

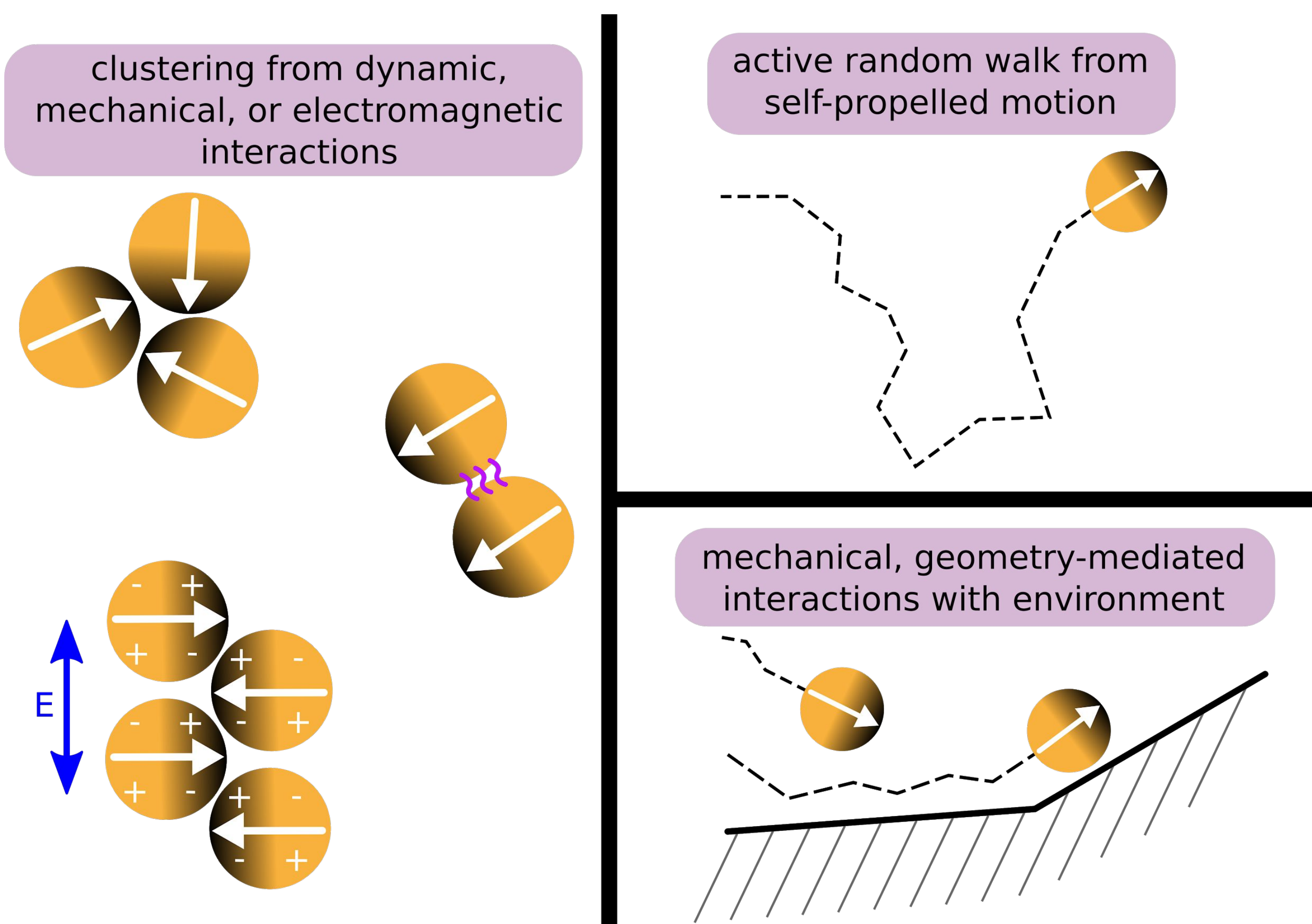
A Hardware and Software Testbed for Underactuated Self-Assembling Robots



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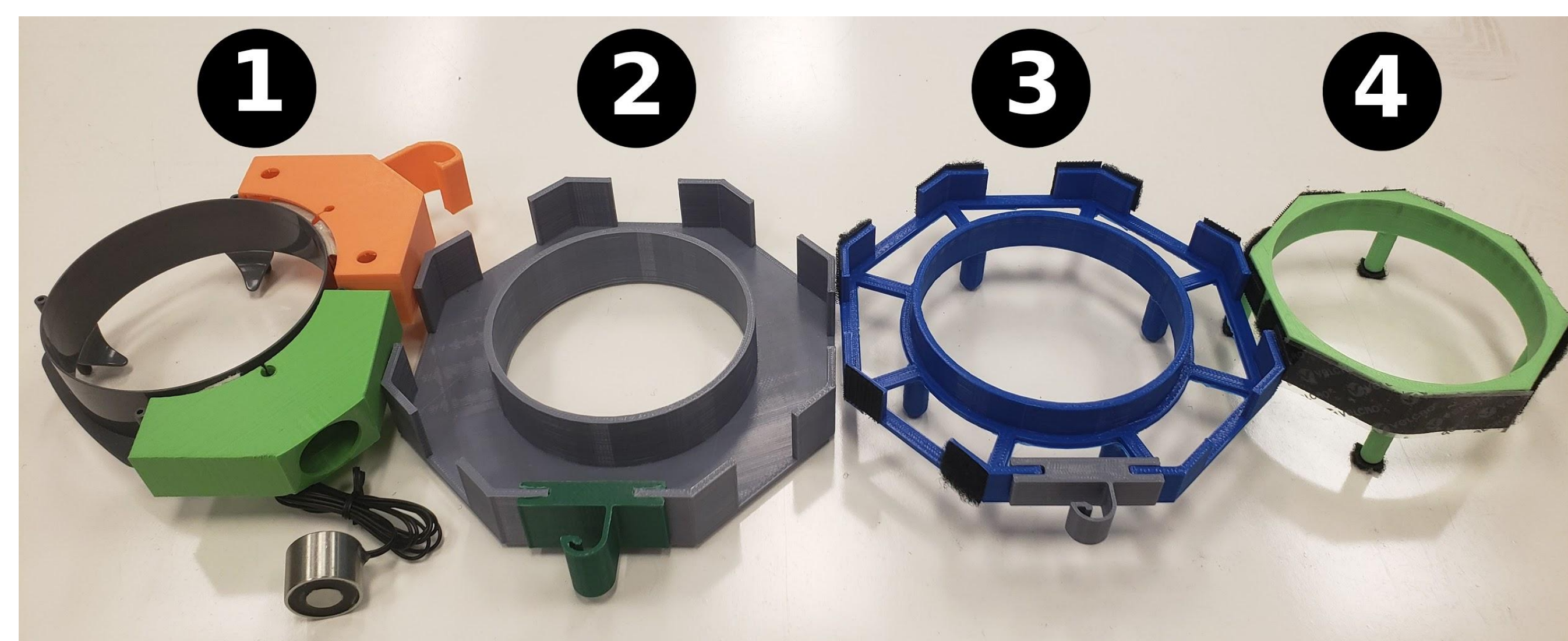
Bridging Agents and Robots



Micro-particles have interesting dynamical properties in complex and crowded environments [1]. As the technology develops, they could be augmented with small circuits and sensors [2].

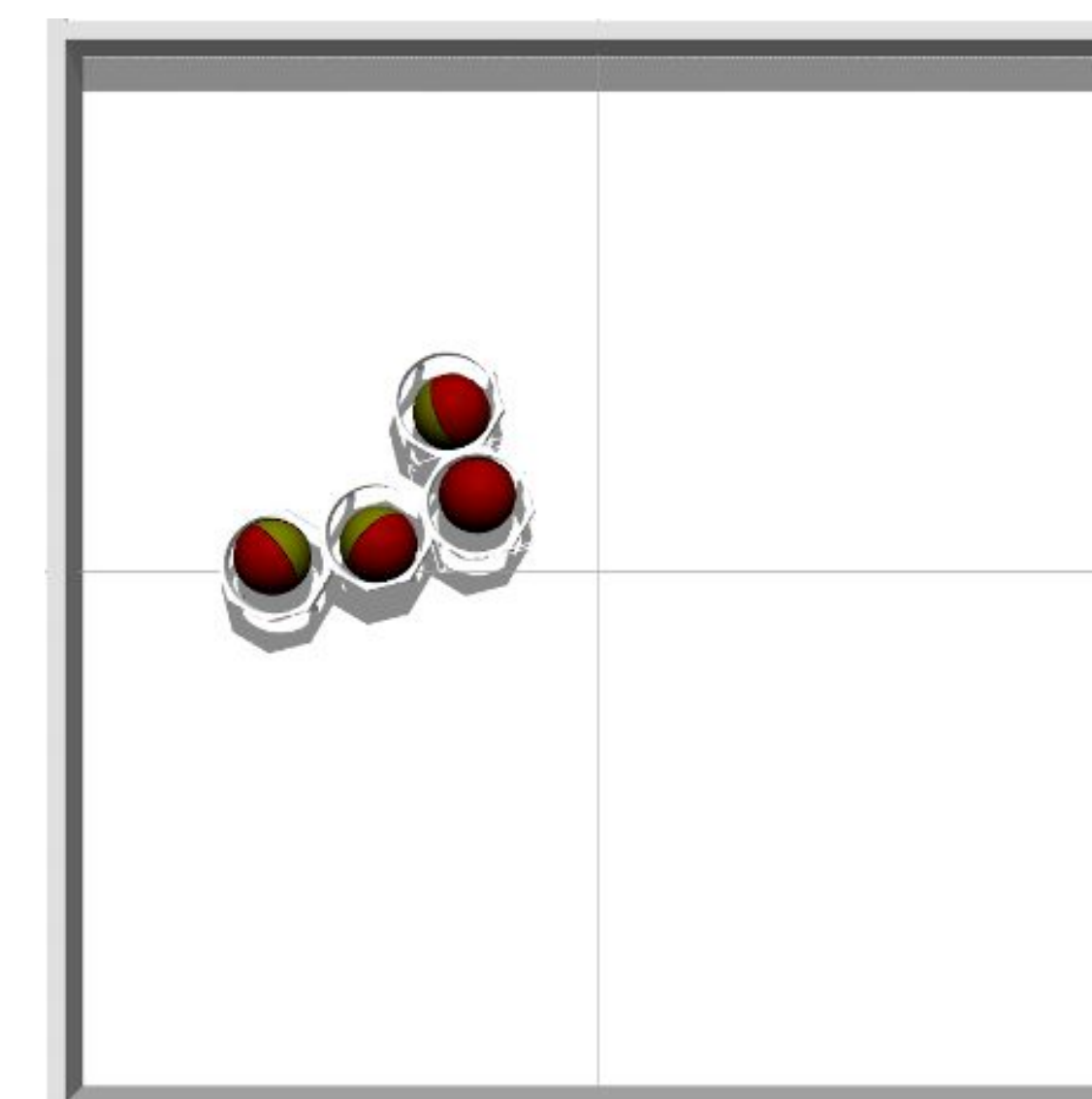
Testbed Features

- 3D-printed hubs around off-the-shelf toys
- **No direct control** over motion of agents
- Control through **shape** and **weight** of hub, **attachment/detachment** of hubs, **geometry** and **topography** of environment
- Agents can move objects via **collision**



Software Toolbox

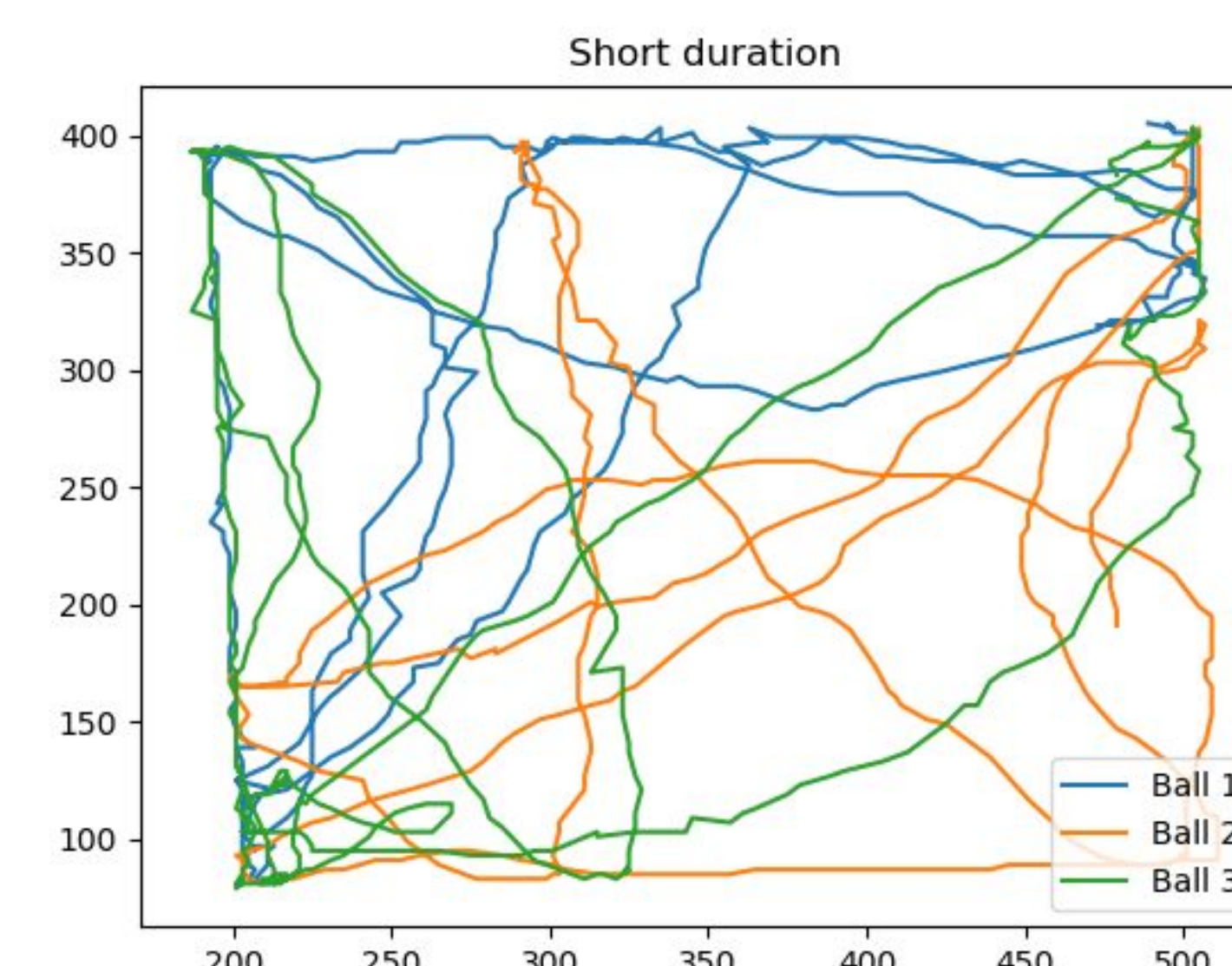
- High-fidelity Gazebo simulator with AWS launch scripts
- Low-fidelity Python particle simulator
- Python utilities for extracting and analyzing trajectories from video and simulation
 - Spatial distribution, velocity, scattering angles for agent-agent and agent-environment collisions



Testbed Characterization

Interesting observations from qualitative and quantitative trajectory analysis:

- Slight chirality from asymmetry of motor in ball
- Occasional synchronization of clusters
- Cluster dynamics dependent on geometry
- Clustering in corners and near obstacles from active brownian dynamics



Next Steps

Software:

- Automated cluster type recognition
- Orientation tracking
- Interactive low-fidelity simulator

Hardware:

- Controllable attaching and detaching with electro-permanent magnets
- Inter-agent communication

Modelling:

- Parameterized active brownian motion model
- Fitting to observed trajectories
- Role of geometry in collisions and scattering

Control:

- Relative populations of different cluster types from simple decentralized connection rules
- Spatial density from environment design and cluster geometry
- Collective object manipulation

Acknowledgements

[1] Bechinger, Clemens, et al. "Active particles in complex and crowded environments." *Reviews of Modern Physics* 88.4 (2016): 045006.

[2] Liu, Pingwei, et al. "Autoperforation of 2D materials for generating two-terminal memristive Janus particles." *Nature Materials* 17.11 (2018): 1005.

NSF grant 10-35345

Leung Student Venture Fund Award