Simulating Escape Panic Using Active Brownian Particles

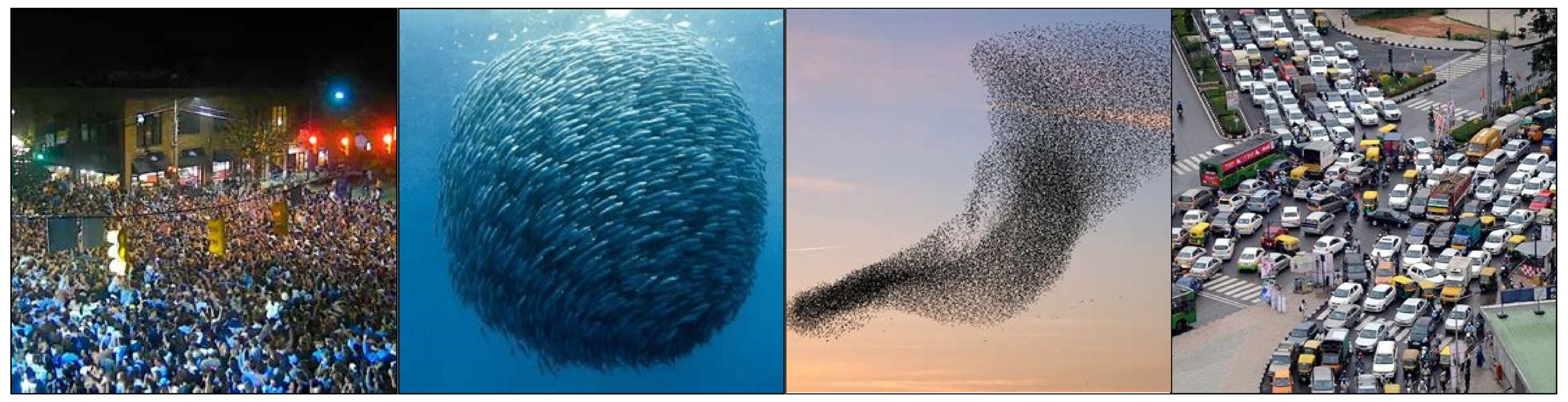
Klotsa Lab
Let's P.RO.GR.A.M

Benjamin Sykes, Department of Physics and Astronomy
Advisor: Dr. Daphne Klotsa, Department of Applied Physical Sciences

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

What is Active Matter?

While watching the aerial view of a music festival, you lose sight of the individuals as the swirling crowds began to form a seemingly "living" mass. Each individual is choosing to jump, dance, or mosh, but as you watch, you only observe the patterns that emerge as mosh pits form and the crowd begins to sway to the rhythm. Greater than the sum of its parts, this is an example of active matter.



images are in order right to left [5], [6], [7], [3]

Active matter is material made up of self-propelling individuals and is a way to understand crowd dynamics by looking at an entire group rather than attempting to understand it at the individual level*[8]*. This heightened understanding becomes invaluable as these crowds become deadly.

Danger in the Crowds

- In any crowd, the introduction of a perceived threat such as fire, natural disasters, or active shooters can trigger **Escape panic***[4]*.
- The rush to escape causes chaos and potential danger.
- We are attempting to better understand its underlying mechanisms using active Brownian particles.

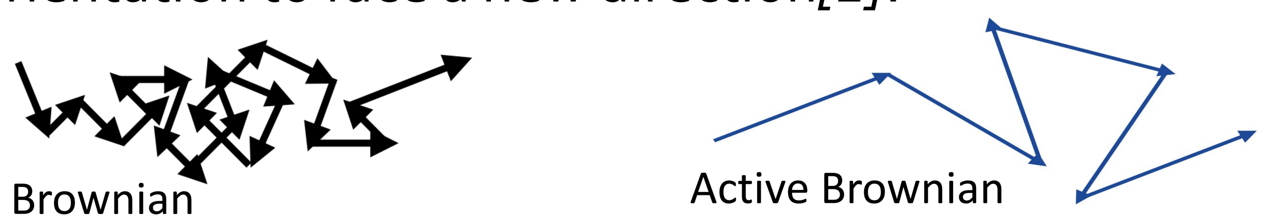
Image from [1]

What is an Active Brownian Particle(ABP)?

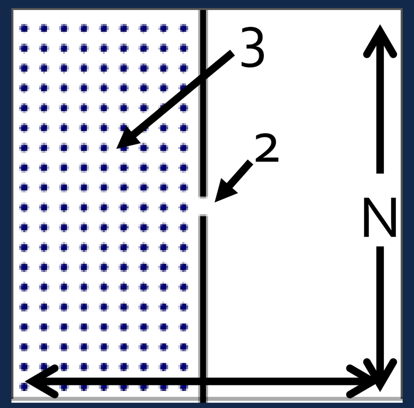
Brownian dynamics is a way to describe the motion of molecules in a fluid that experience no acceleration and can be summarized by the equation*[2]*:

$$\sum F = F_{noise} + F_{collision} + F_{drag} + F_{Active} = 0$$

This last term adds activity to these particles, allowing us to observe unique group dynamics and "run-and-tumble" motion, where a particle travels a certain distance and then changes its orientation to face a new direction*[2]*.



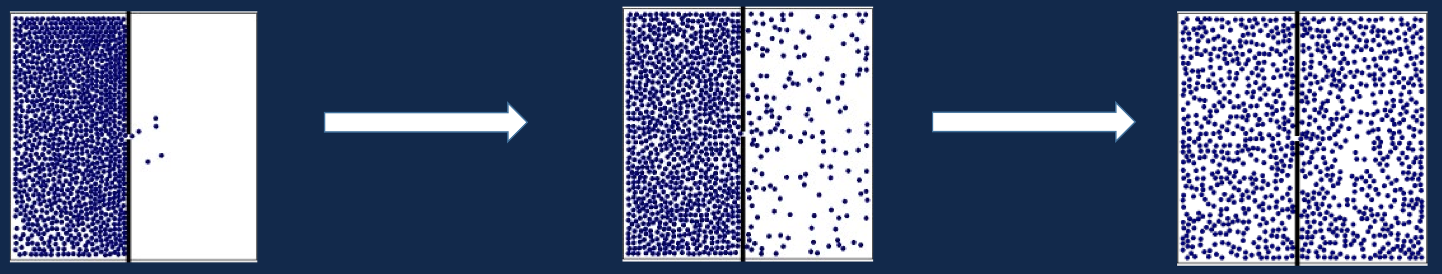
Set-Up

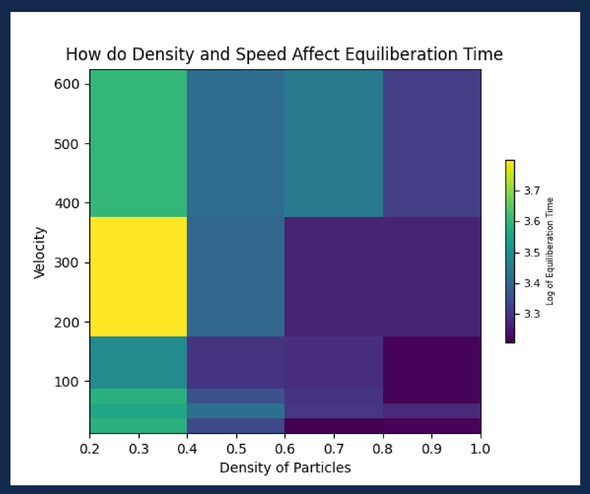


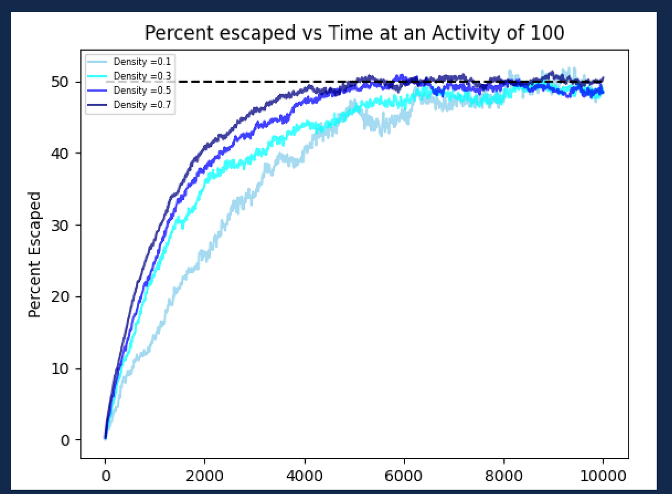
1. Start with NxN box
2. Place wall in the middle with an exit placed in the very center
3. Place a number of particles in the box on the left based on density.

Results: Active Brownian Model

- While not an accurate escape panic model, we used ABPs to measure how the speed and number of particles effect their movement.



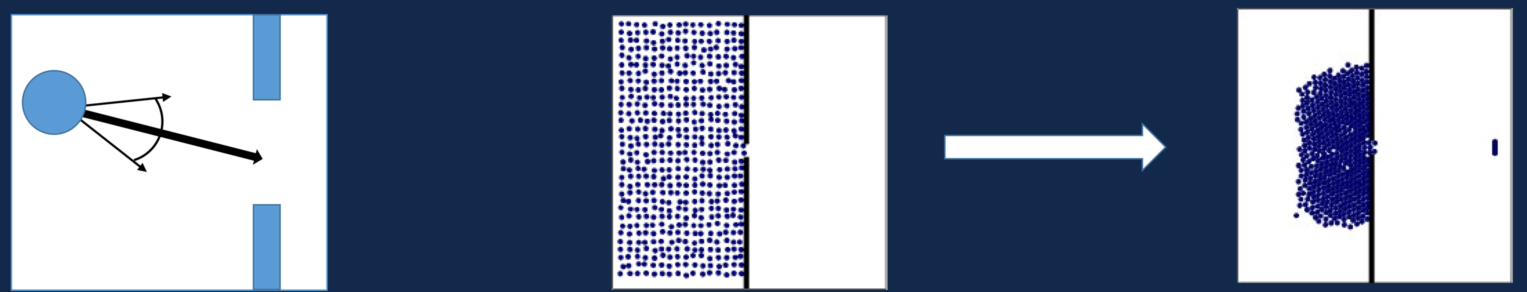


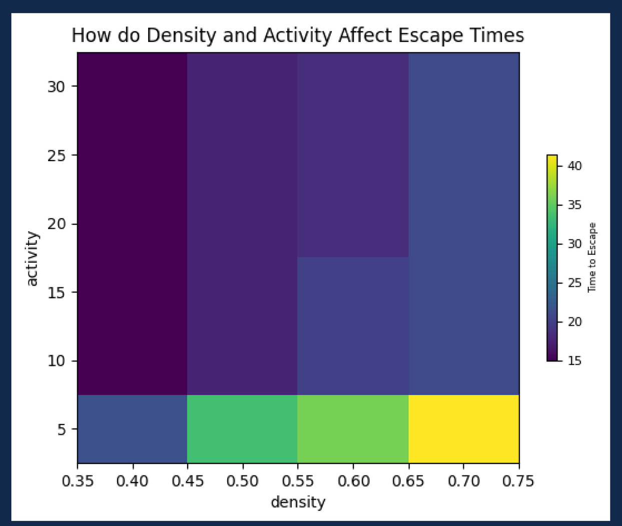


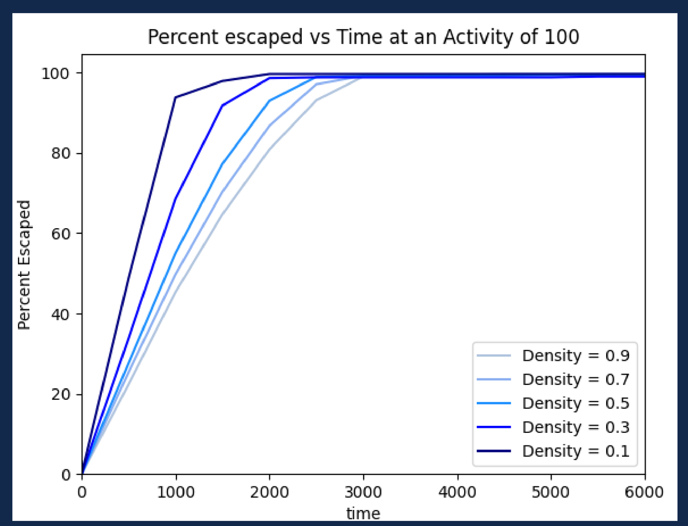
- From our simulations, equilibration time seems to decrease with particle velocity, but increase with density.

Results: Bias towards Exit

- In order to simulate escape panic, a "bias" towards the door is added by limiting the angle of the particle to face towards the door with a set amount of noise.

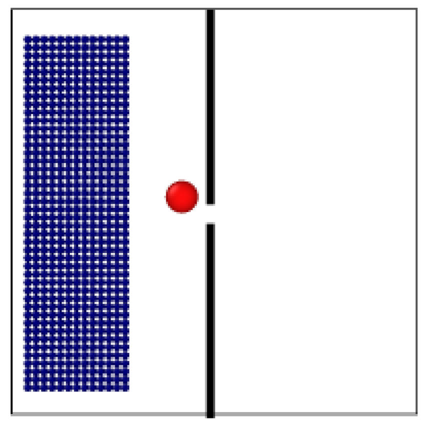


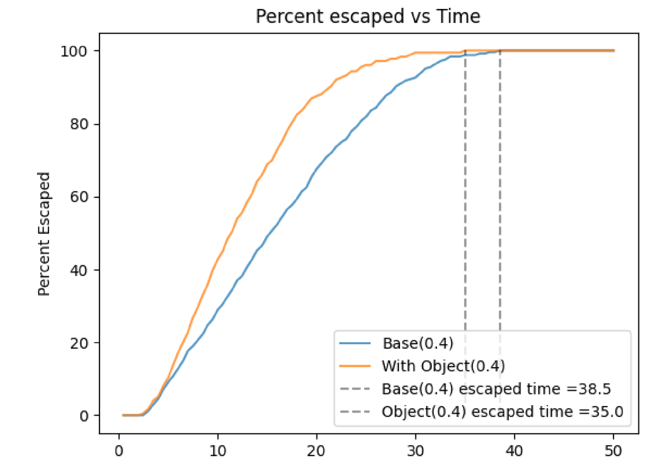


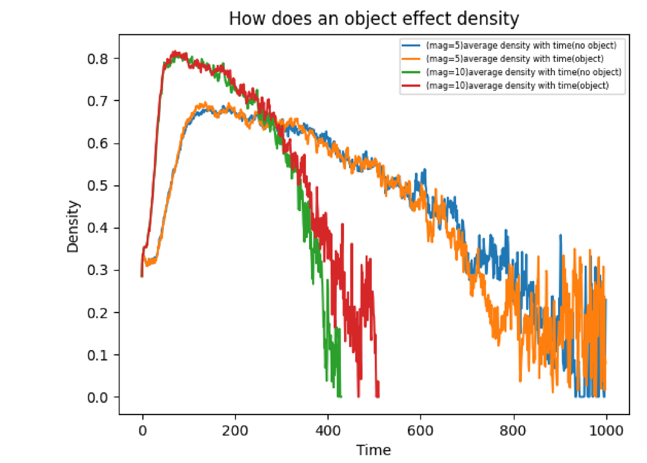


- This shows that time to escape increases as density increases, and decreases as activity increases.

Results: Adding Object in Front of Exit







- In order to compare this model to previous models, an object was placed asymmetrically in front of the exit.
- We tested time to escape and average local density.
- Overall, the use of an object does seem to decrease the time to escape which is consistent with results from previous models and real world data[9].
- Despite decreasing the time to escape, the object does not seem to effect the local density of the escaping particles.

Conclusions and Future Directions

- Overall, our APB model would be a useful tool in modelling crowd dynamics.
- Our model does agree with previous models as well as the limited real world data
- Further tests are required to determine how closely this model matches reality.
- In future simulations, the density and activity of the simulations should be pushed further to see what happens as the model is put under further stress.
- The overall lay out and structure of the simulations could also be adjusted. The shape of the box could be restructured, the number and position of the exits could be adjusted, and the placement of the particles moved.
- I am also working with fellow lab member Amber van der Pol in using this model to simulate the Franklin Street Rush.

References

[1]Perkowitz, Sidney. "Can a Physics of Panic Explain the Motions of the Crowd?: Aeon Ideas." *Aeon*, Aeon Magazine, 8 Apr. 2021, https://aeon.co/ideas/can-a-physics-of-panic-explain-the-motions-of-the-crowd.
[2]"Active Brownian Particle." *Wikipedia*, Wikimedia Foundation, 8 Feb. 2023, https://en.wikipedia.org/wiki/Active_Brownian_particle.
[3]Bengaluru Becomes World's Most Traffic Congested City in the World, 71 % Extra Travel Time Stuck in Traffic." *GSTV*, 30 Jan. 2020, https://english.gstv.in/bengaluru-becomes-worlds-most-traffic-congested-city-in-the-world-71-extra-travel-time-stuck-in-traffic/.
[4]Helbing, Dirk, et al. "Simulating Dynamical Features of Escape Panic." *Nature News*, Nature Publishing Group, https://www.nature.com/articles/35035023.
[5]McMasters, Jared, et al. "Rushing Franklin Street: A History of Celebration." *UNC Media Hub*, 16 Mar. 2021, https://mediahub.unc.edu/rushing-franklin-street-a-history-of-celebration/.
[6]"New Study Sheds Light on This Fishy Behavior." *HuffPost*, HuffPost, 18 Sept. 2013, https://www.huffpost.com/entry/fish-schools-genes_n_3947303.
[7]Team, How It Works. "Why Do Birds Flock Together?" *How It Works*, 9 July 2019, https://www.howitworksdaily.com/why-do-birds-flock-together/.
[8]"What Is Active Matter?" *Stephen j. Decamp*, https://www.stephenjdecamp.com/what-is-active-matter.html.
[9]Zhao, Y., et al. "A Review on the Performance of an Obstacle near an Exit on Pedestrian Crowd Evacuation." *Safety Science*, Elsevier, 24 Nov. 2018, https://www.sciencedirect.com/science/article/abs/pii/S0925753518300675.