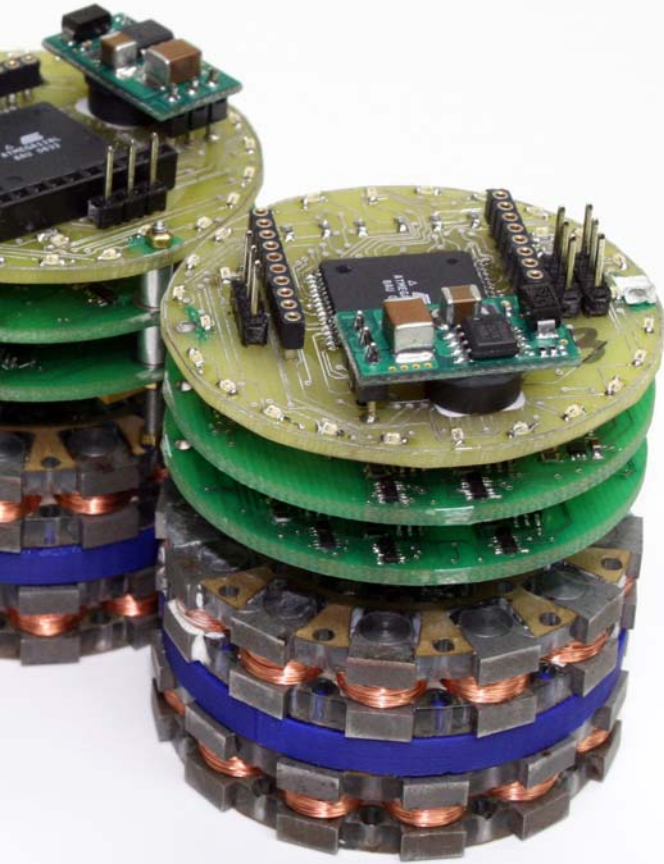


Ensemble Motion



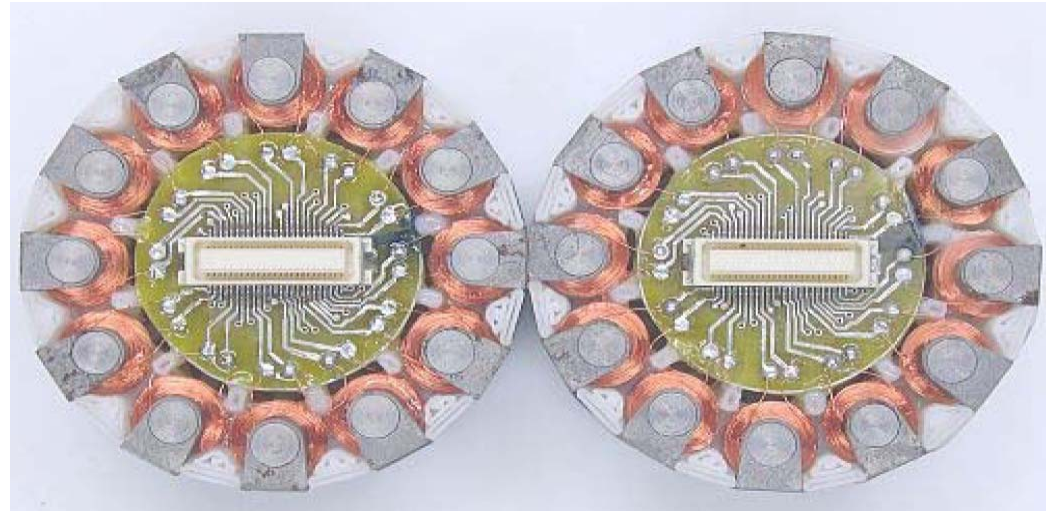
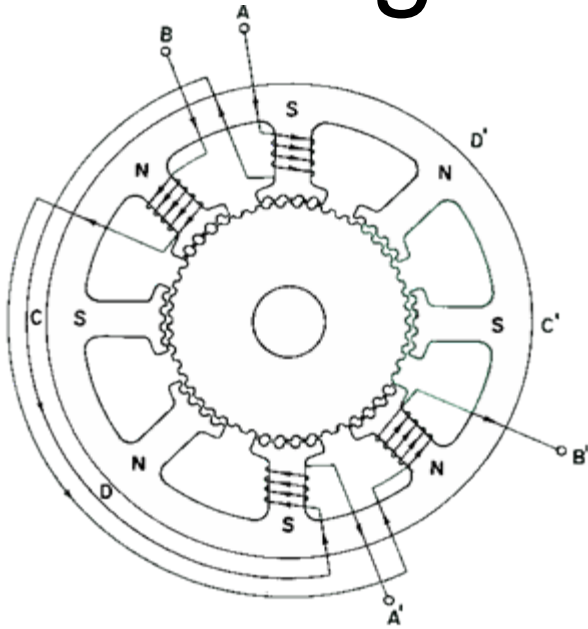
(Actual Speed)

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

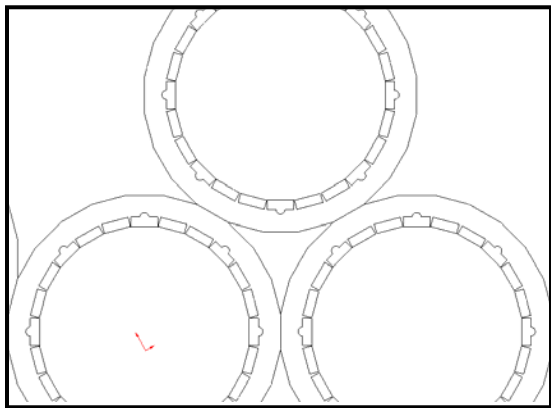
Stator/Rotor
Switching
Friction
Misalignment
Motion Constraints

Planar Catoms

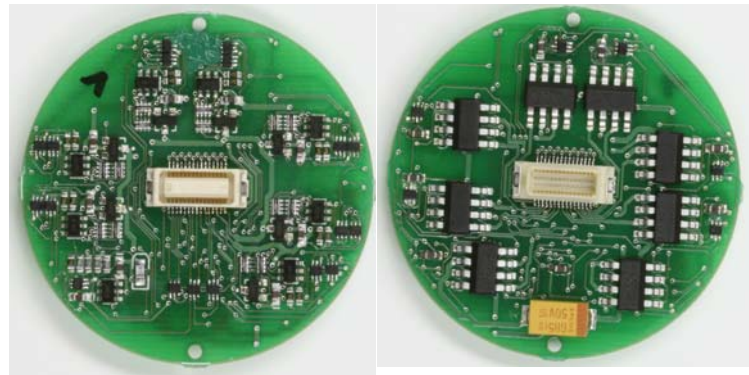
Adjacent
Complex
Plane Surface
Potentially Fatal
Soft

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



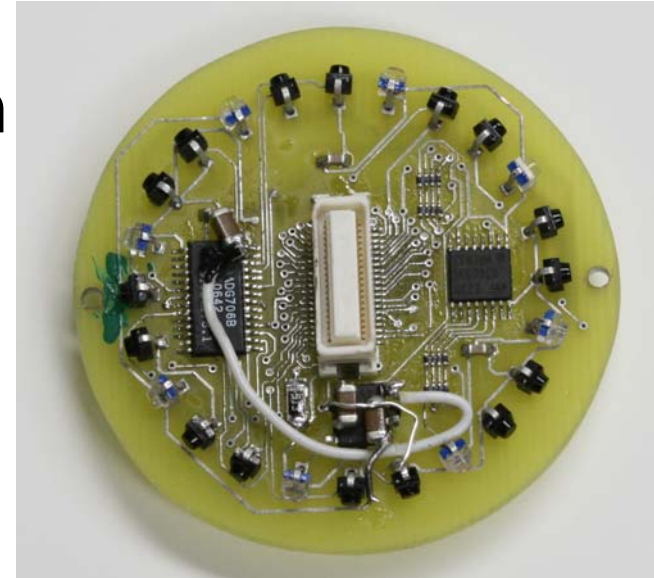
Packed modules



12 magnet driver array, top / bottom

Sensing and Communications

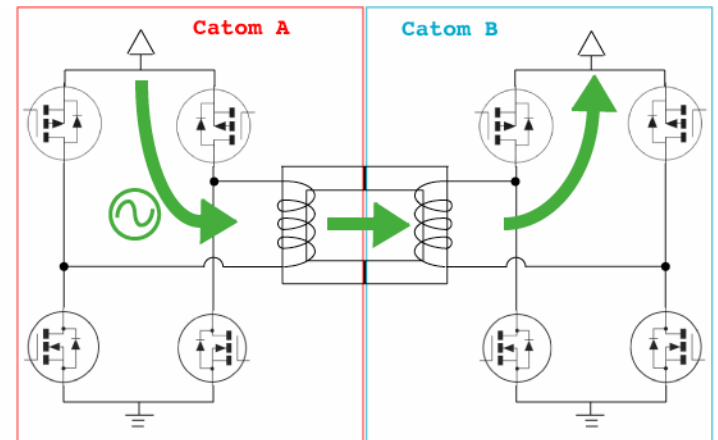
- Key for coordinating all actuation
- IR emitter/detector array
 - localization
 - local communications
- 802.15.4 wireless serial
 - Basic module maintenance
 - Ties into DPRsim to drive hardware



...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?