Mixing of Fluids

Derek Hammar
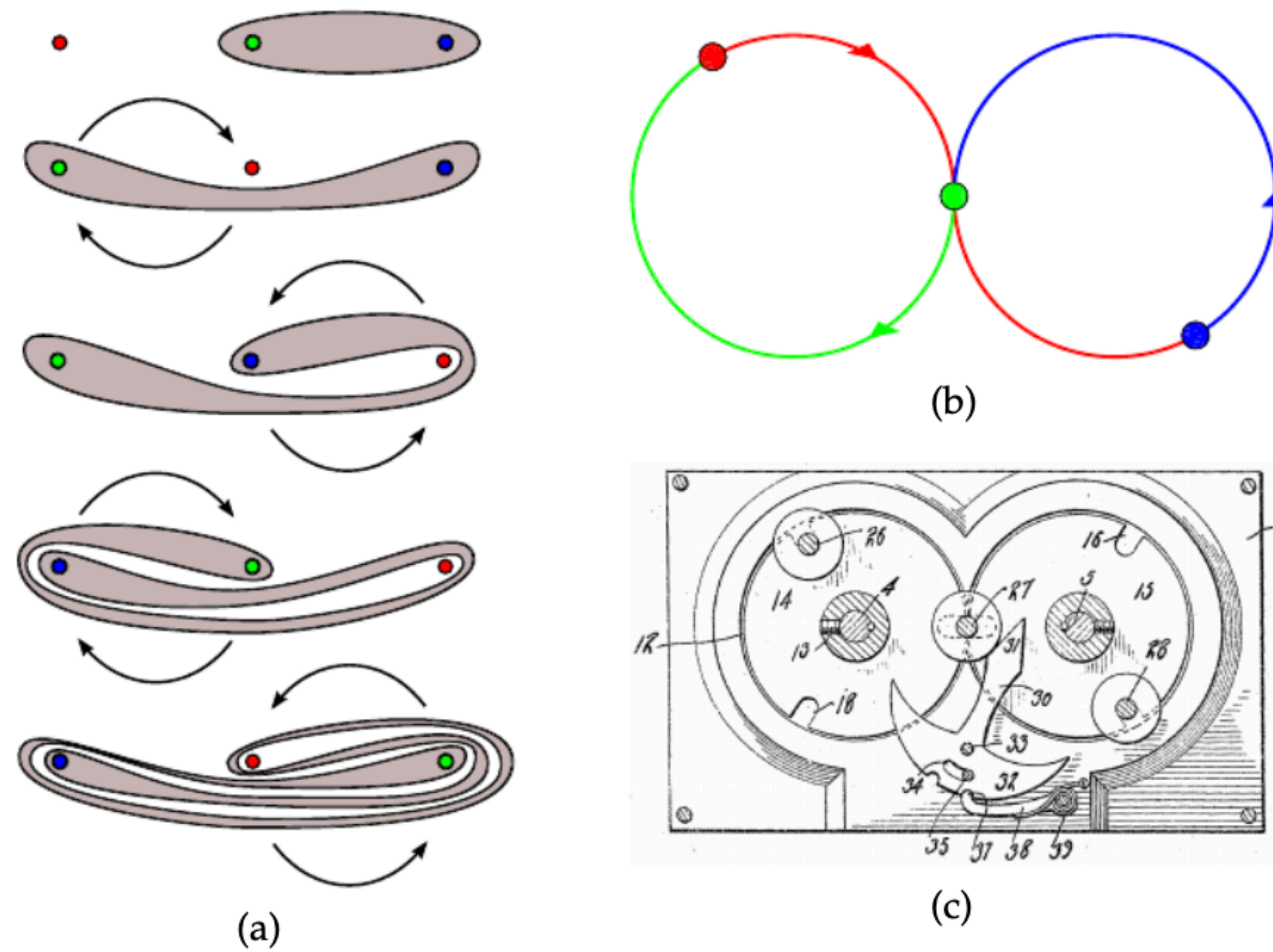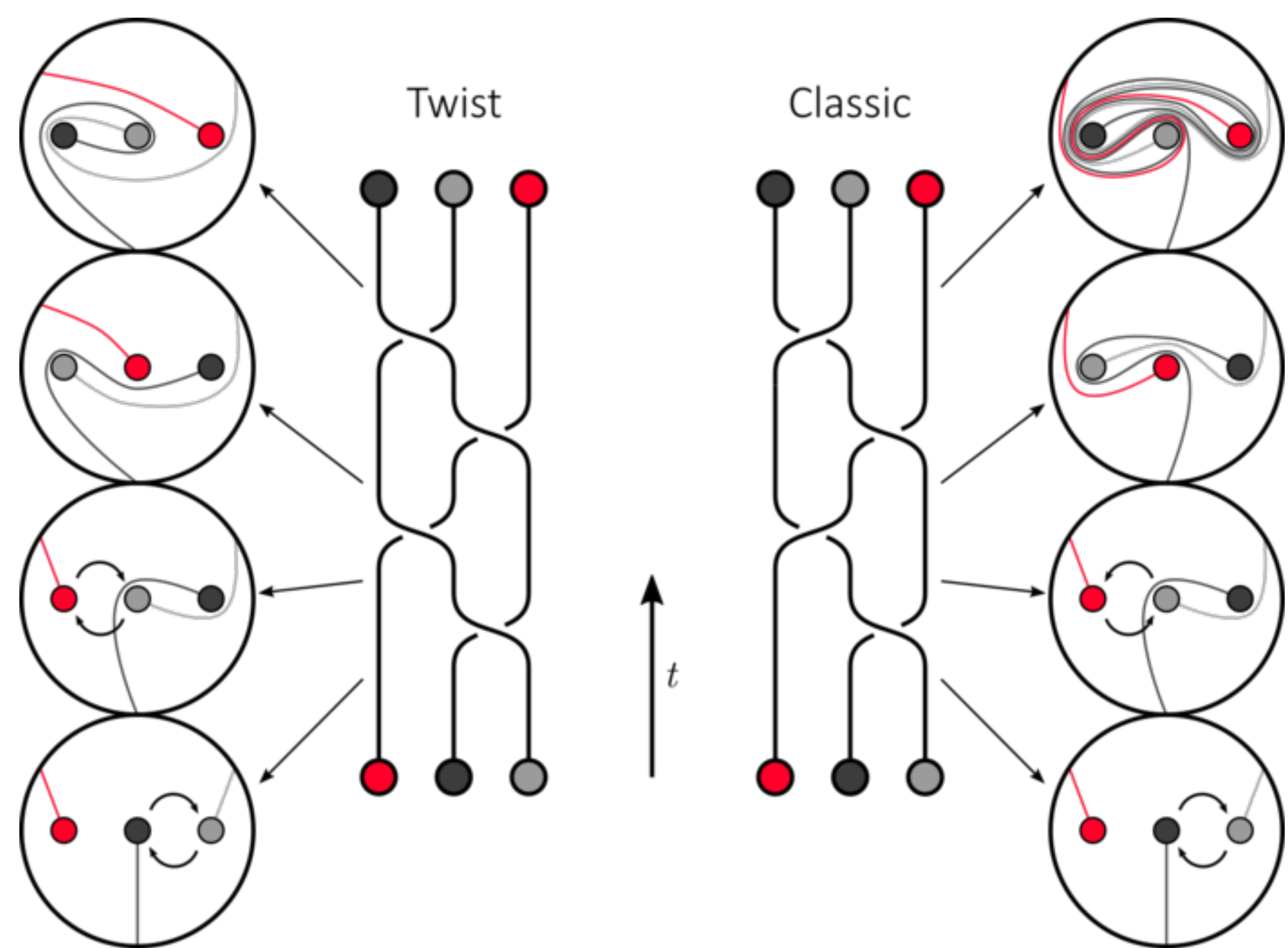
Jason Ngo

(a)

(b)

(c)

FIGURE 3. (a) The action of a 3-rod taffy puller. The first and second rods are interchanged clockwise, then the second and third rods are interchanged counterclockwise. (b) Each of the three rods moves in a Figure-8. (c) Taffy puller from the patent of Nitz (1918), where rods alternate between the two wheels.
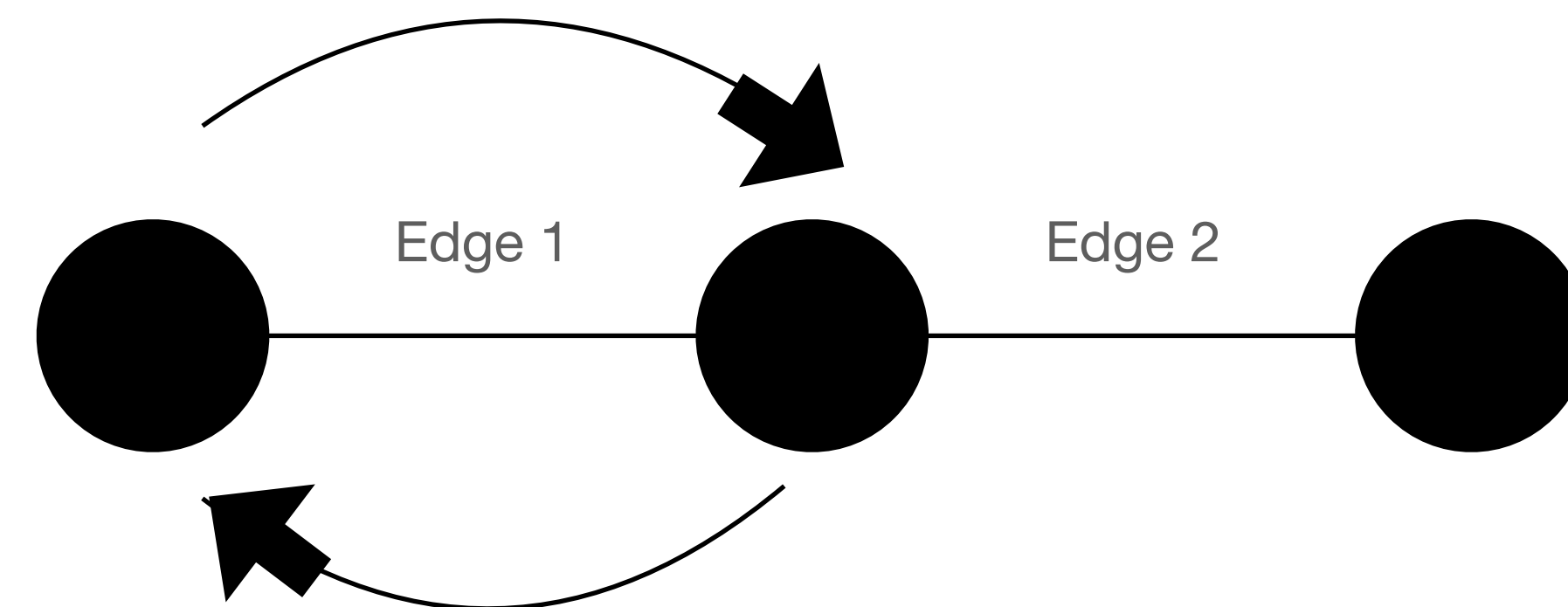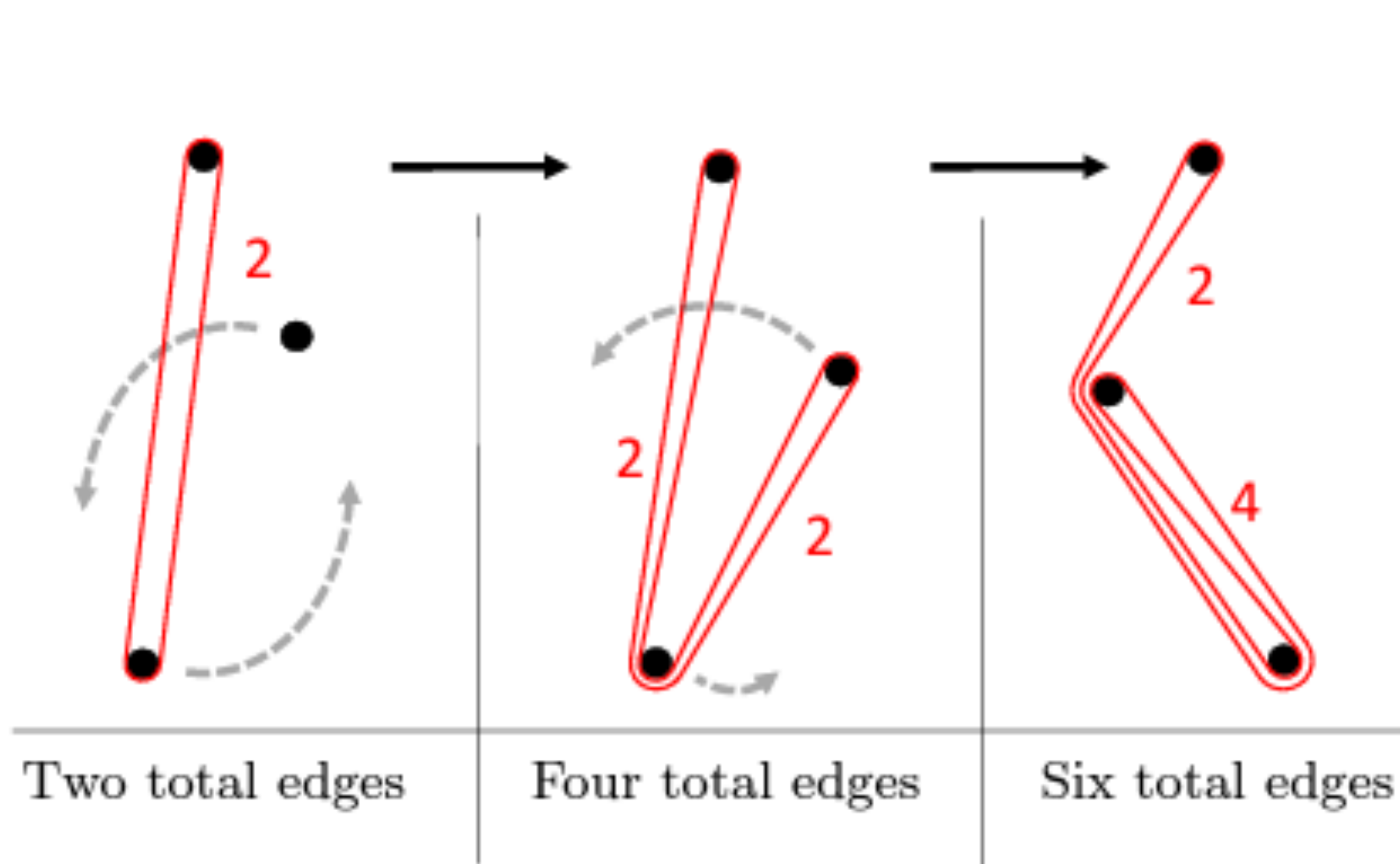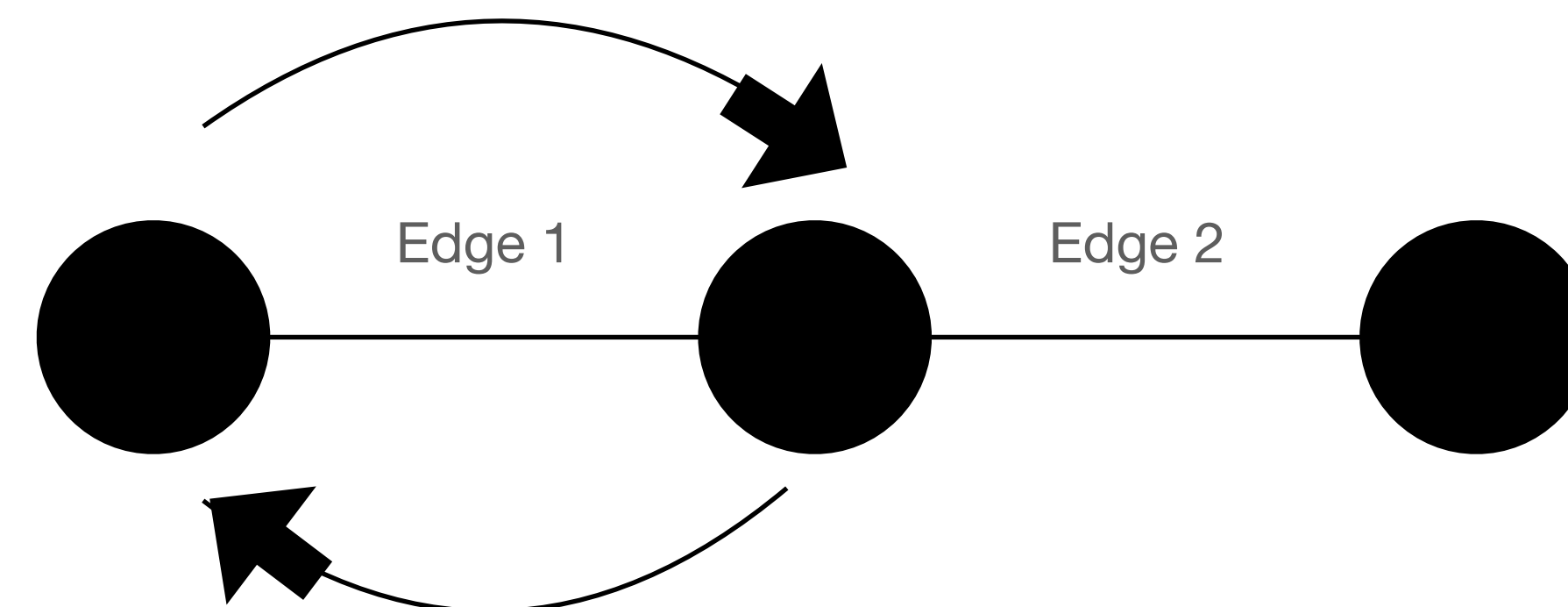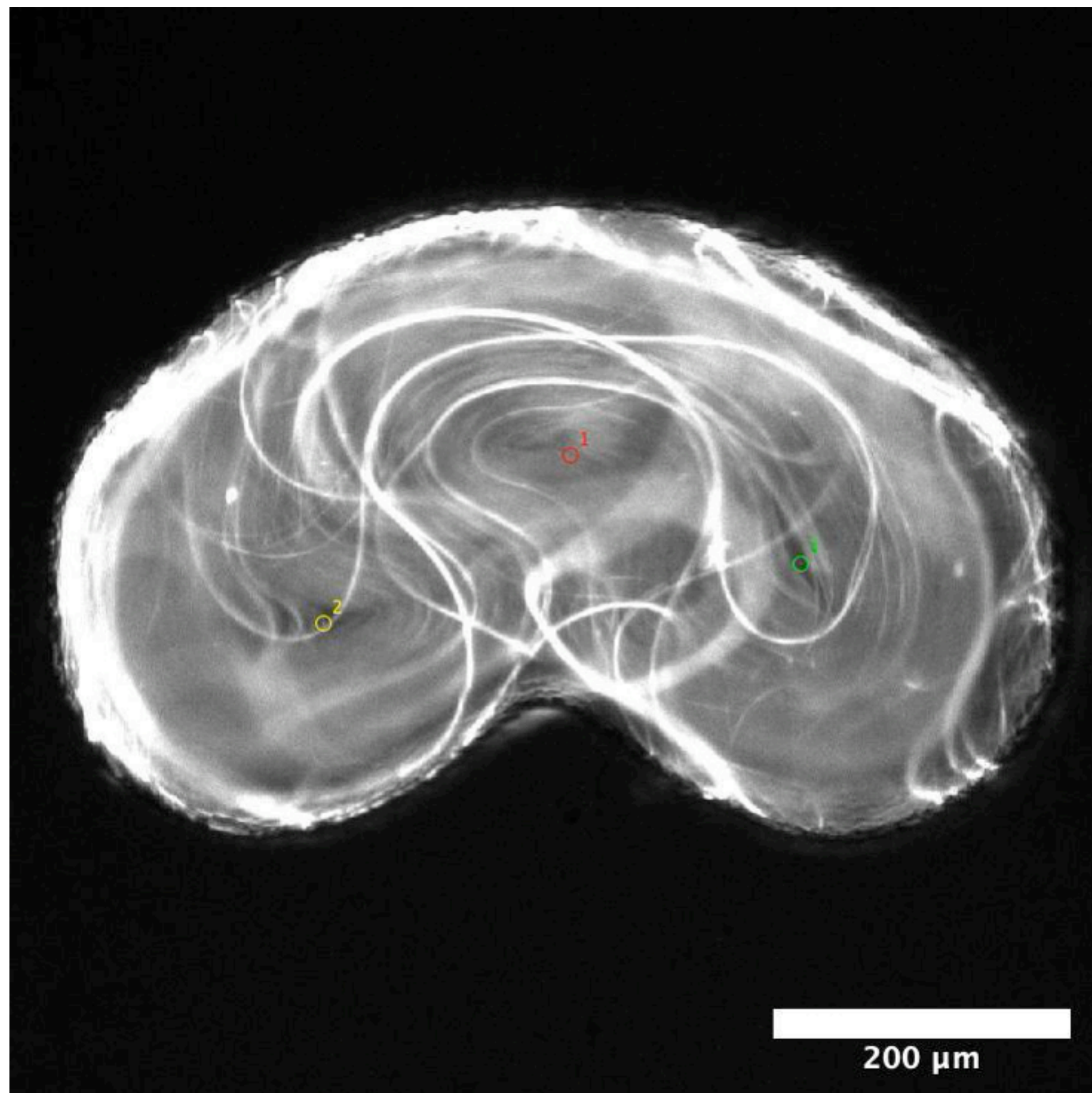
Bad Mixing

Good Mixing

How good is the mixing?

Two total edges   Four total edges   Six total edges

```
Set 1: Edge 1 - cw
Set 2: Edge 1 - ccw
Set 3: Edge 2 - cw
Set 4: Edge 2 - ccw
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1D and 2D Mixing
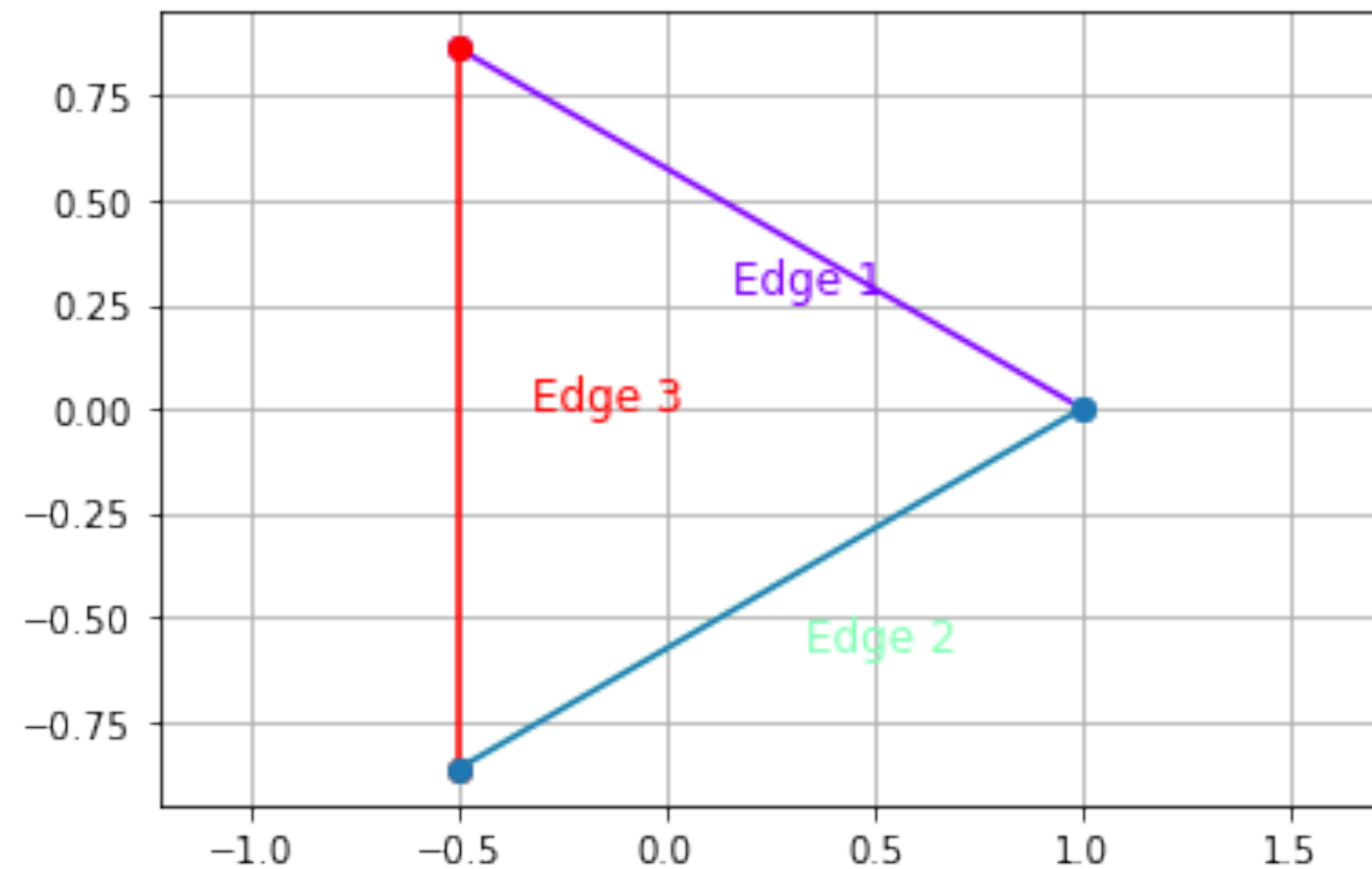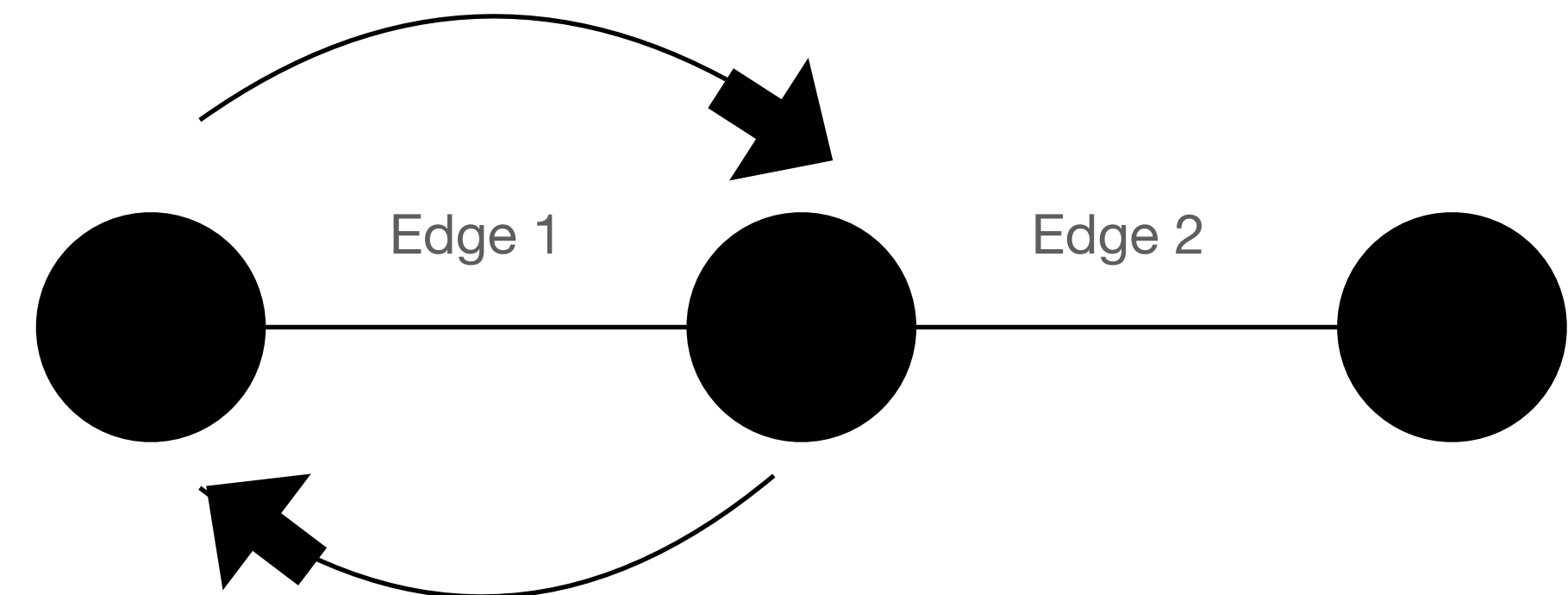

Set 1: Edge 1 - cw
Set 2: Edge 1 - ccw
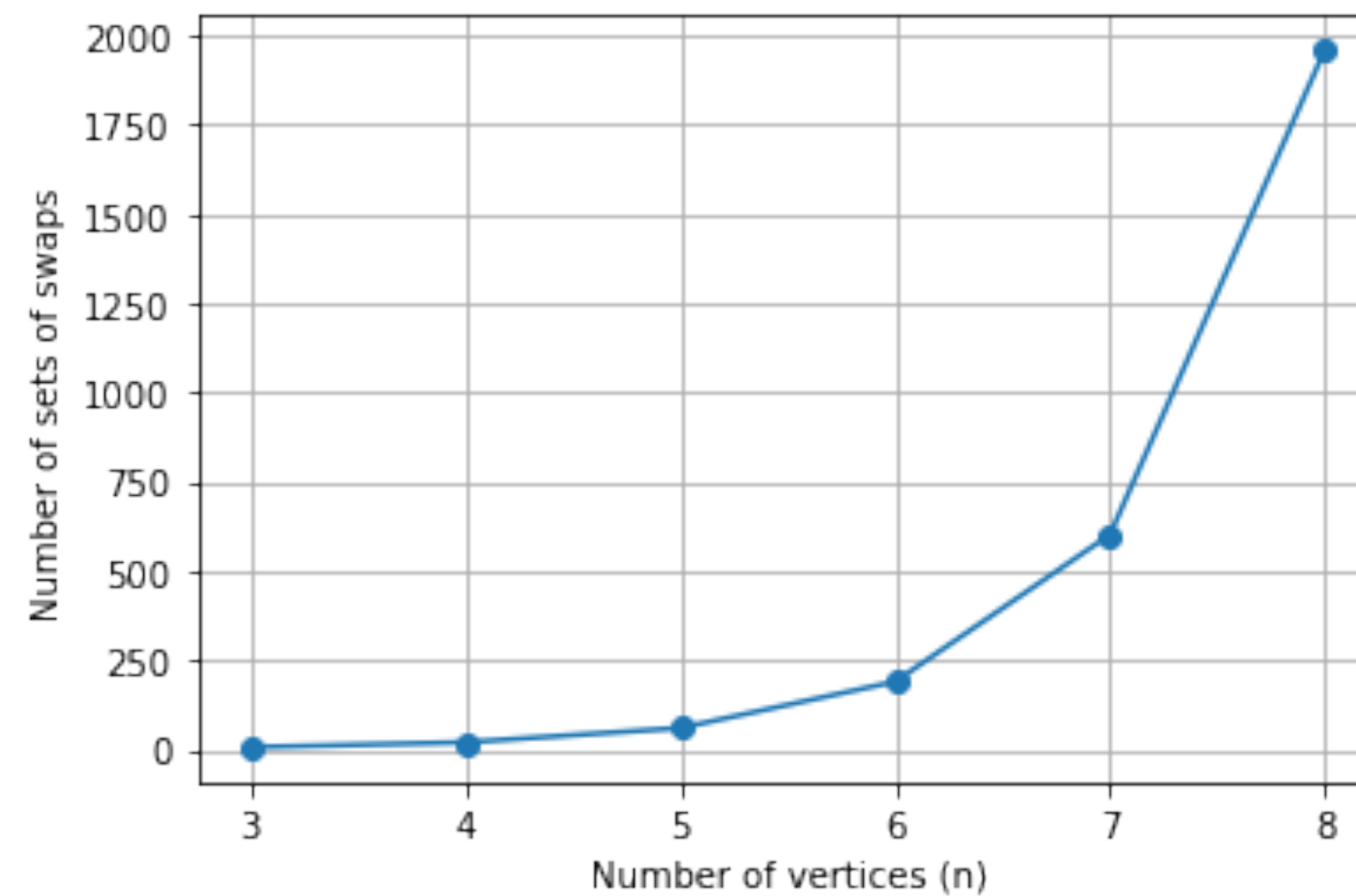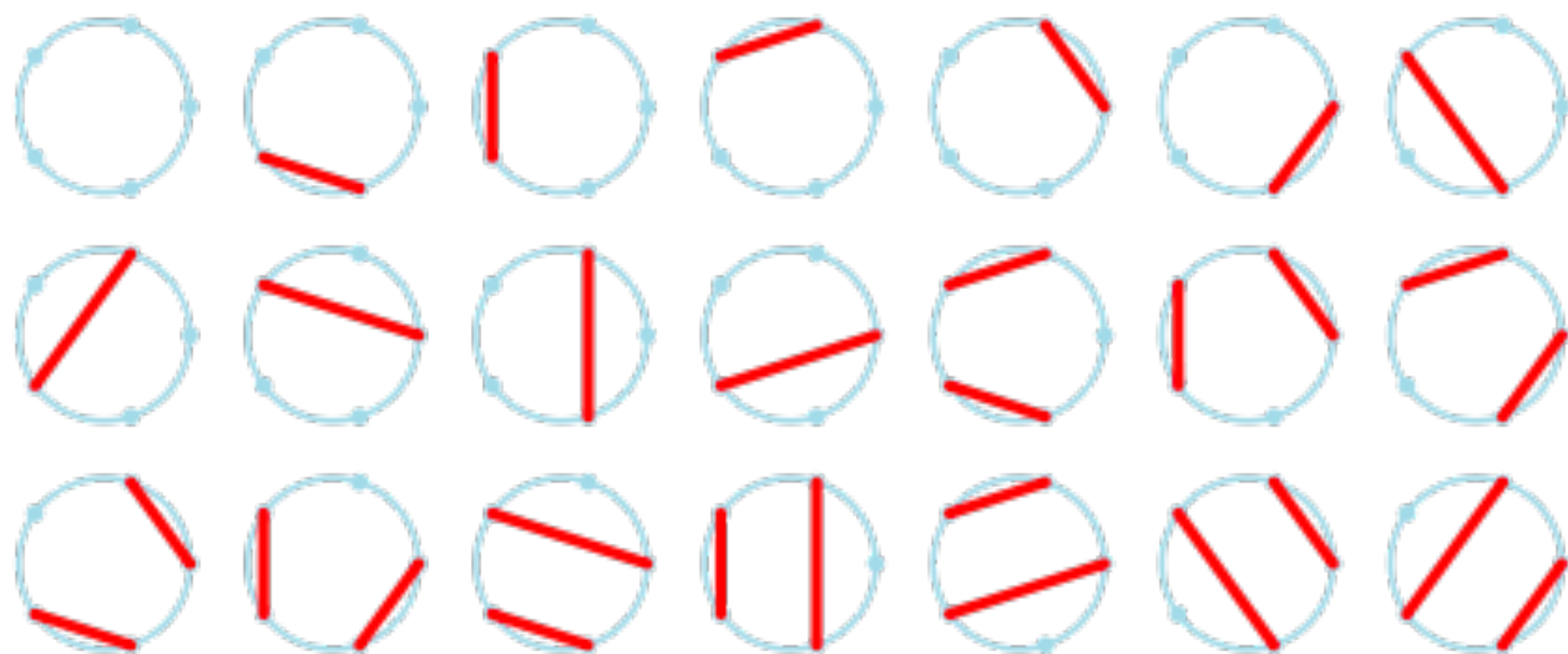Set 3: Edge 2 - cw
Set 4: Edge 2 - ccw

1D and 2D Mixing

Set 1: Edge 1 - cw
Set 2: Edge 1 - ccw
Set 3: Edge 2 - cw
Set 4: Edge 2 - ccw
Set 5: Edge 3 - cw
Set 6: Edge 3 - ccw

Set 1: Edge 1 - cw
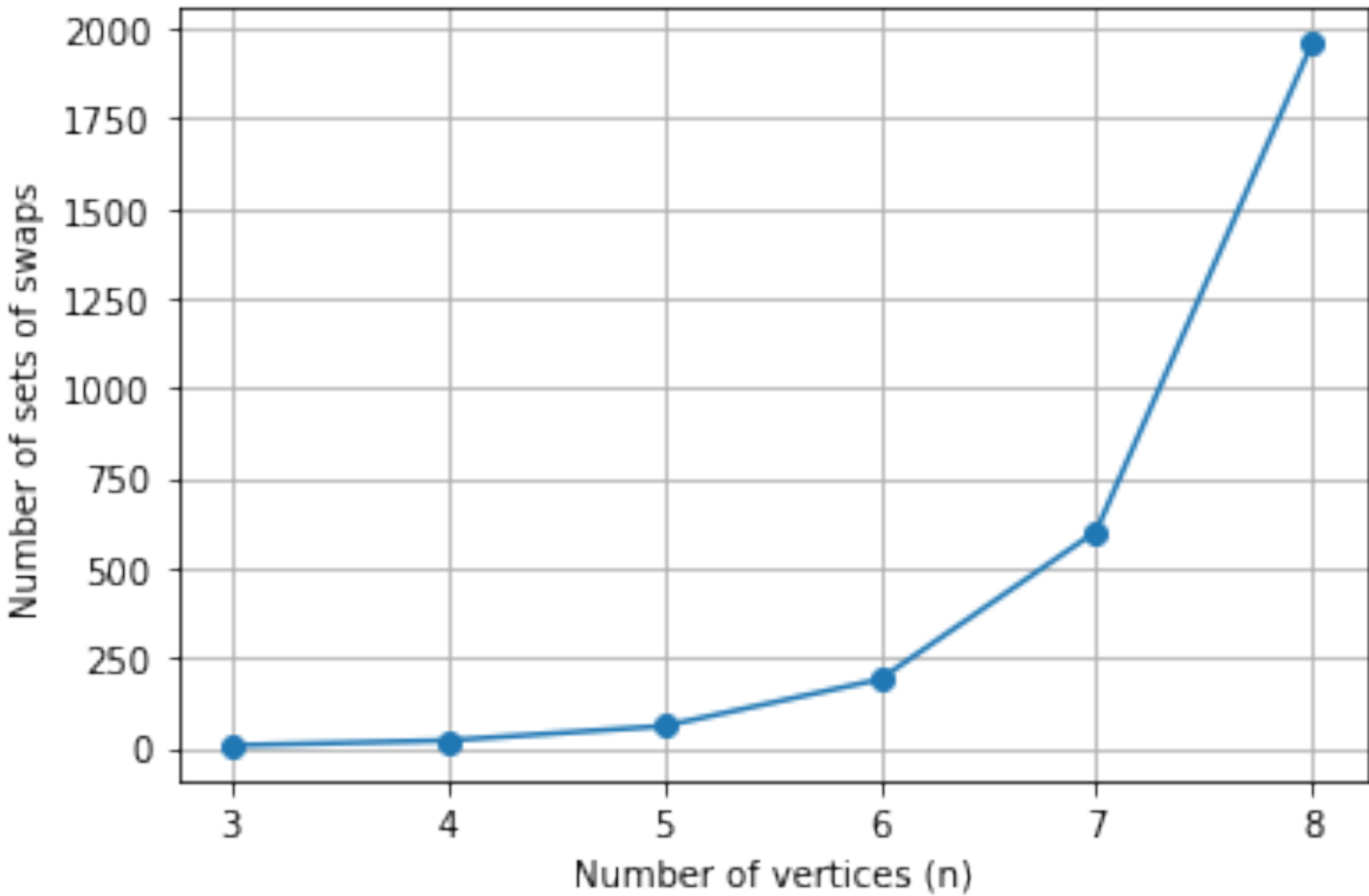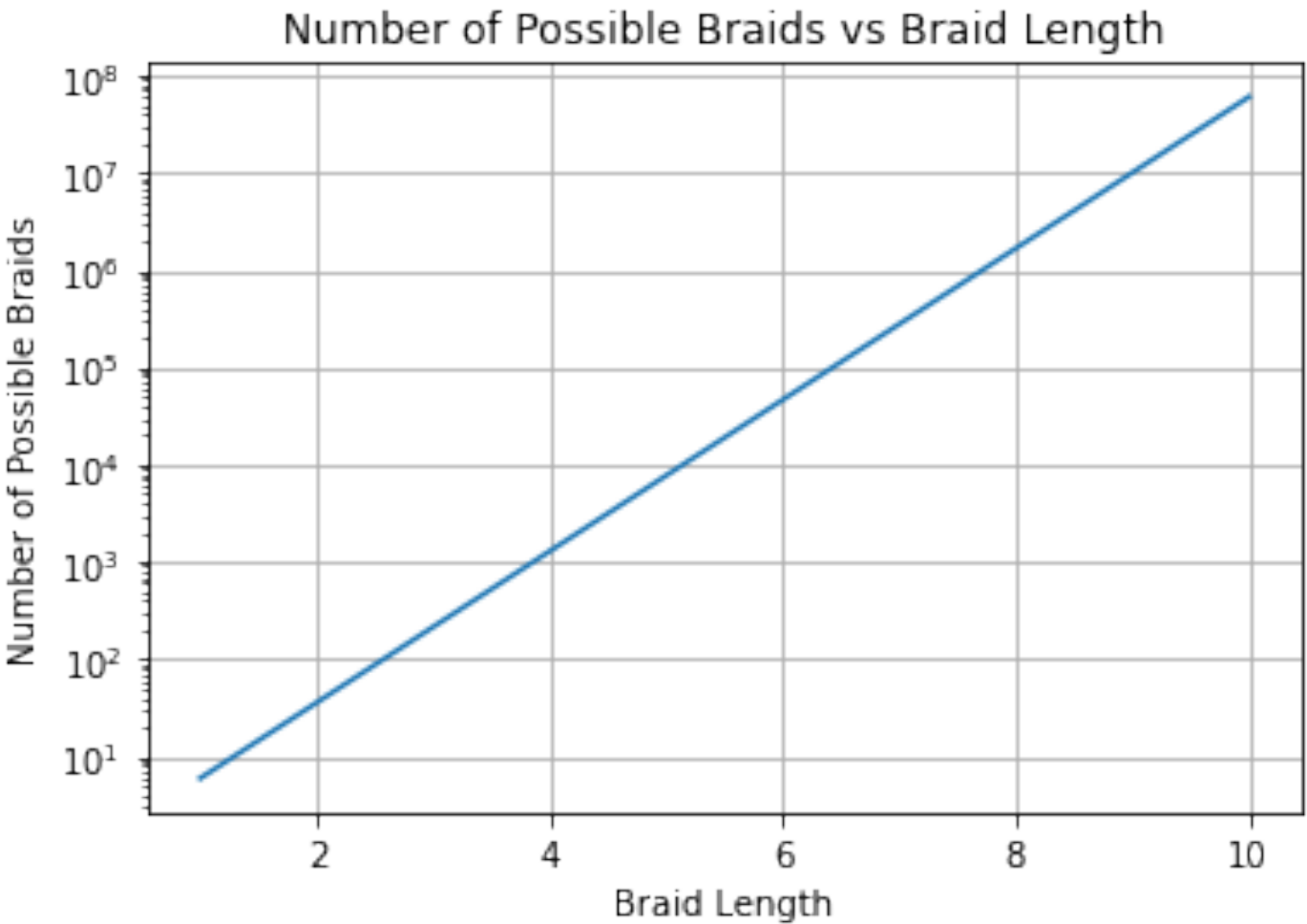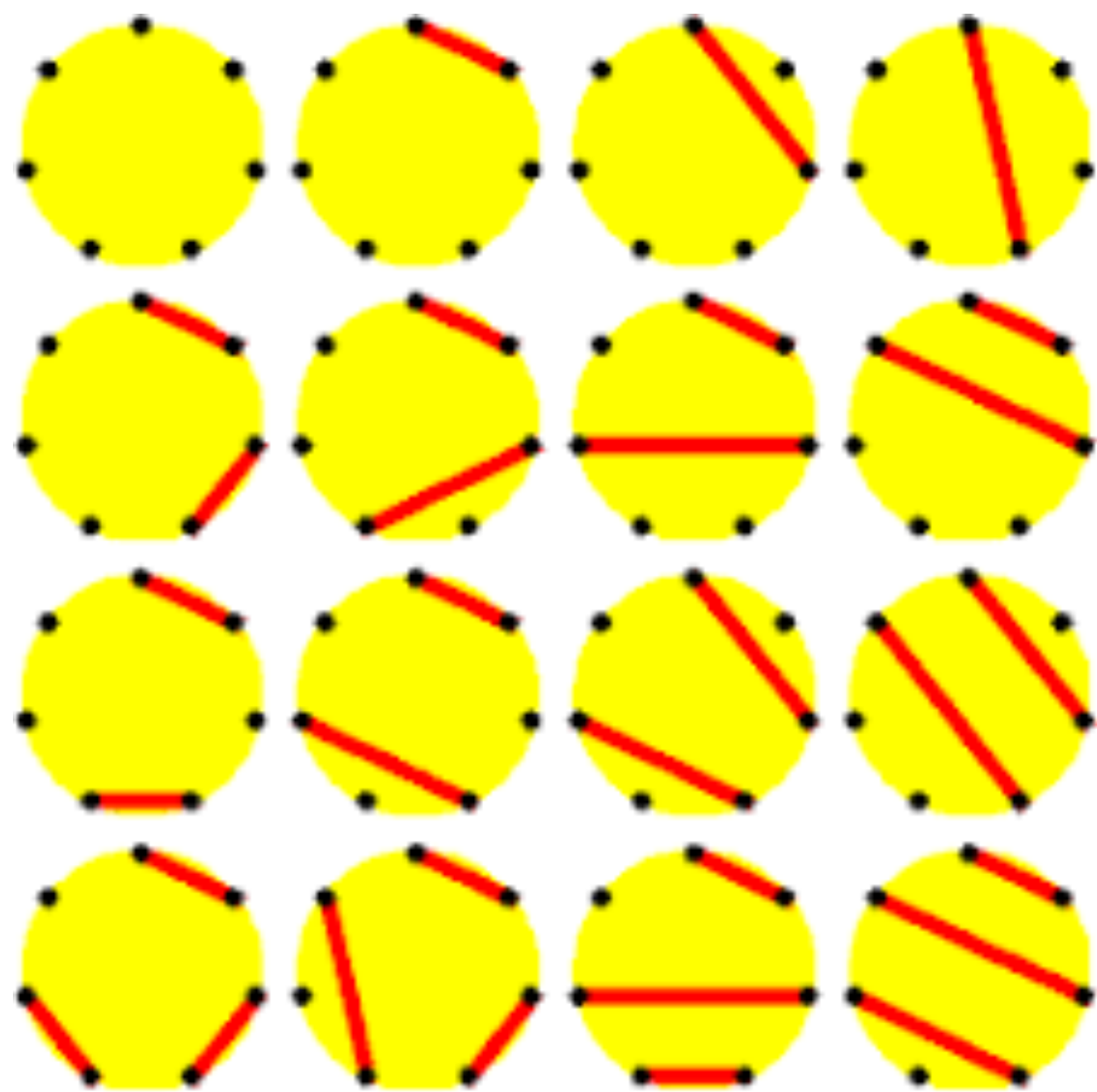Set 2: Edge 1 - ccw
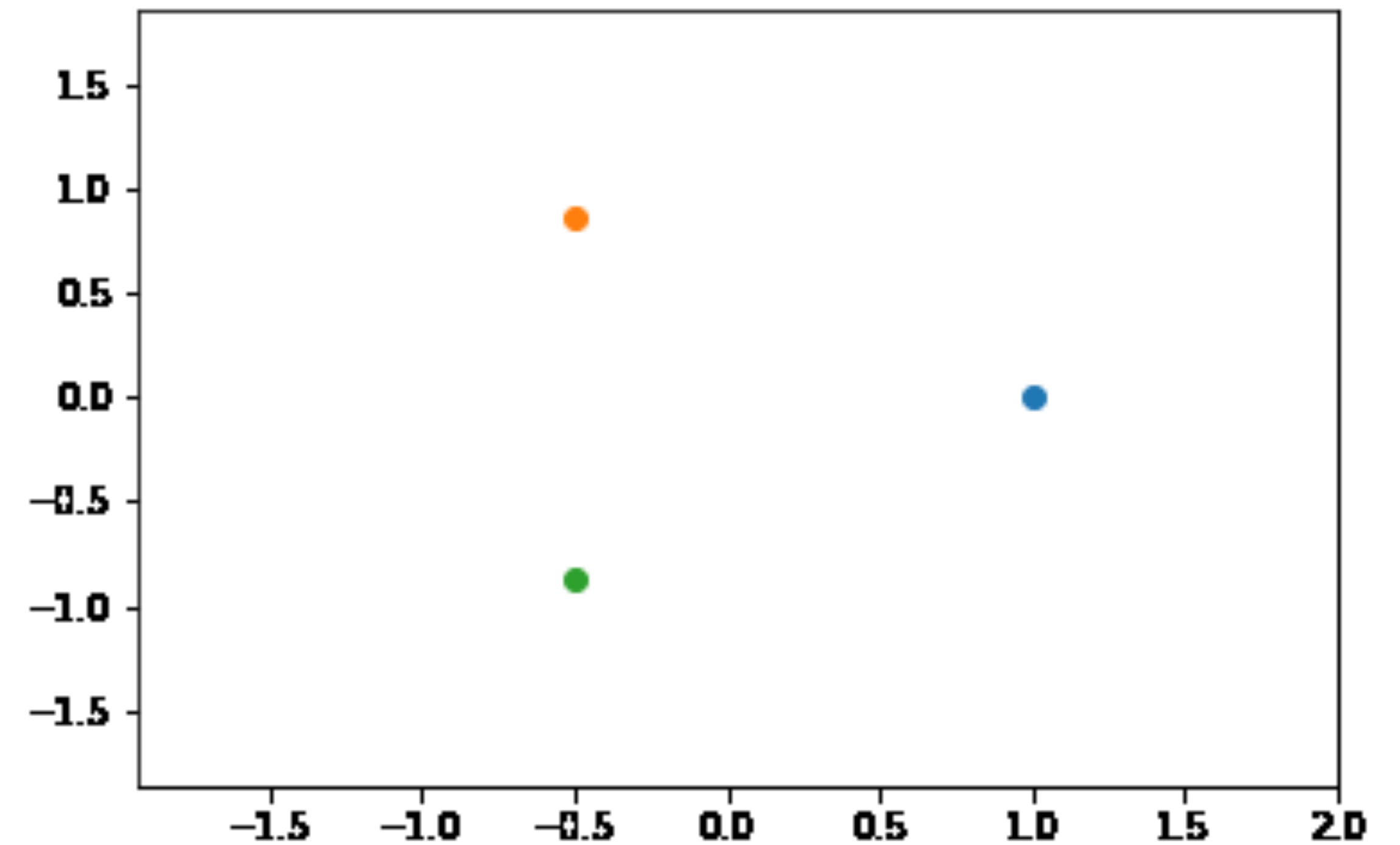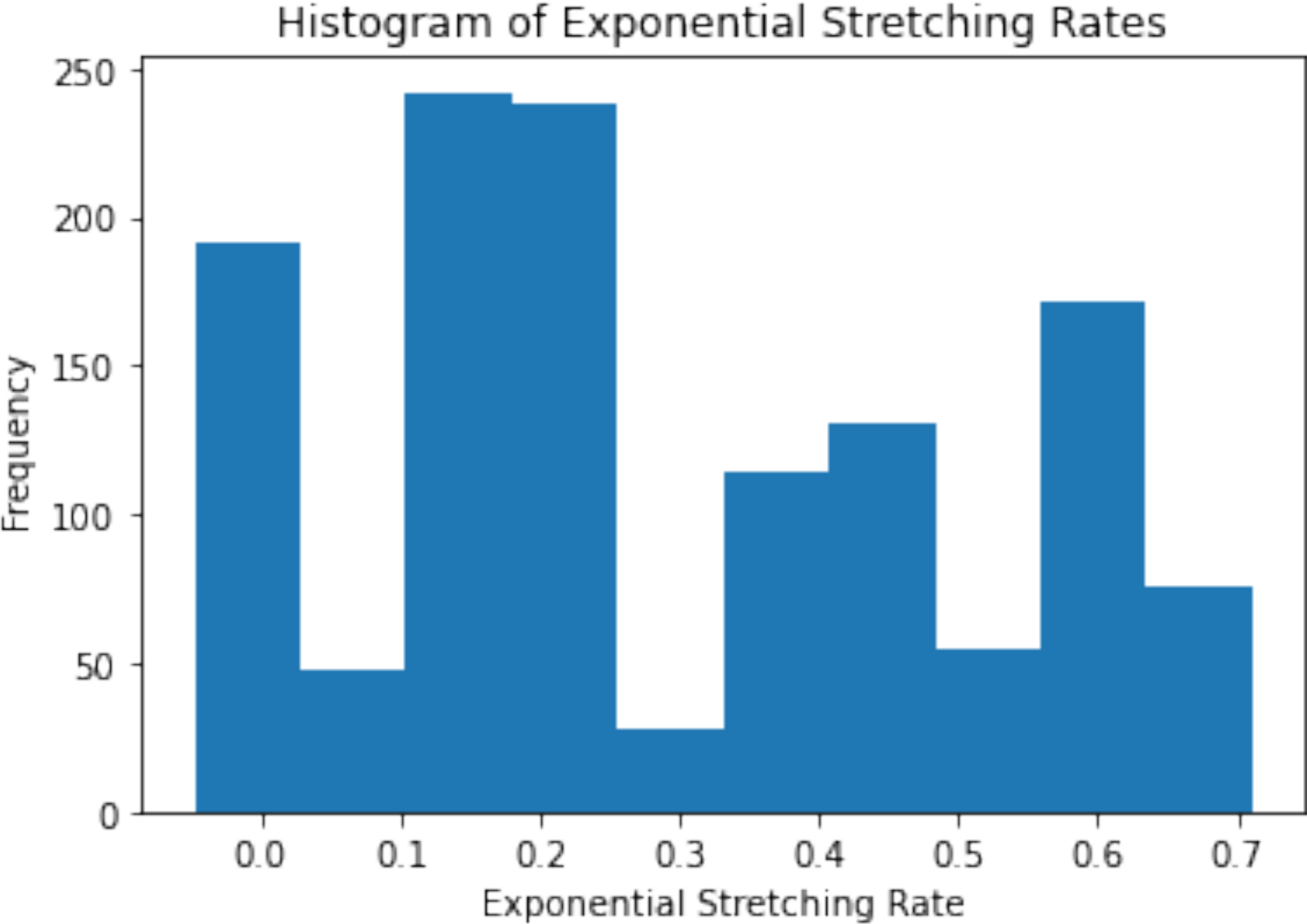Set 3: Edge 2 - cw
Set 4: Edge 2 - ccw

How many ways to mix?

n=5

How many ways to mix?

n=6

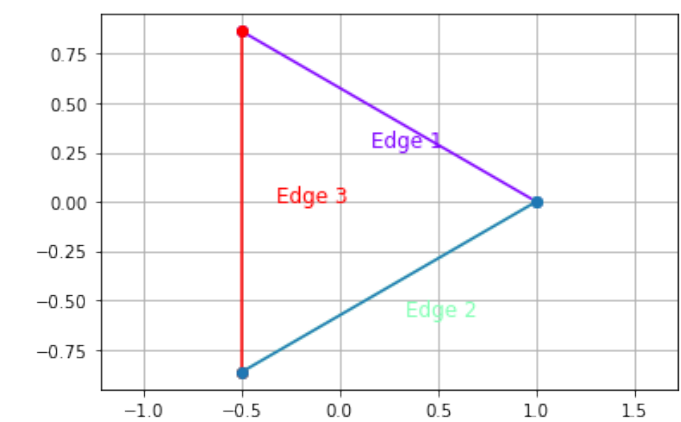# 3-Rod Mixing

Mixing of N=3 L=4
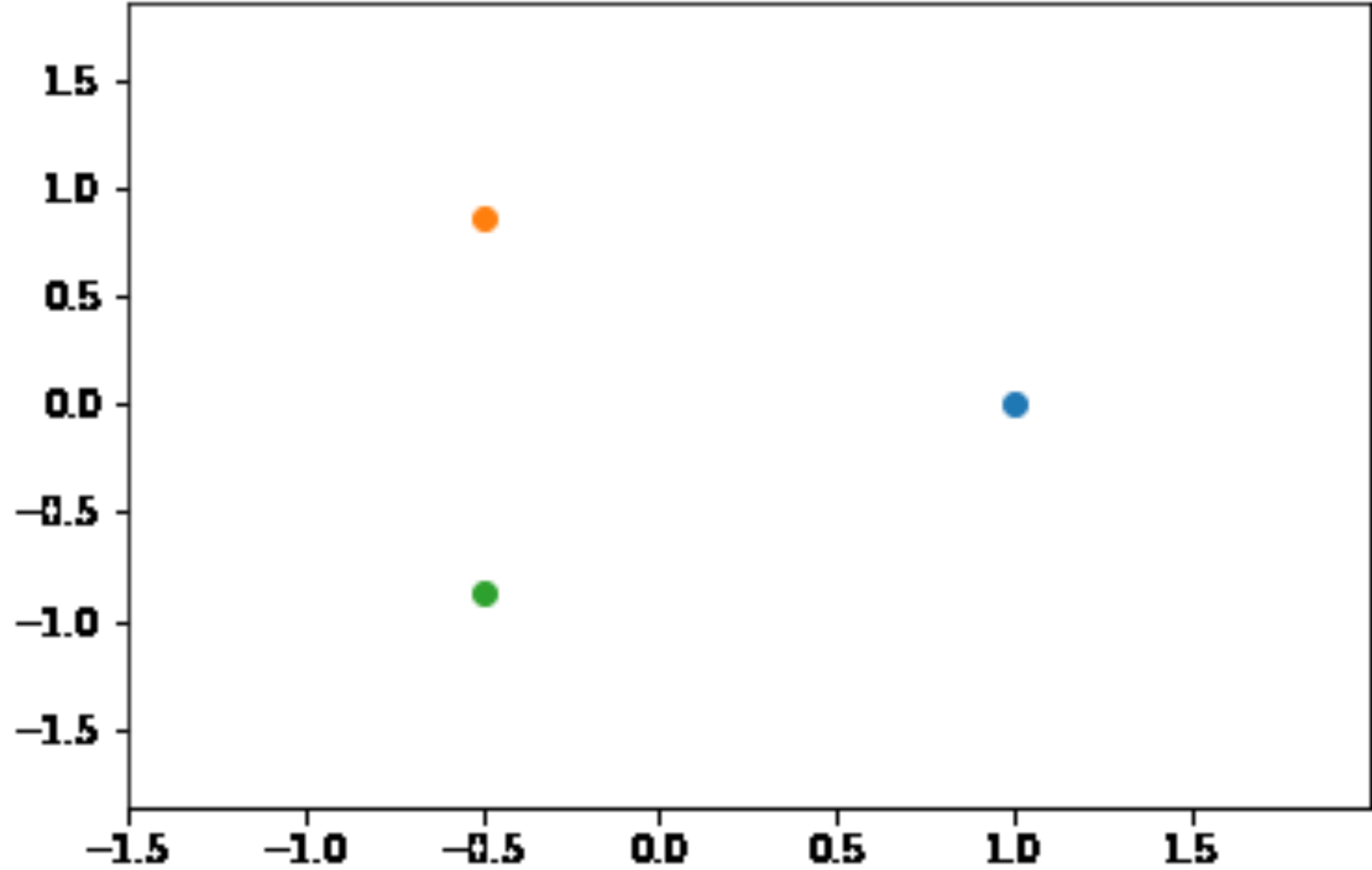
Mixing of N=3 L=6

Lowest entropy mixing N=3 L=4
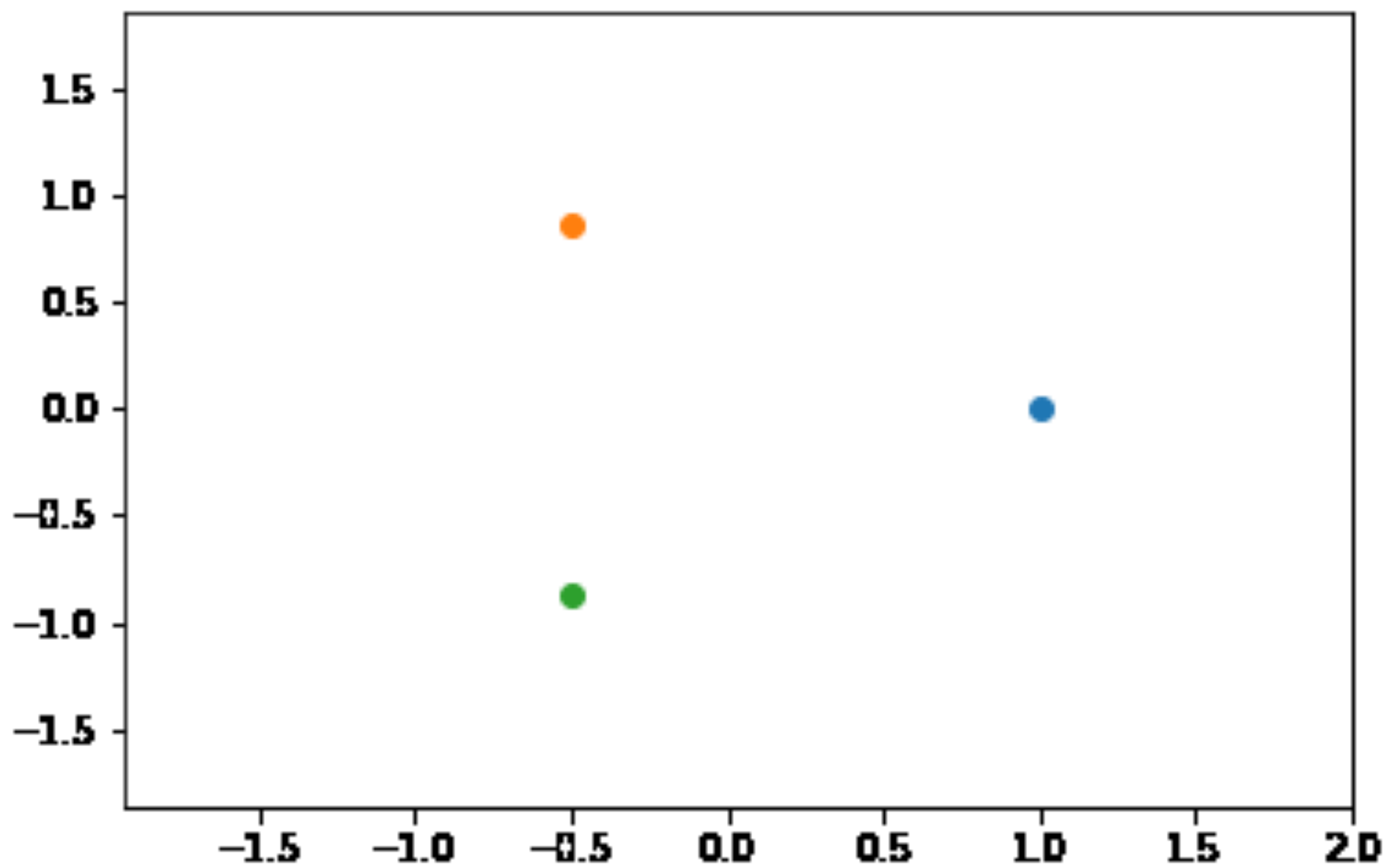
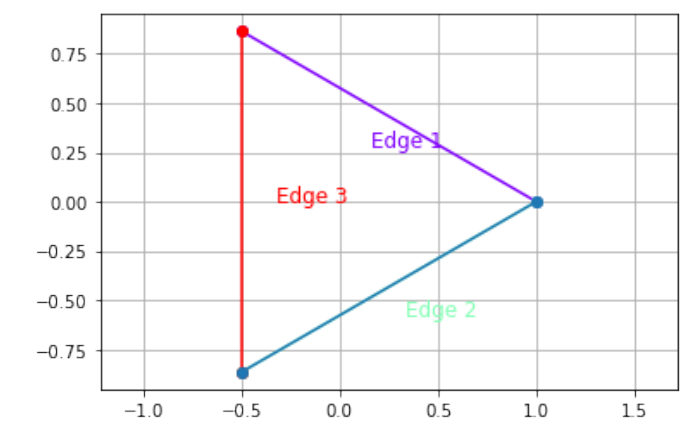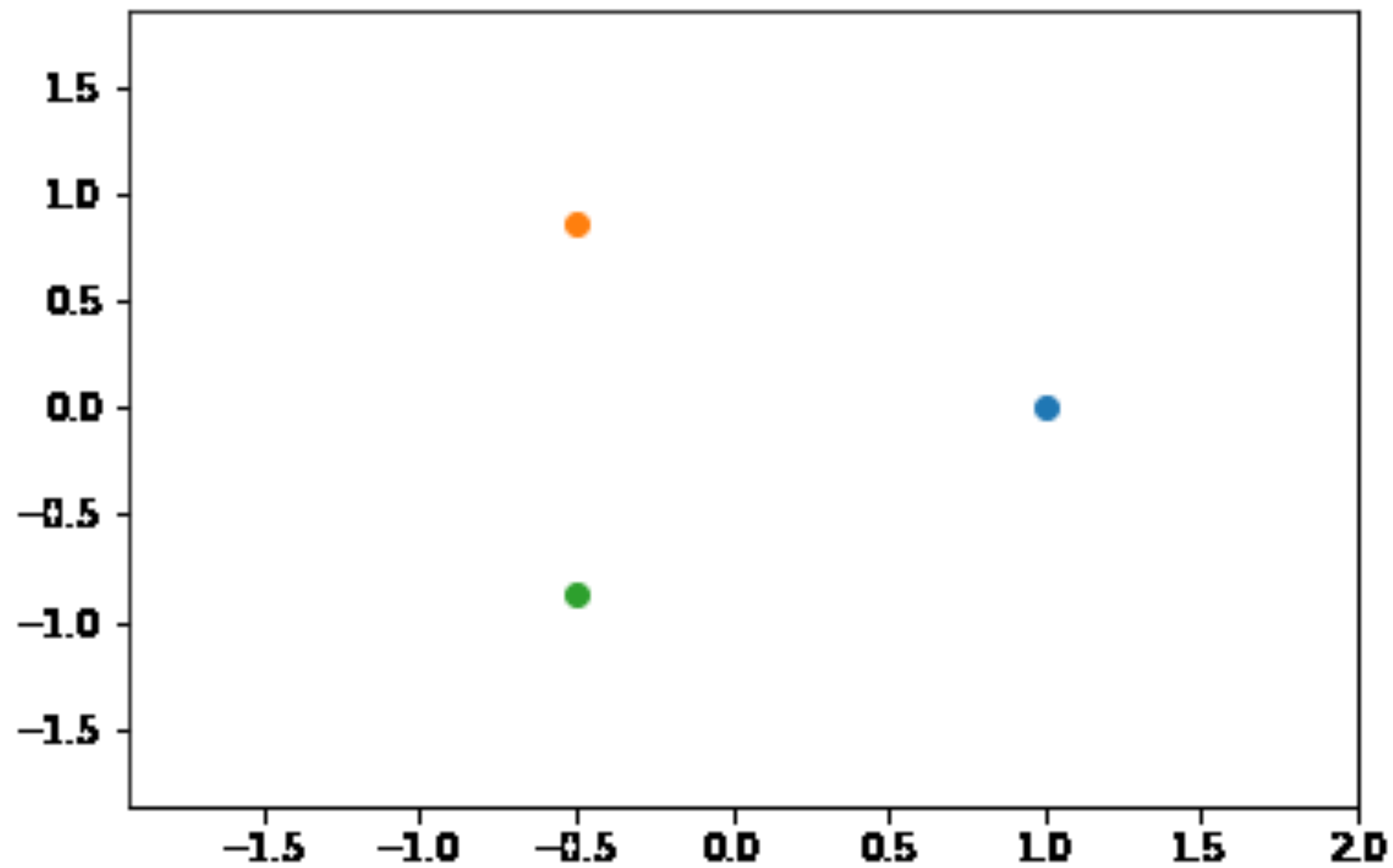# Highest entropy mixing N=3 L=4
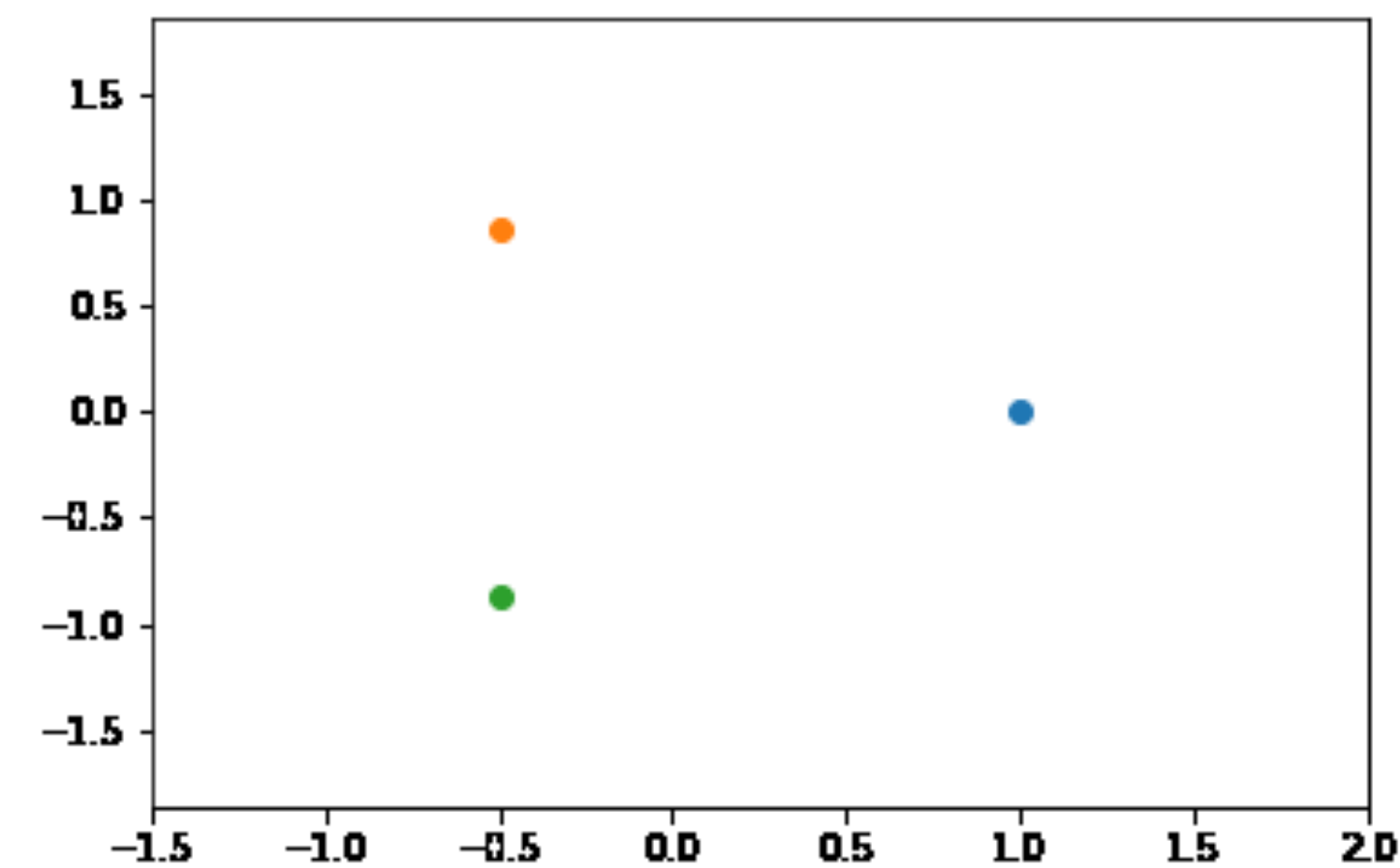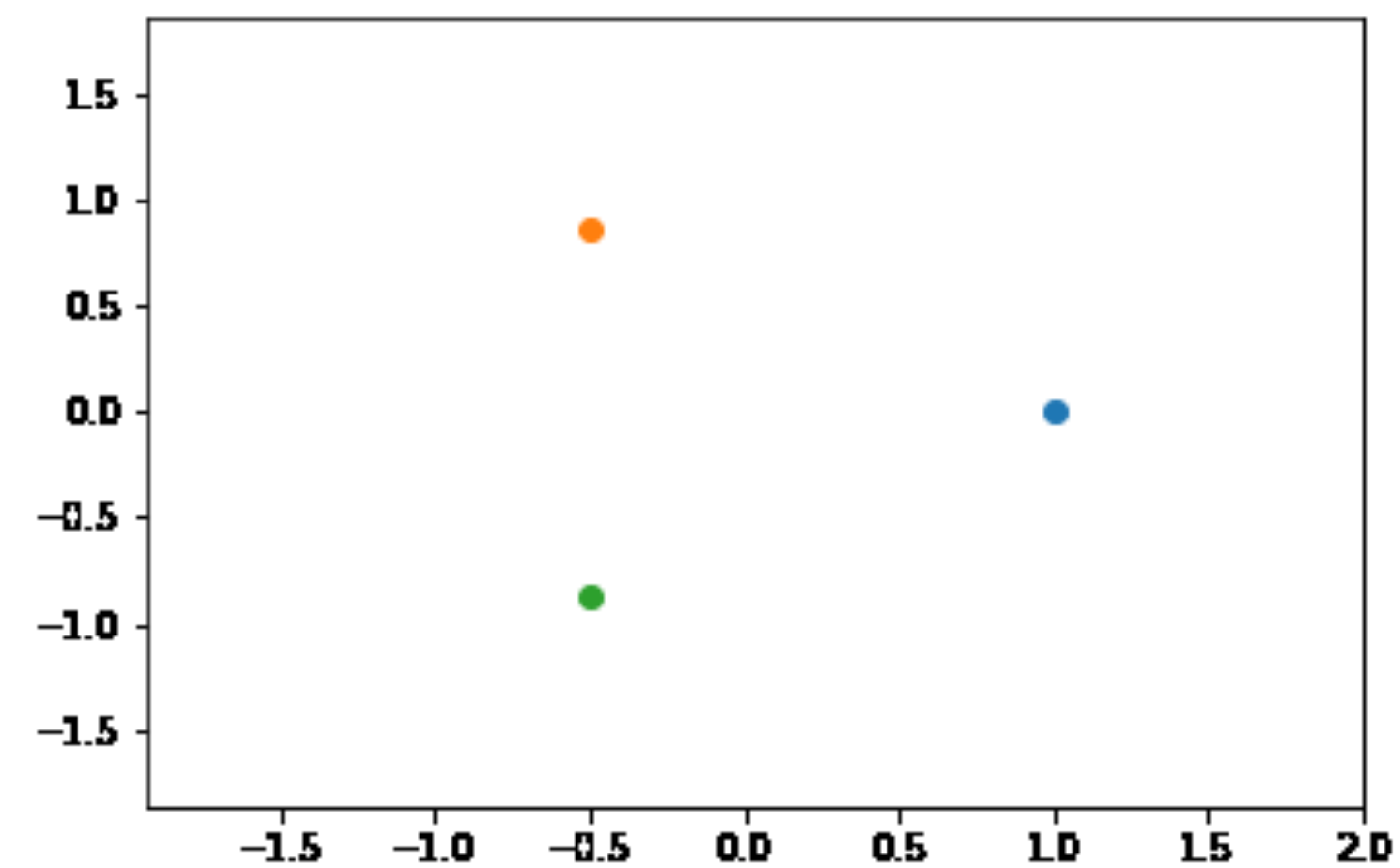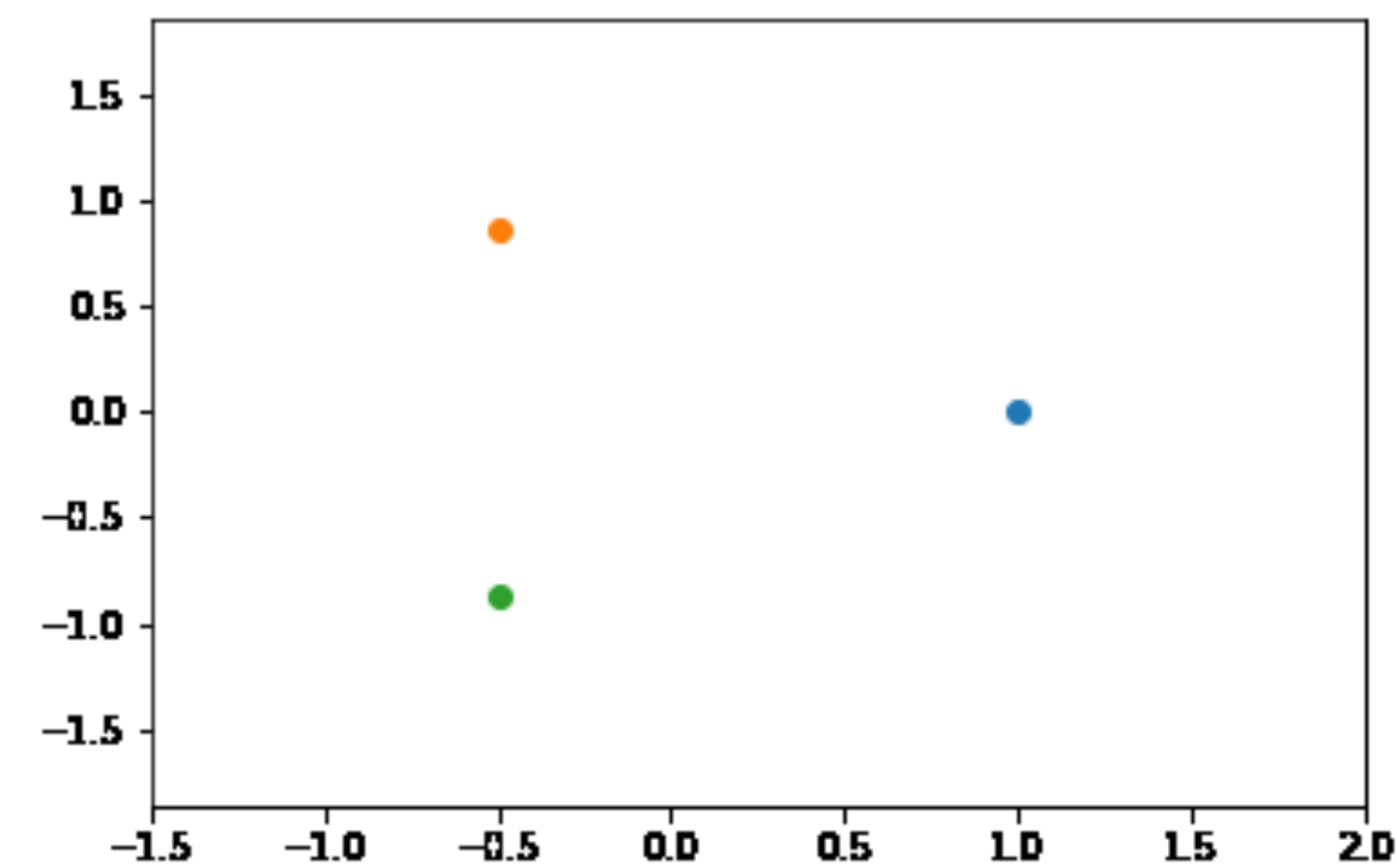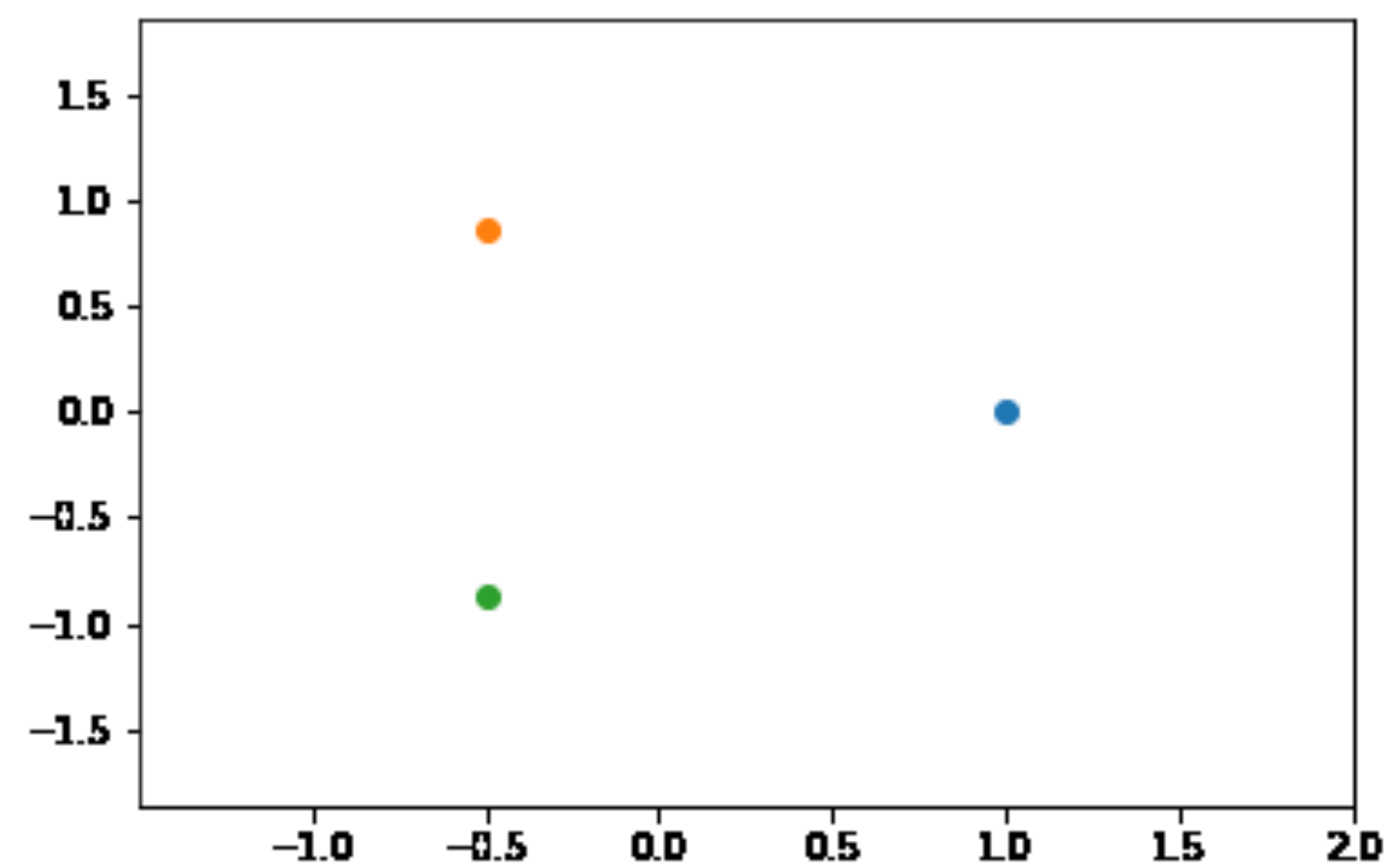
Comparison N=3 L=4

Low

High
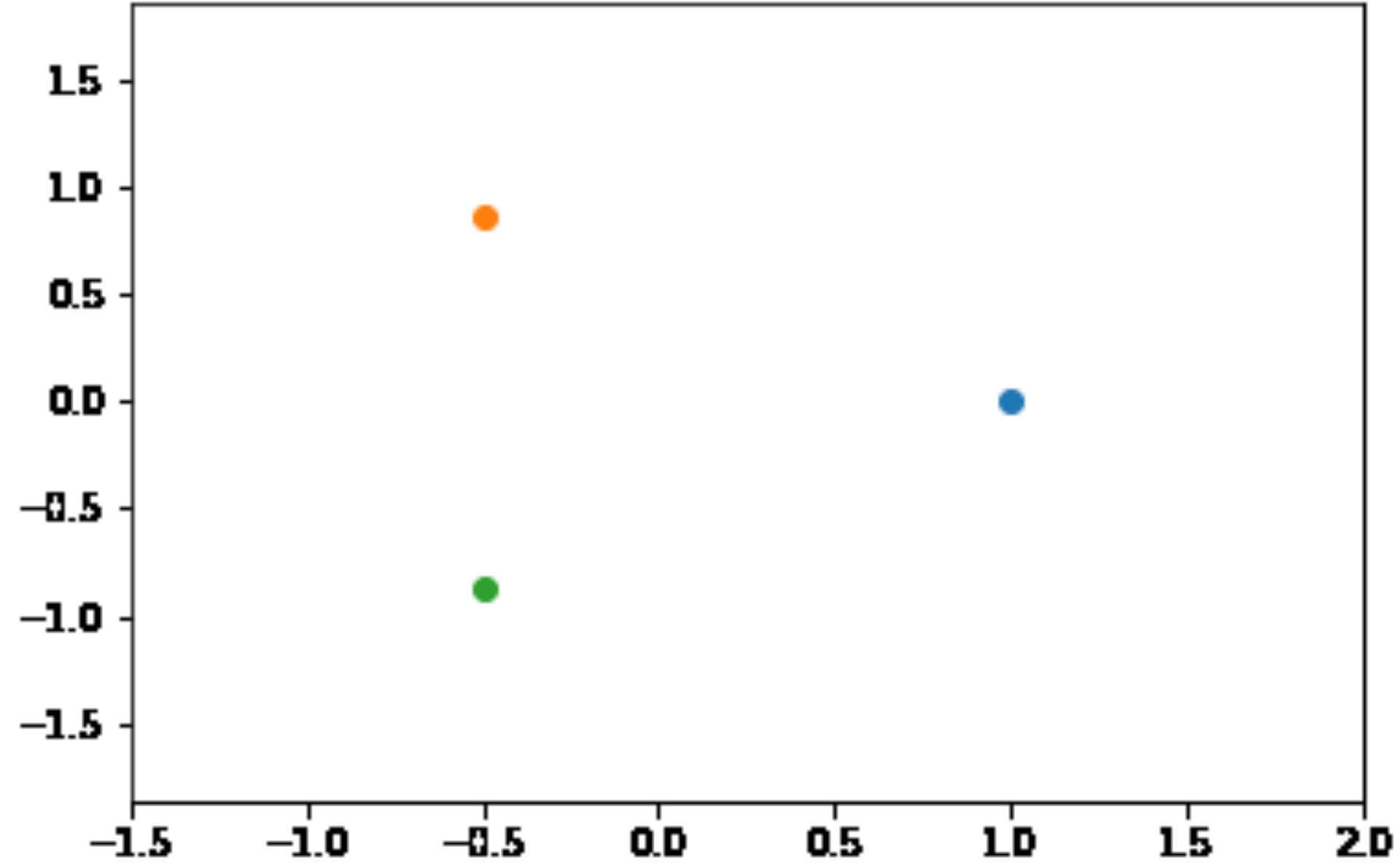
Lowest entropy mixing N=3 L=6
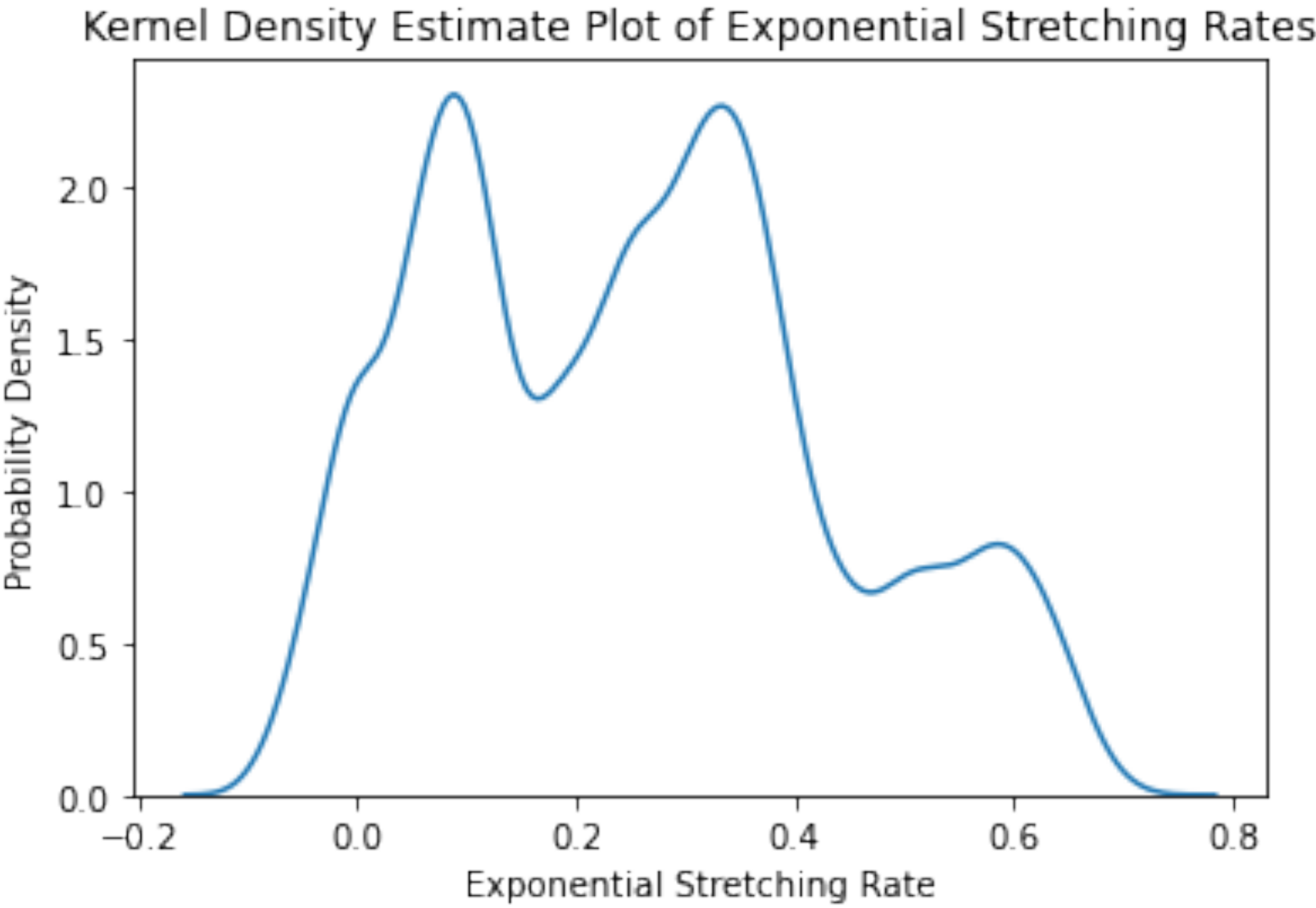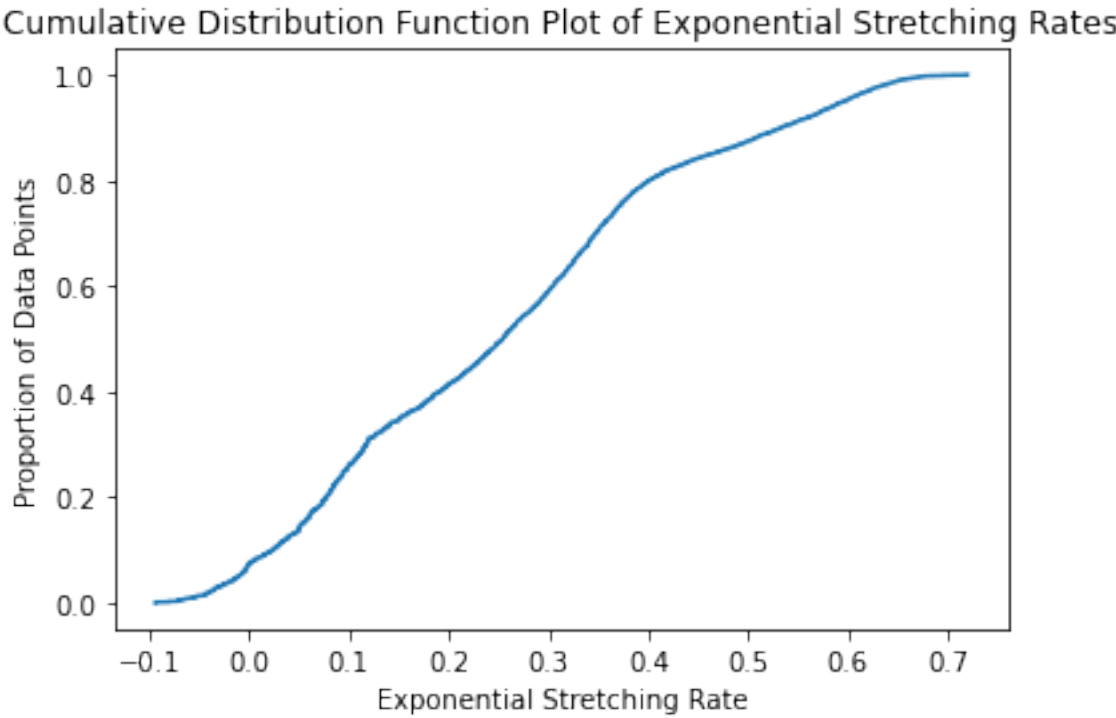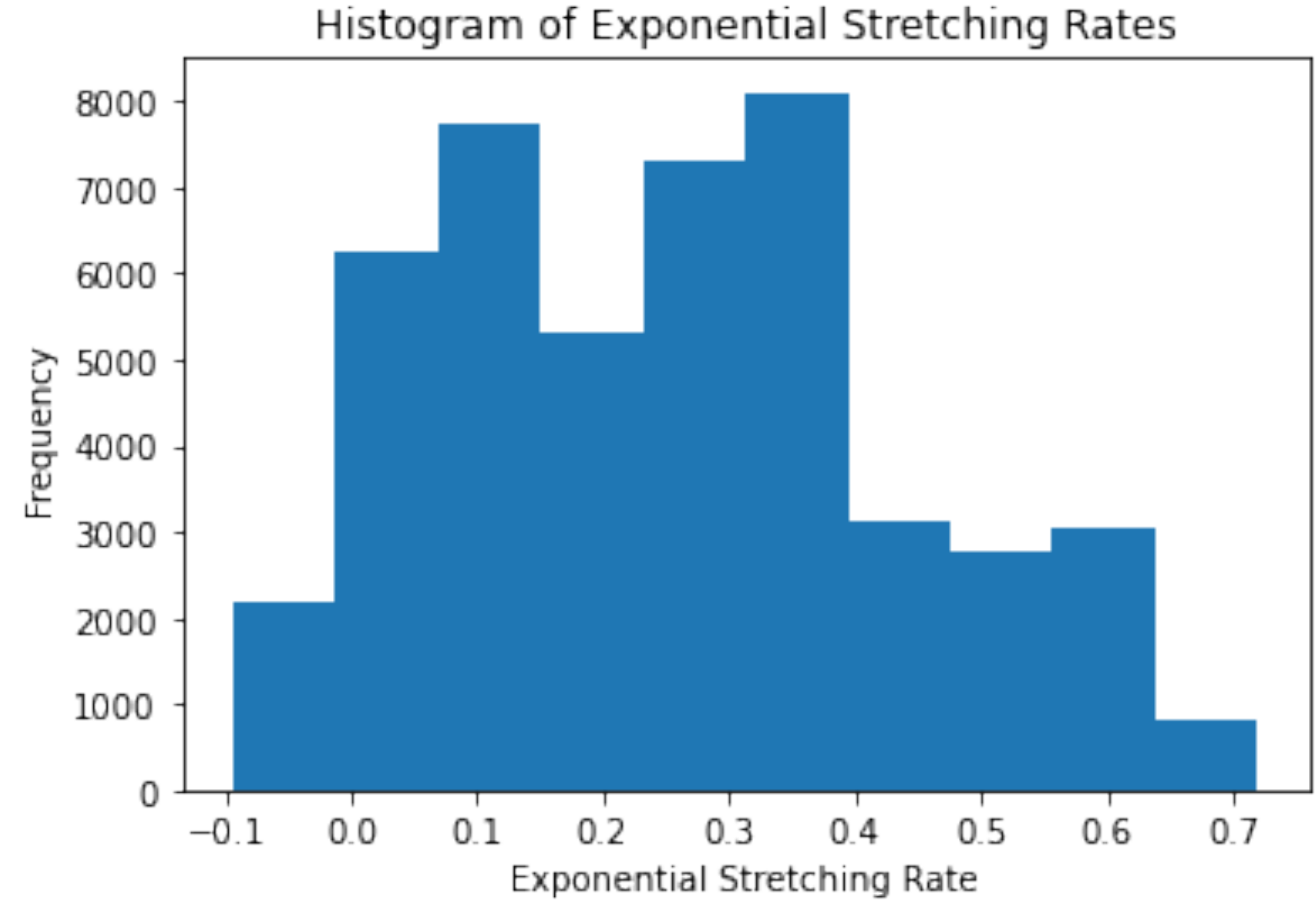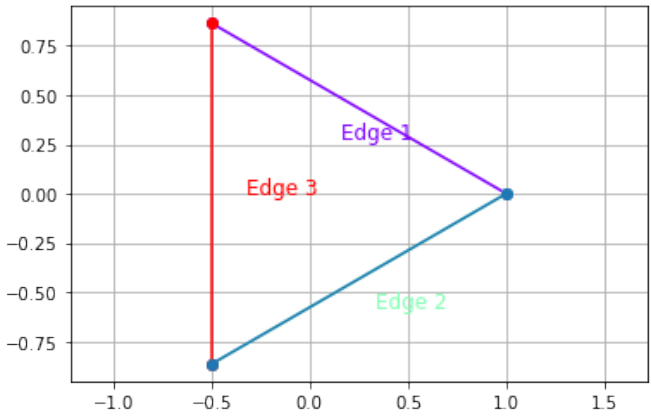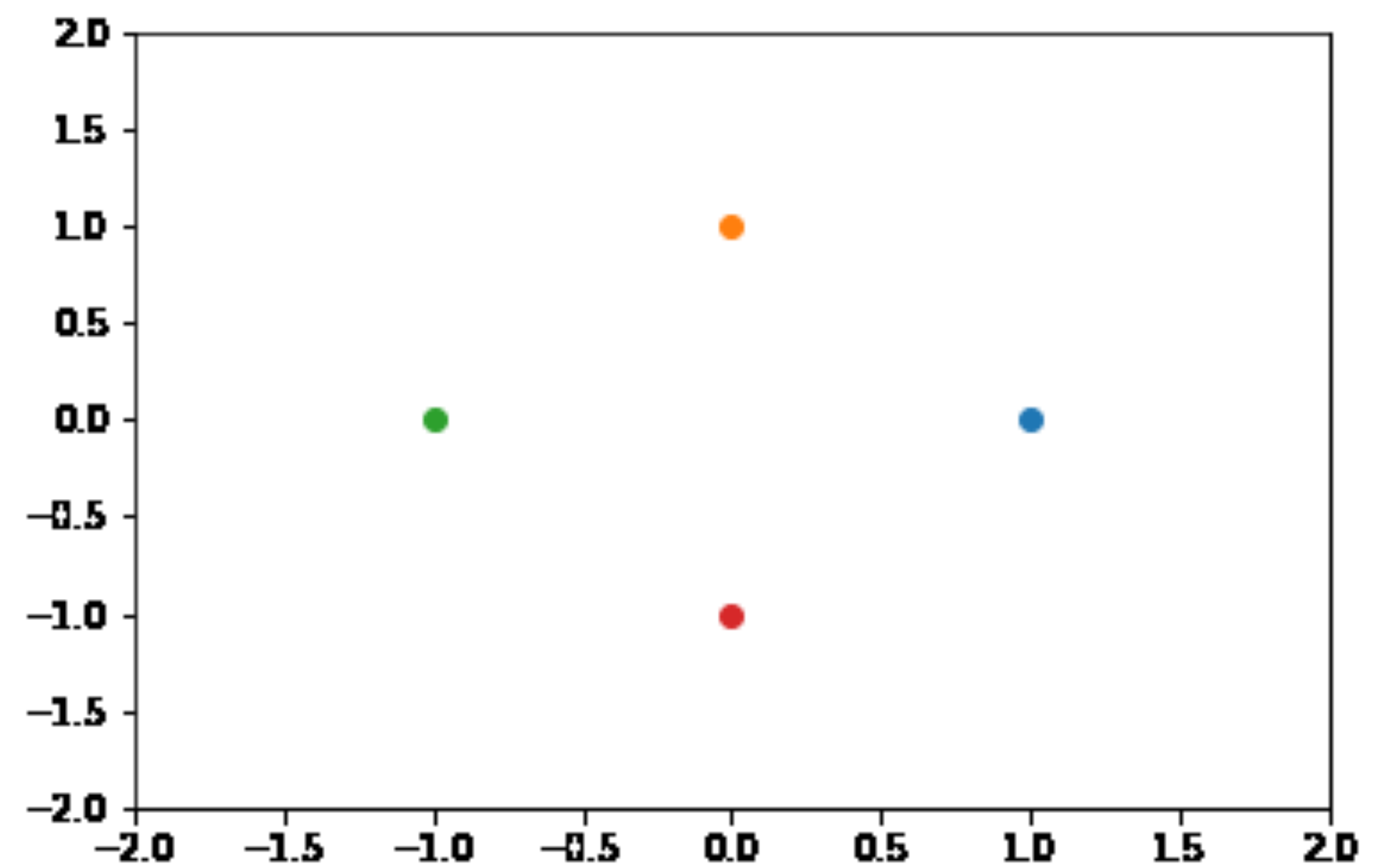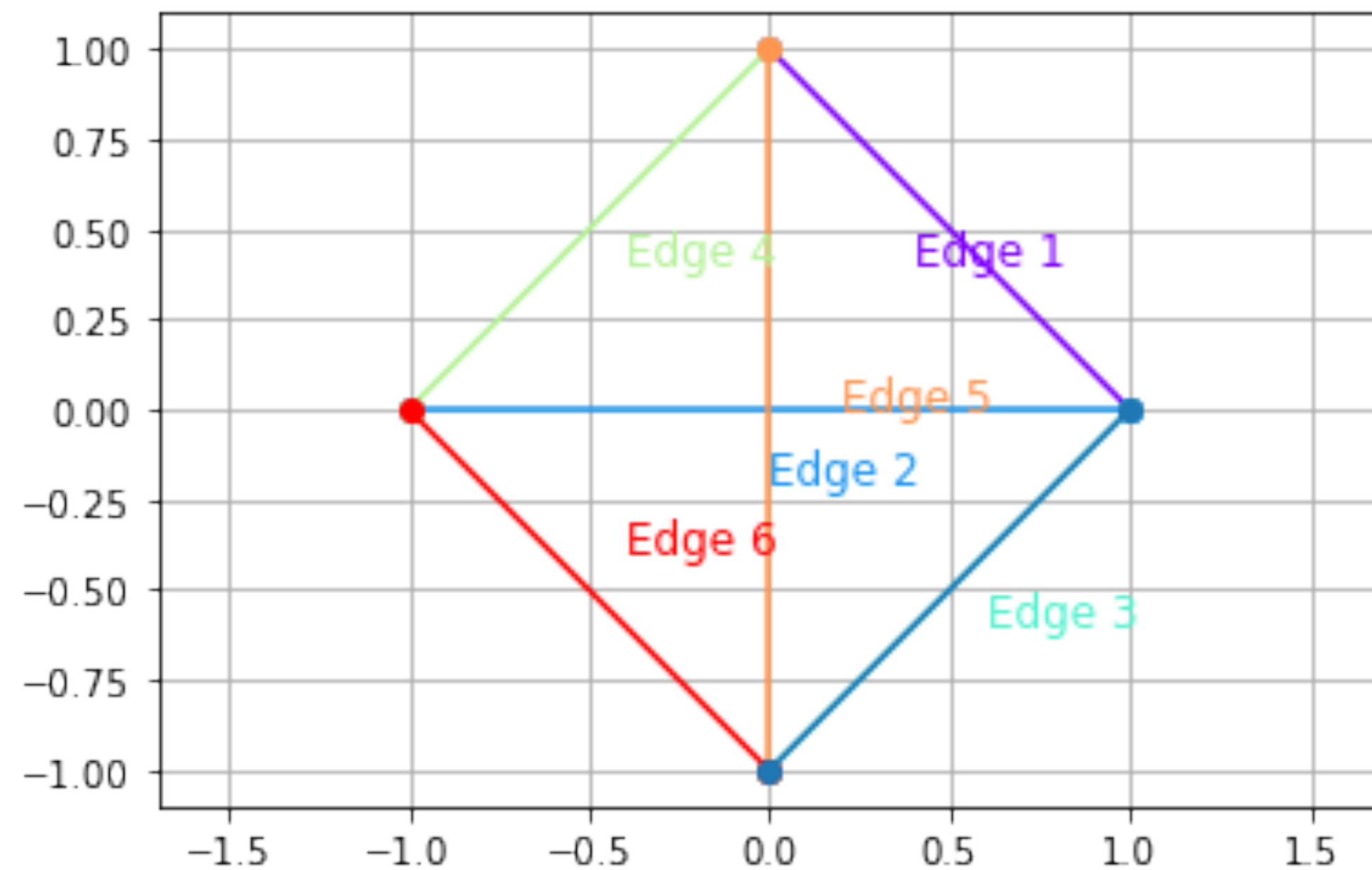
Highest entropy mixing N=3 L=6
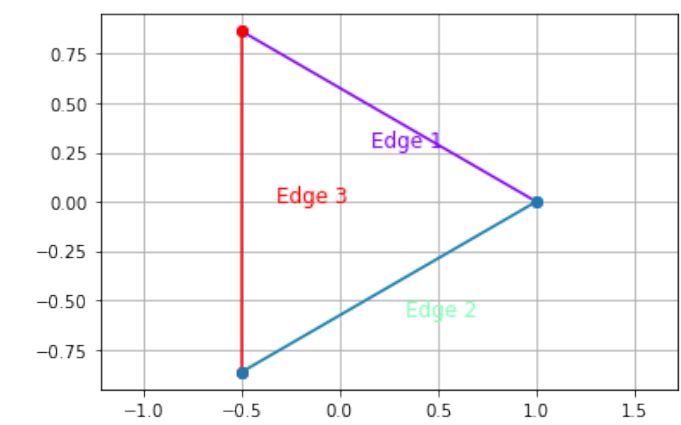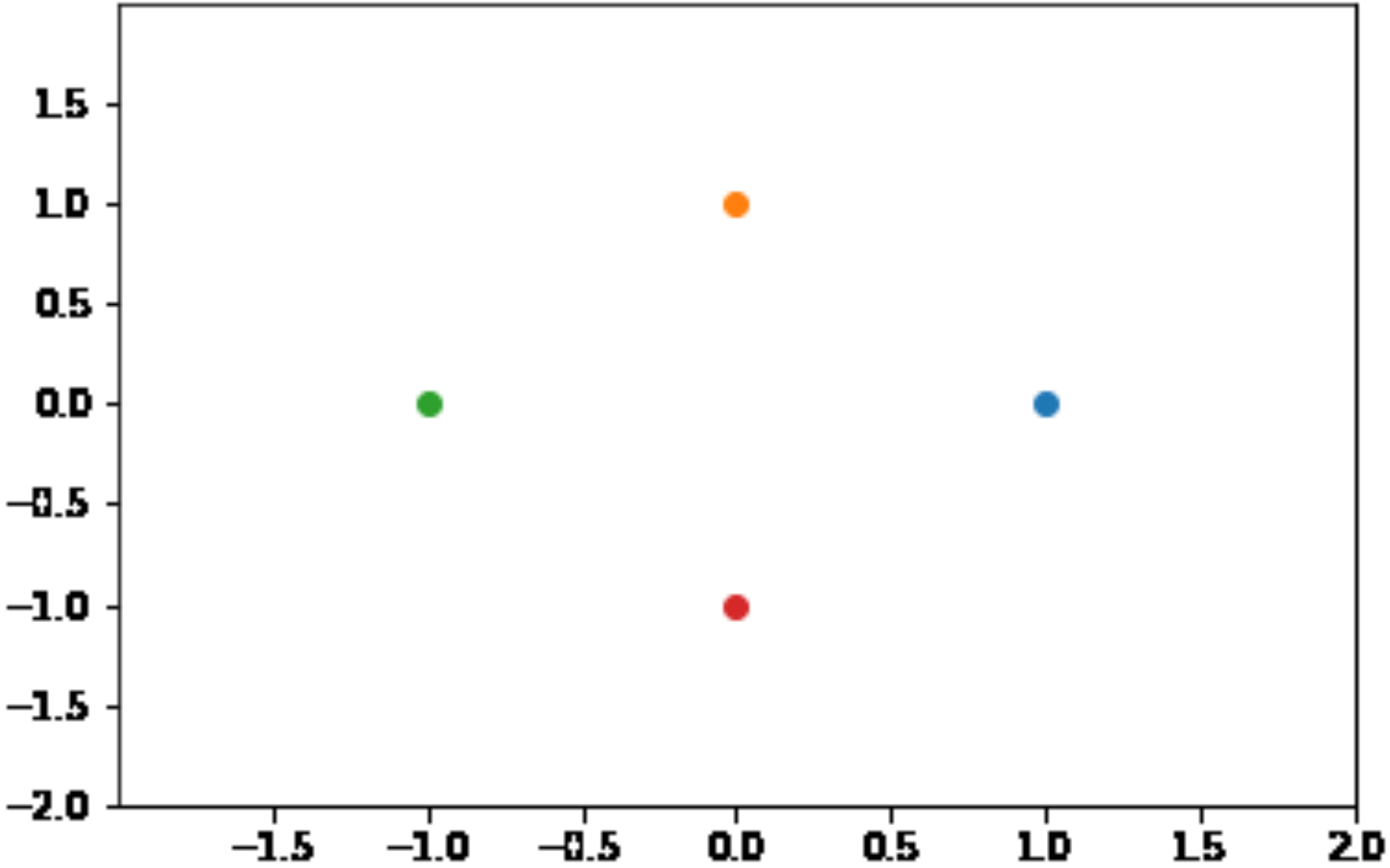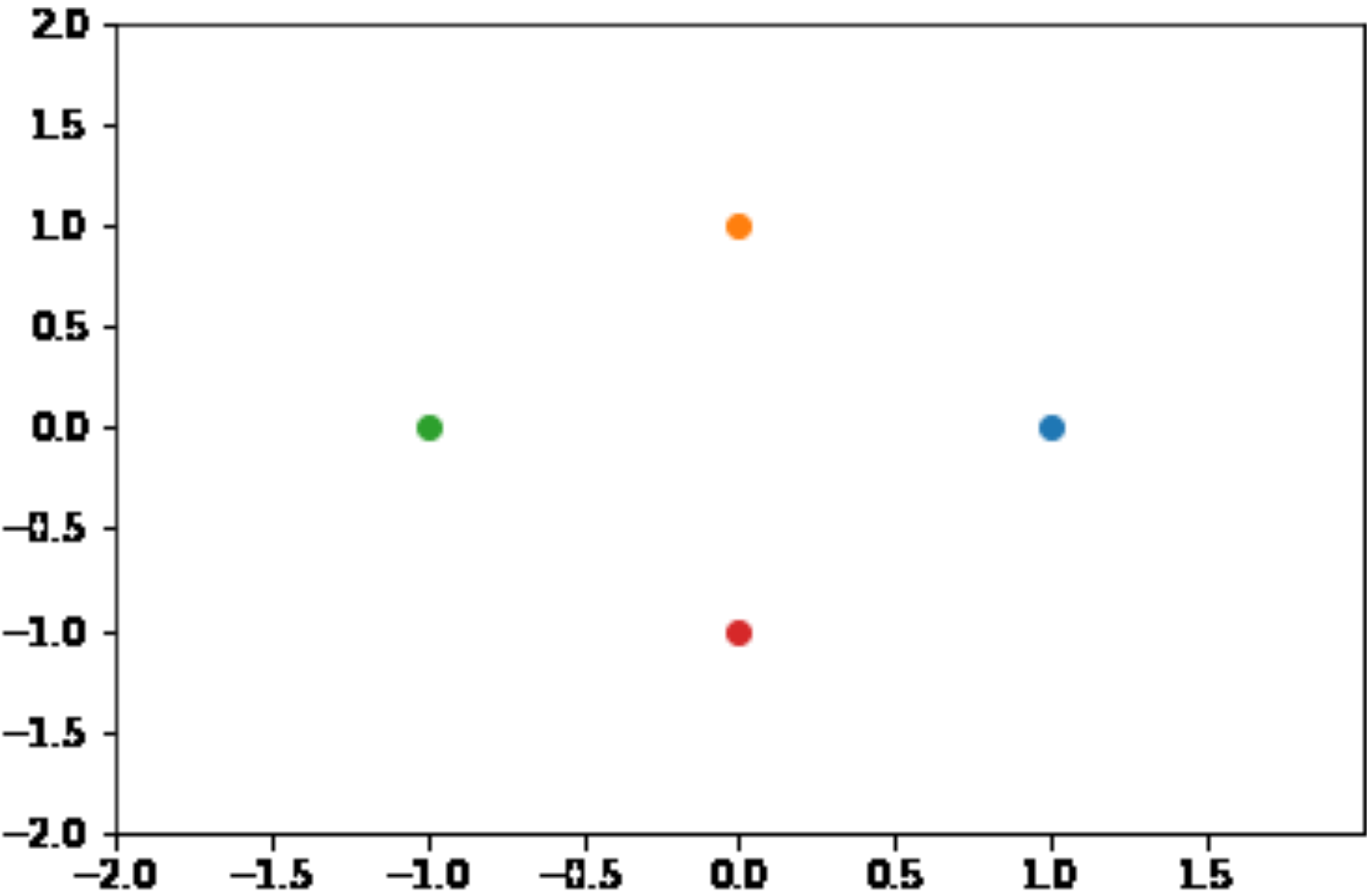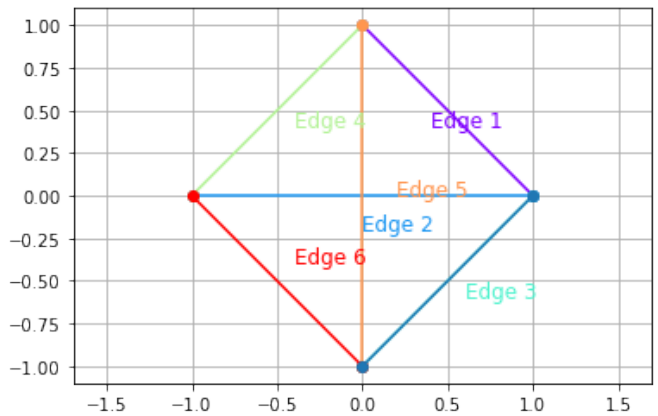
Mixing of N=3 L=6

4-Rod Mixing

Lowest entropy mixing N=4 L=4

Highest entropy mixing N=4 L=4
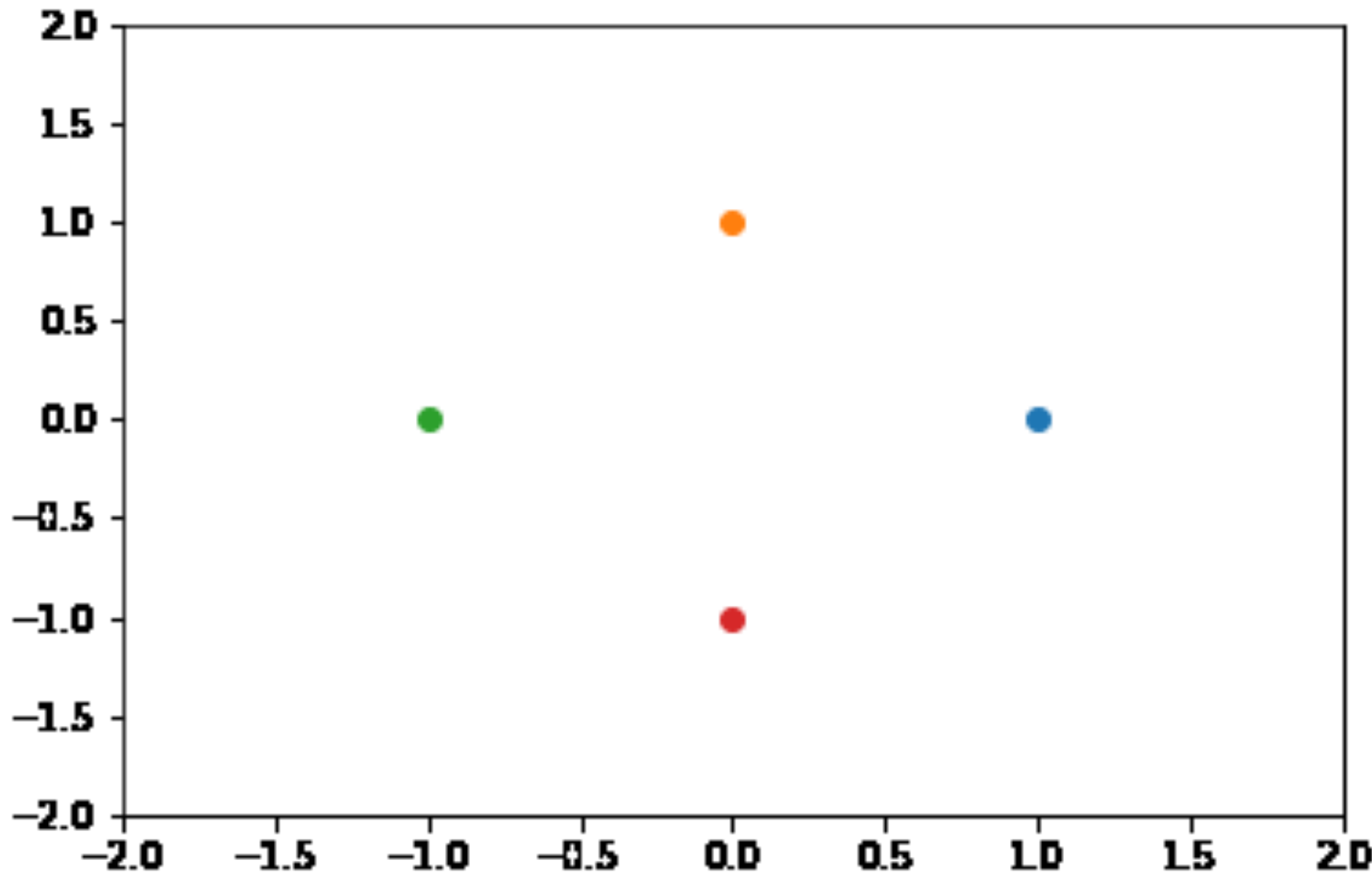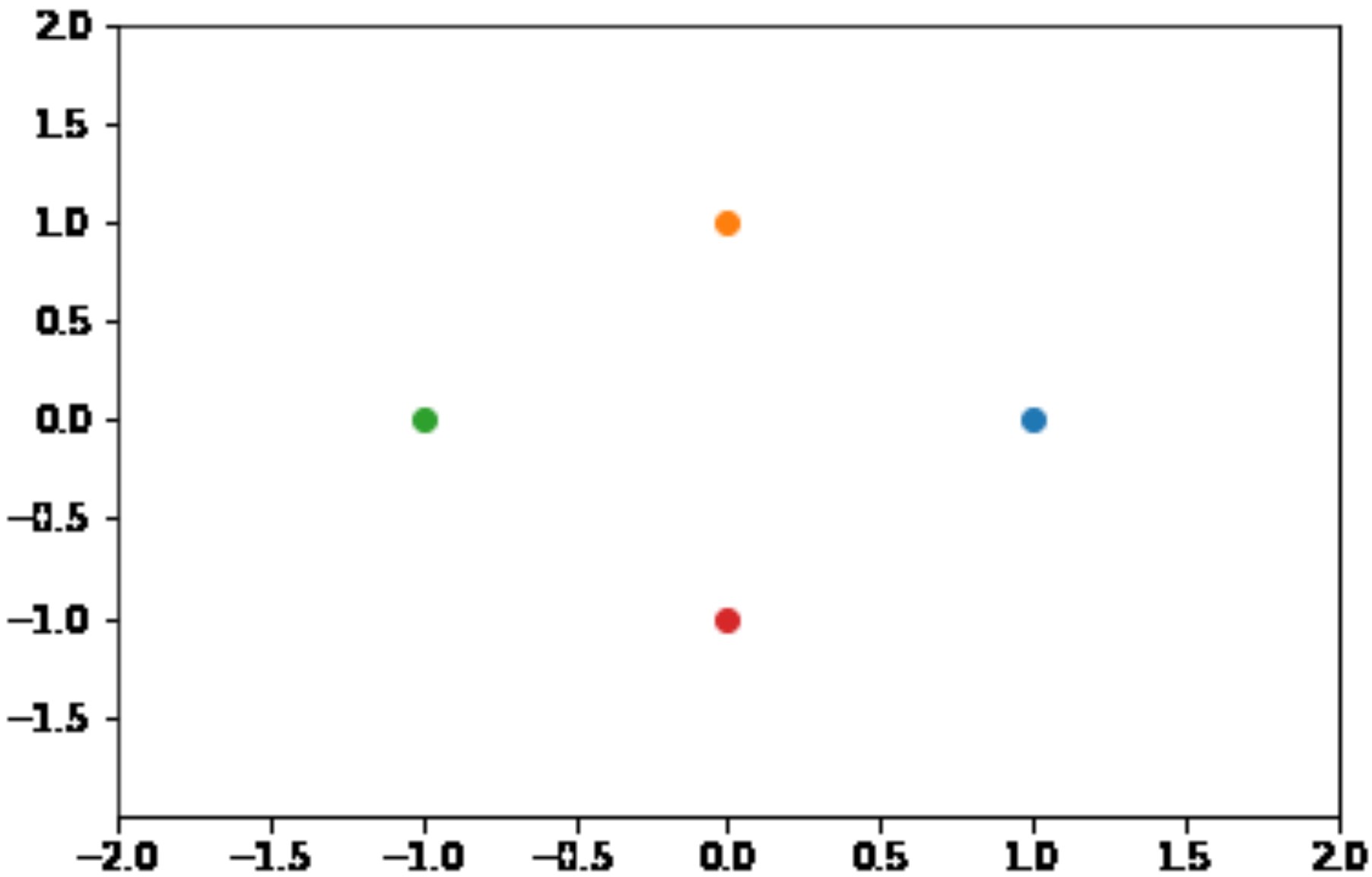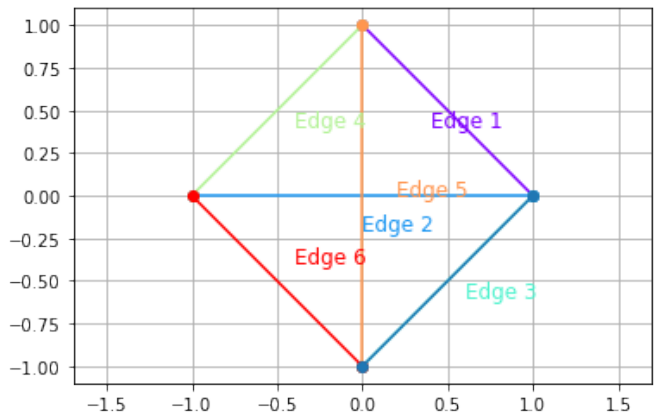
Mixing of N=4 L=4

4-Rod Mixing

Length 4 -> 5   9 hrs

5-Rod Mixing

Lowest entropy mixing N=5 L=3
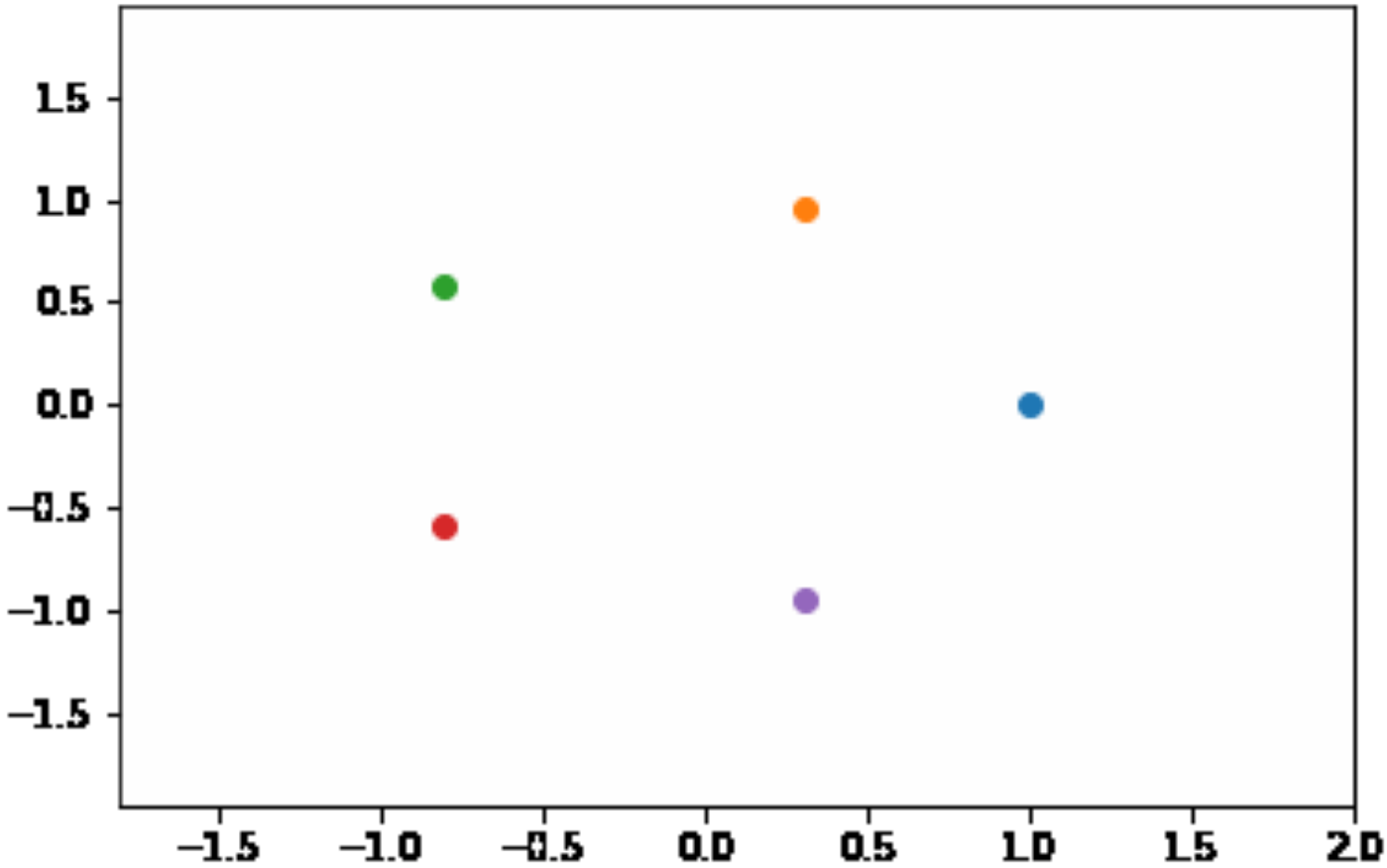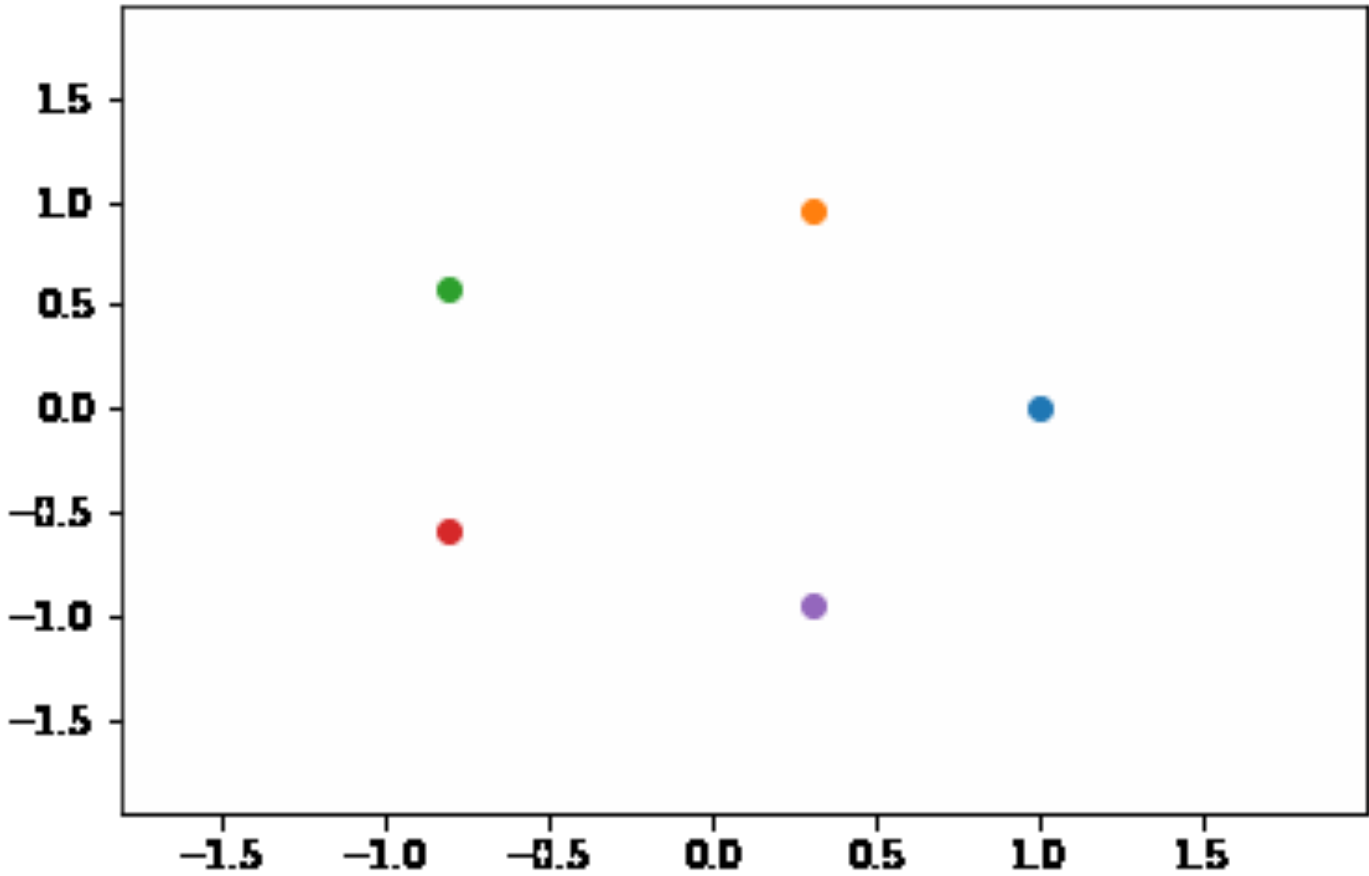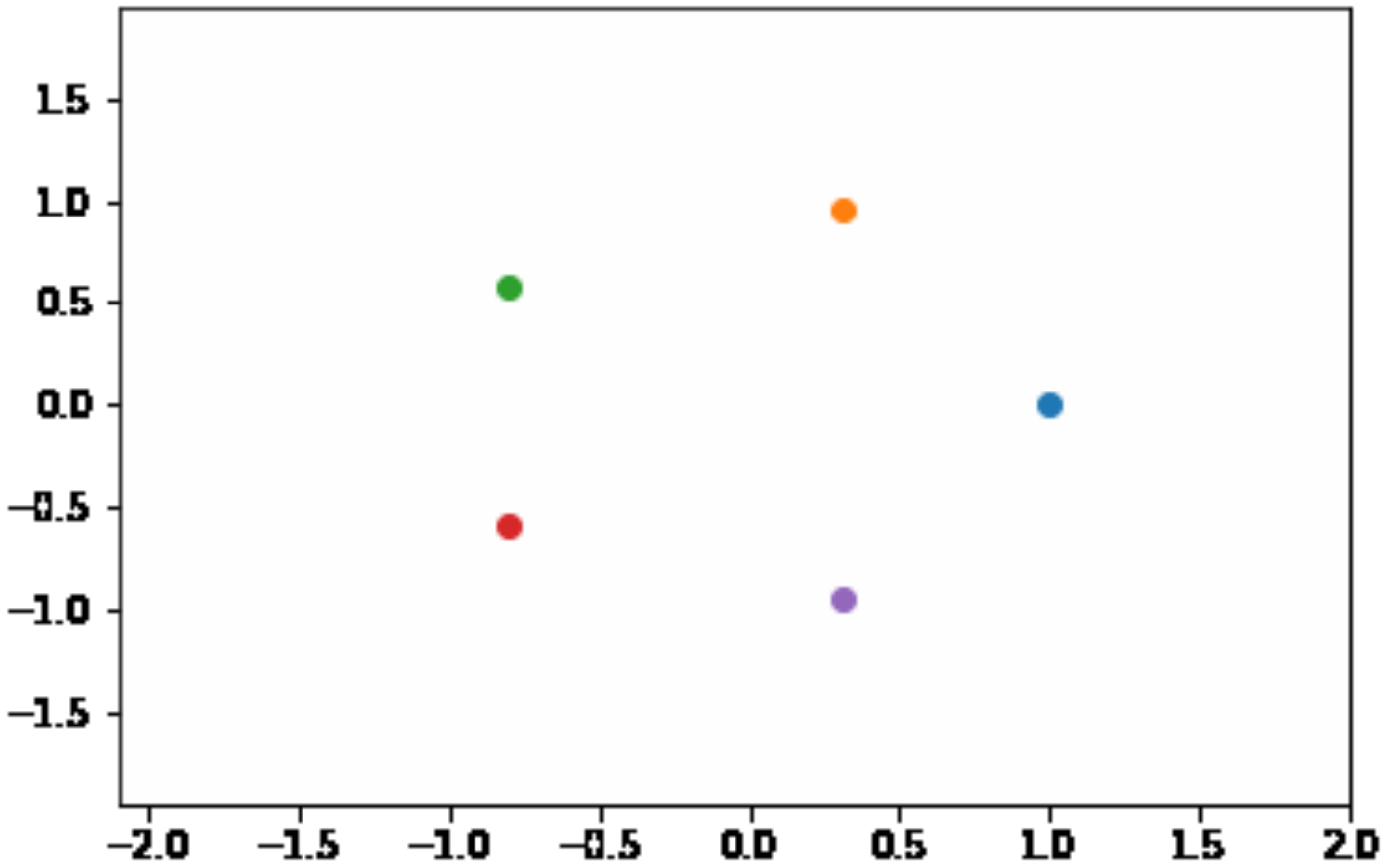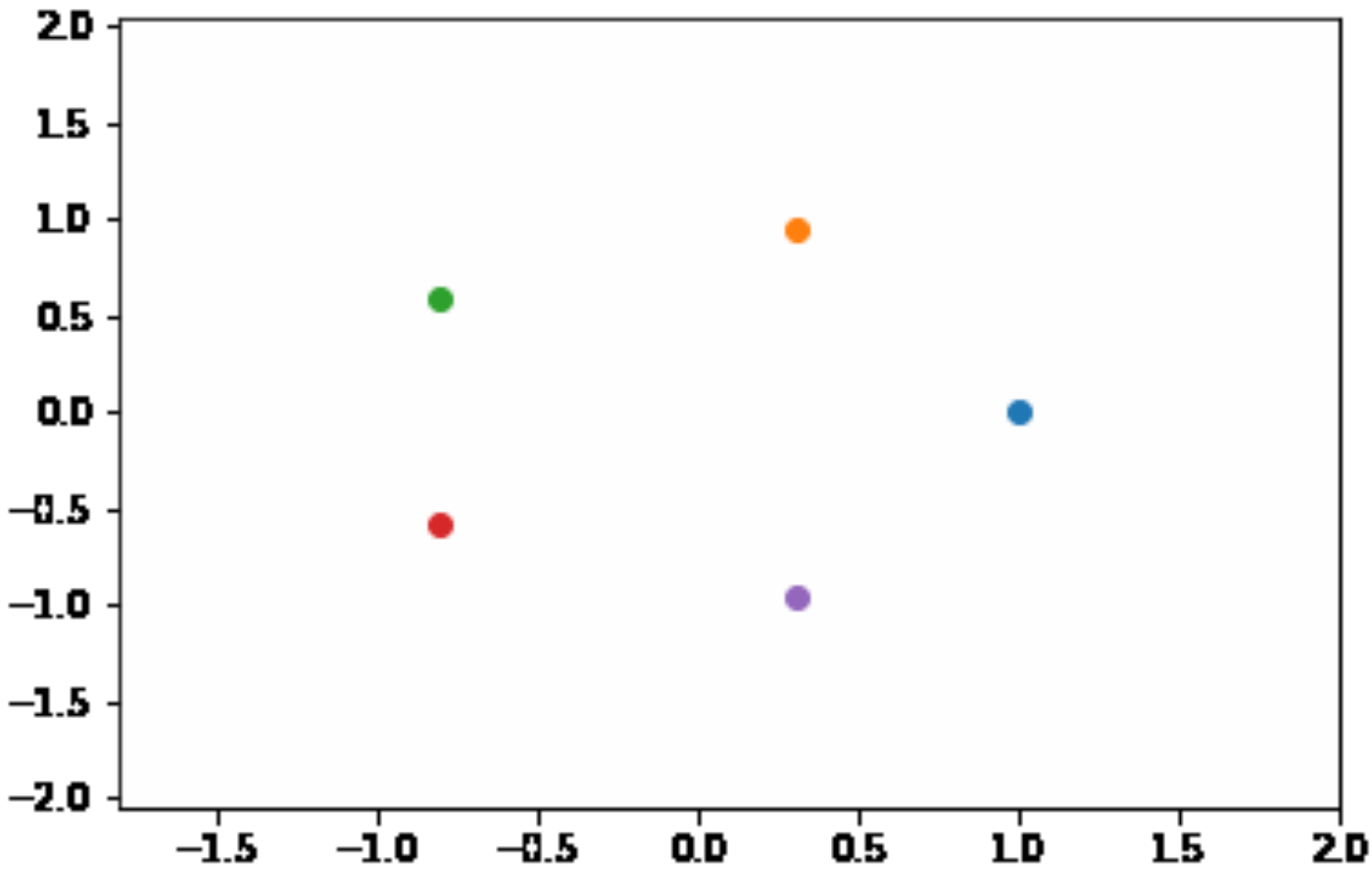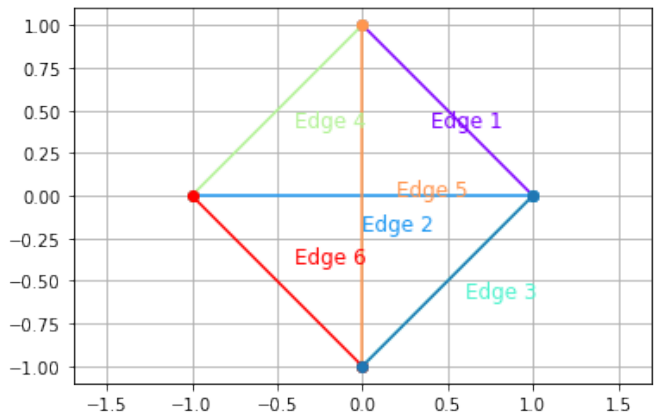
Highest entropy mixing N=5 L=3

Mixing of N=5 L=3

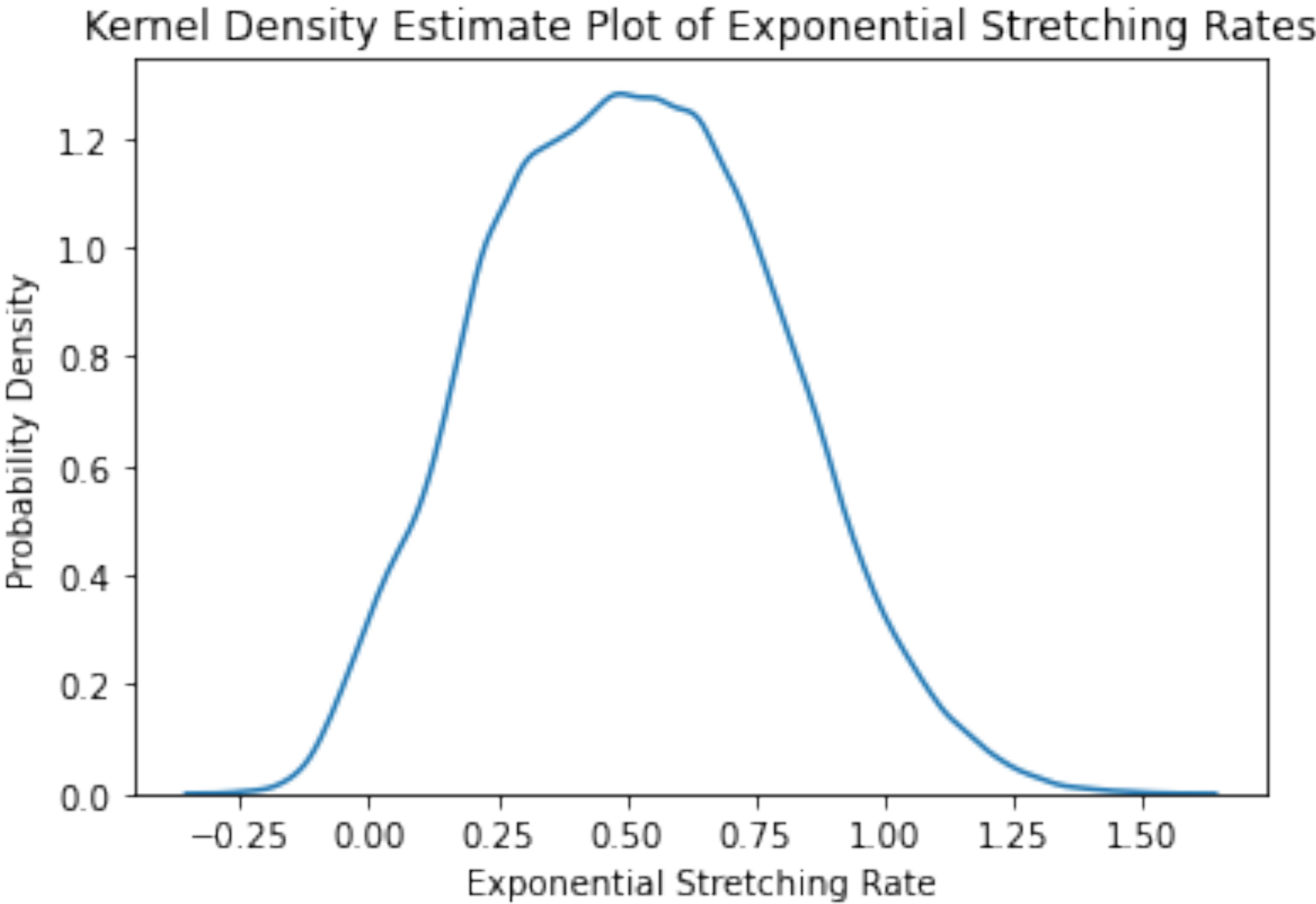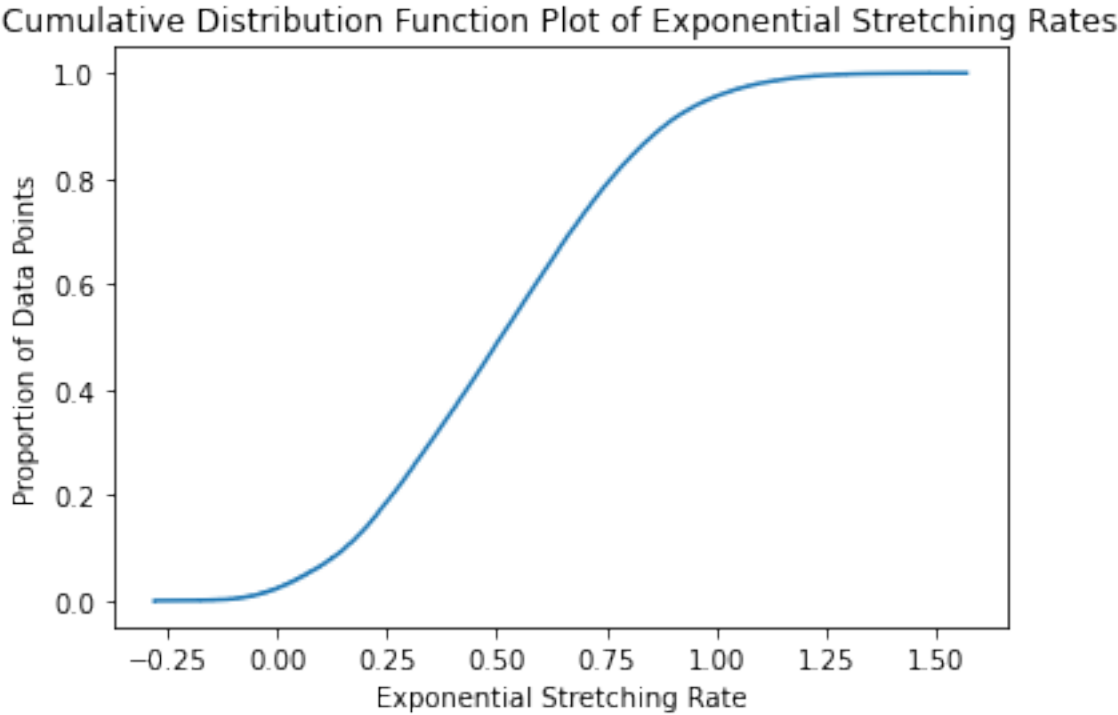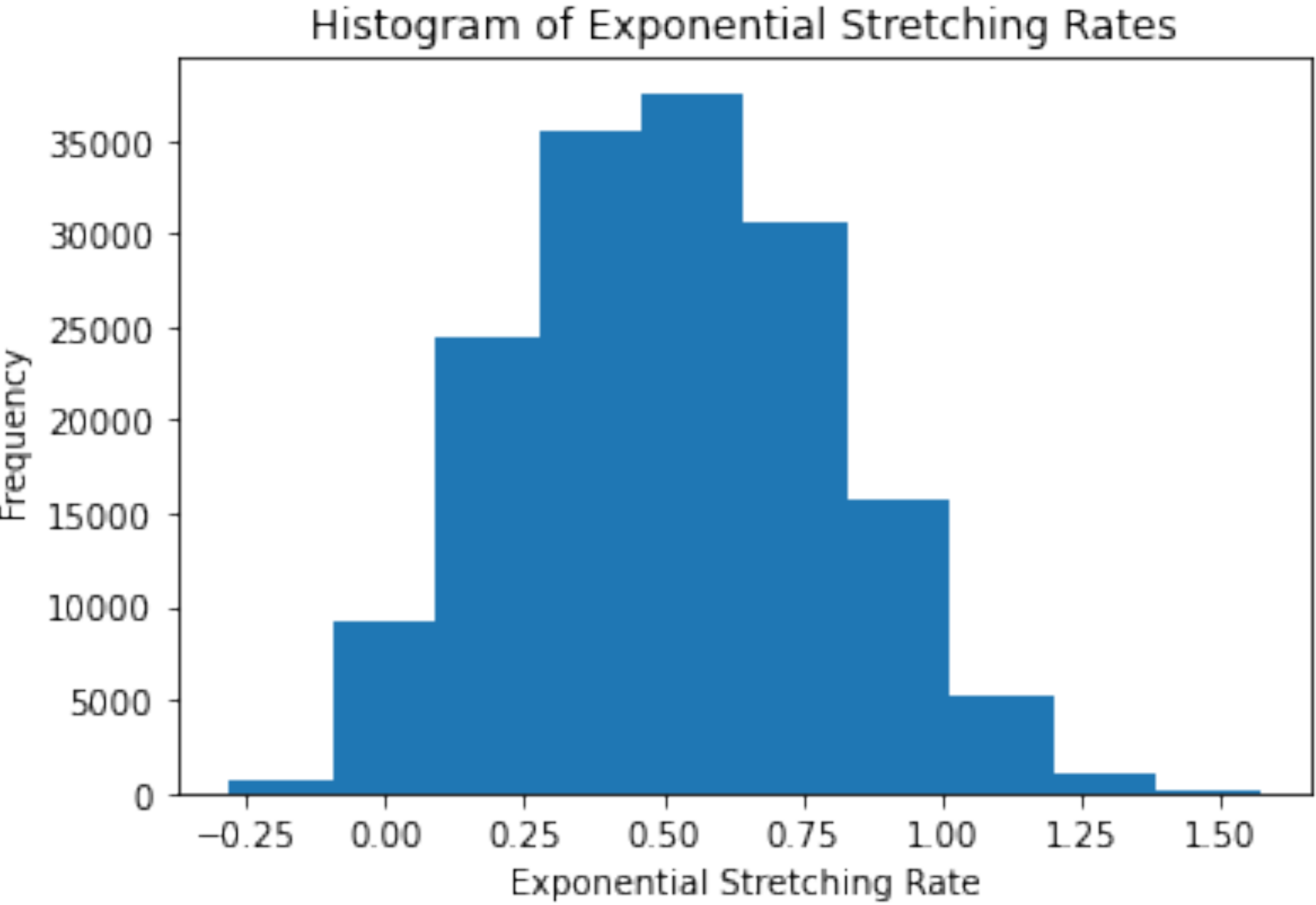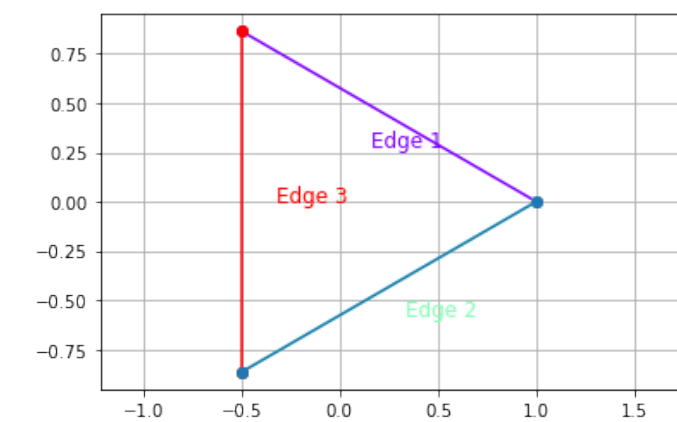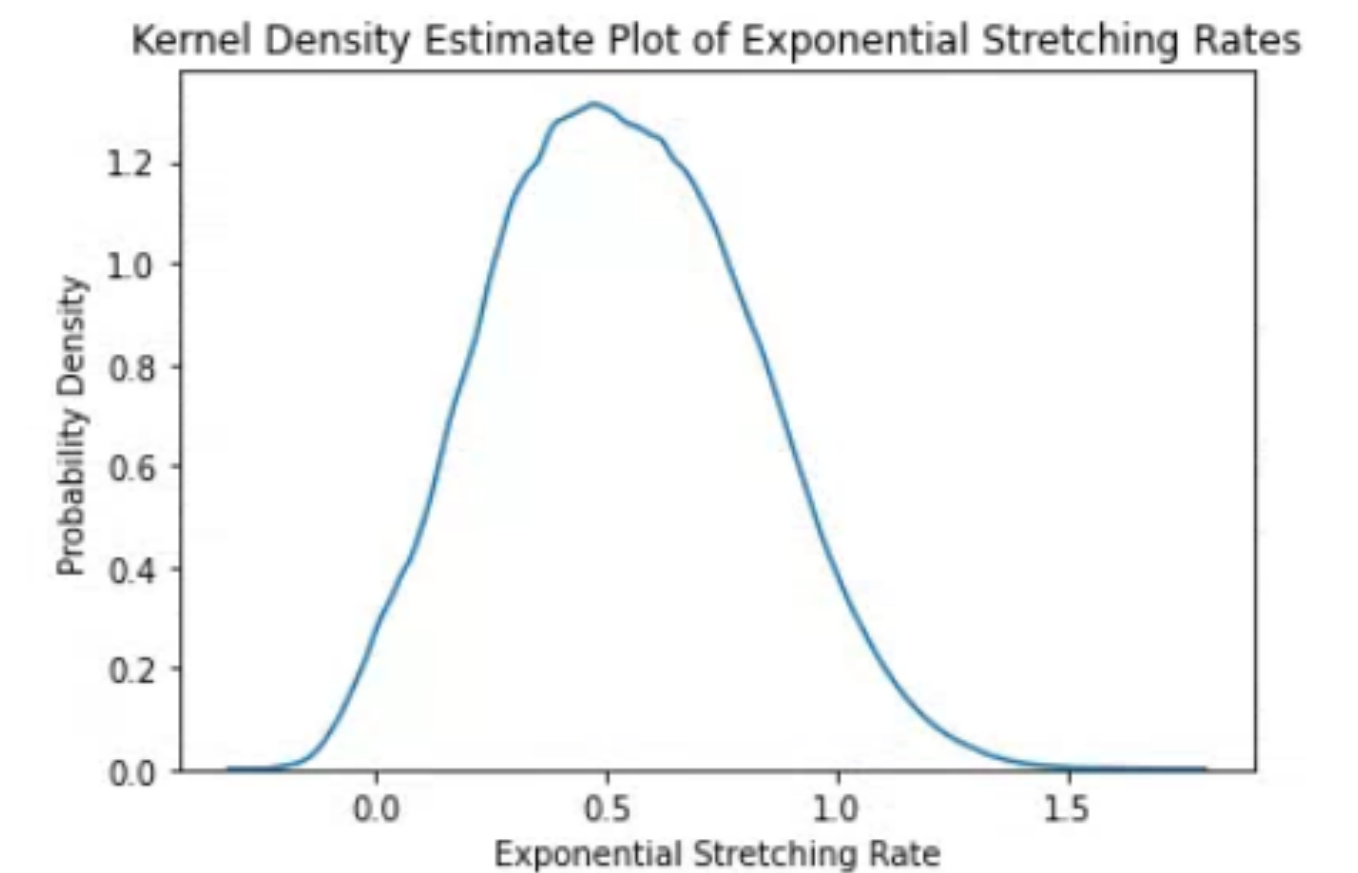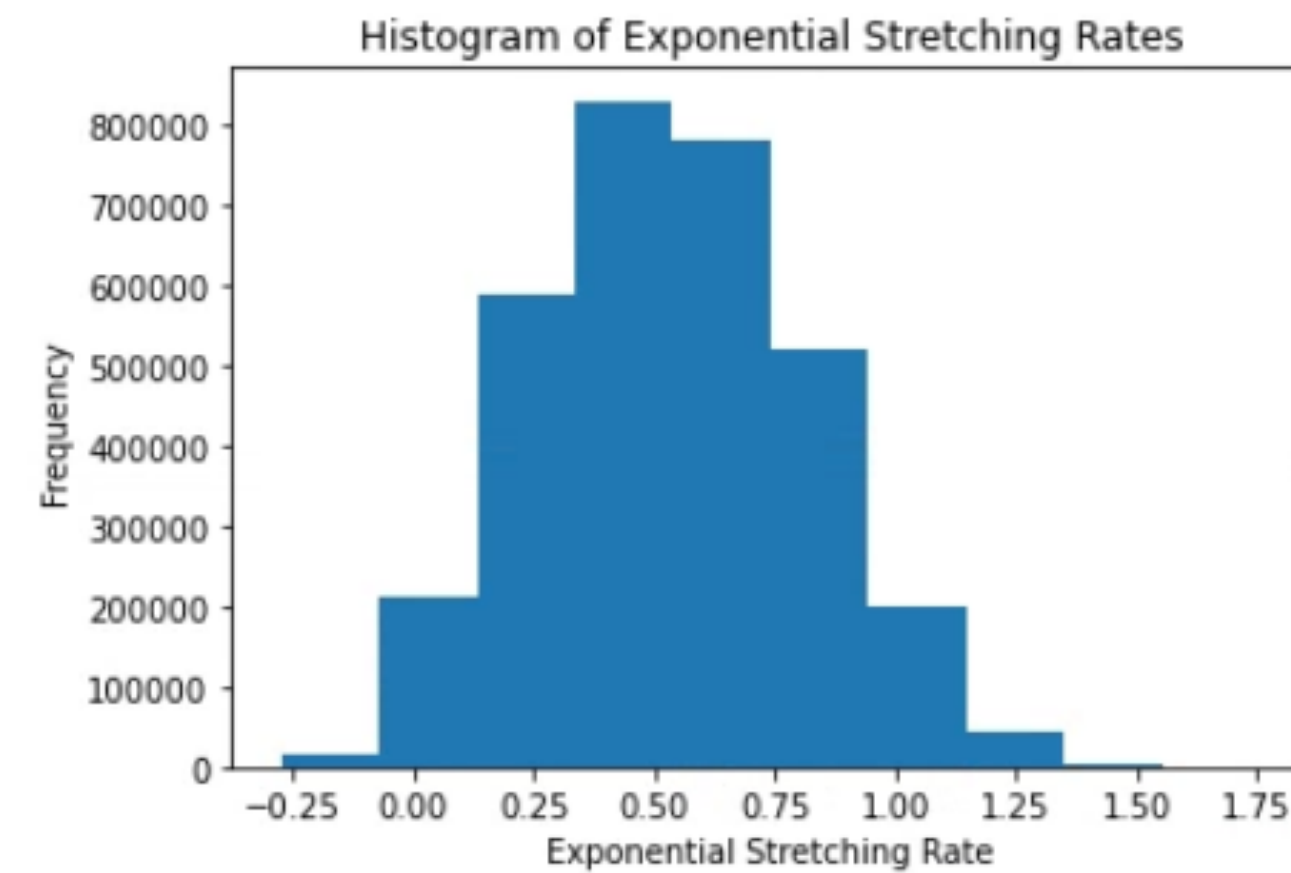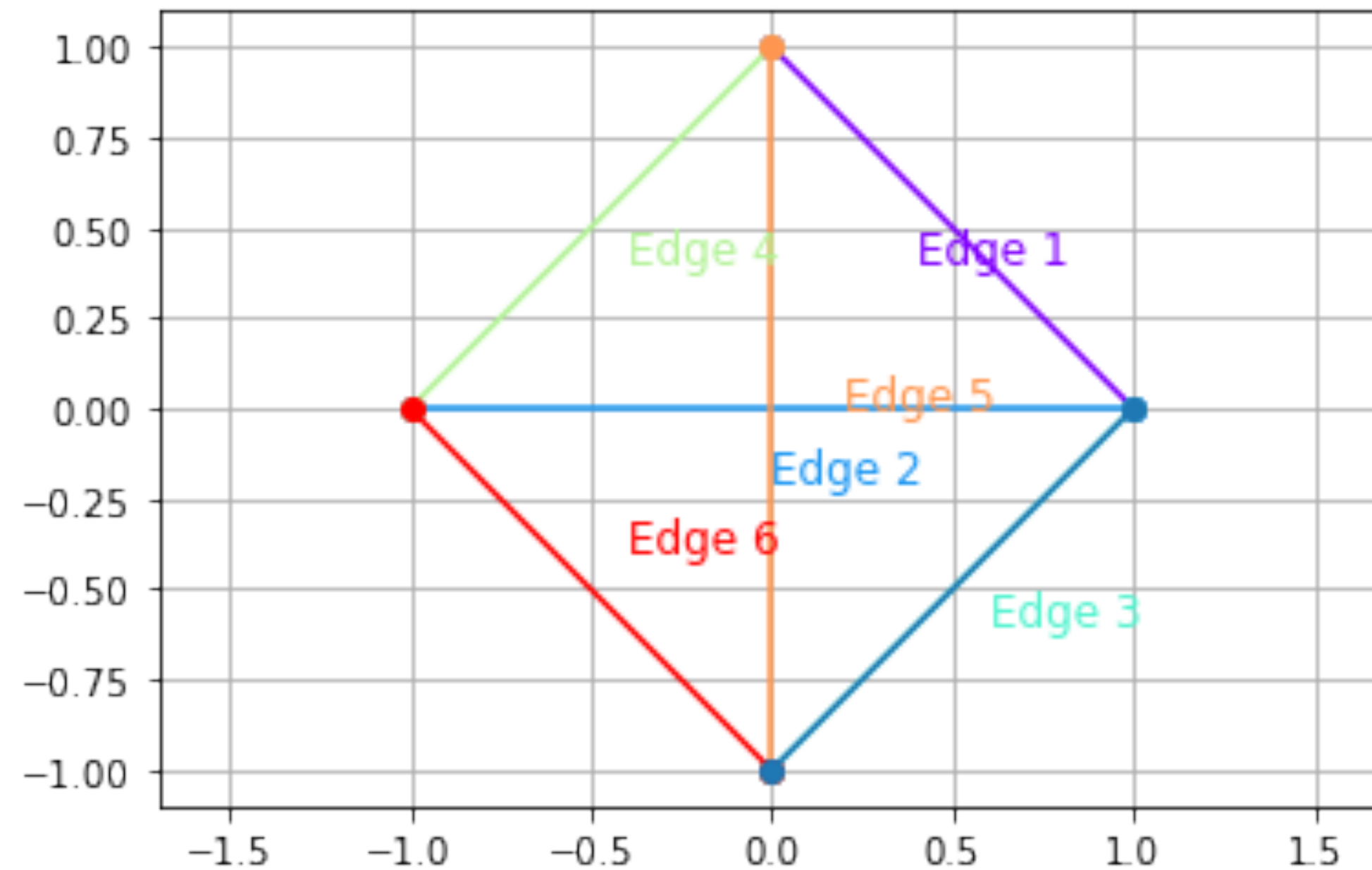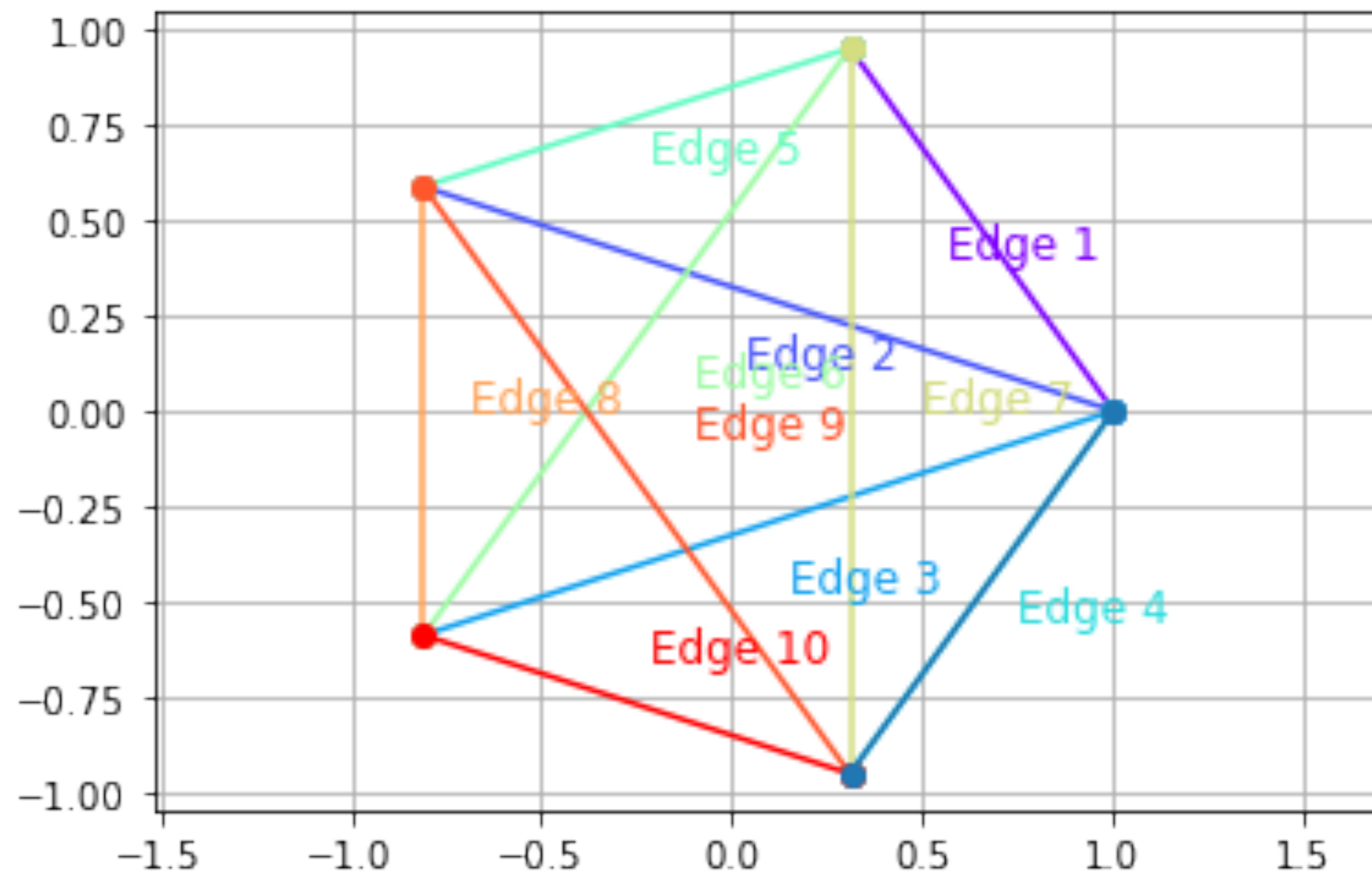Histogram of Exponential Stretching Rates
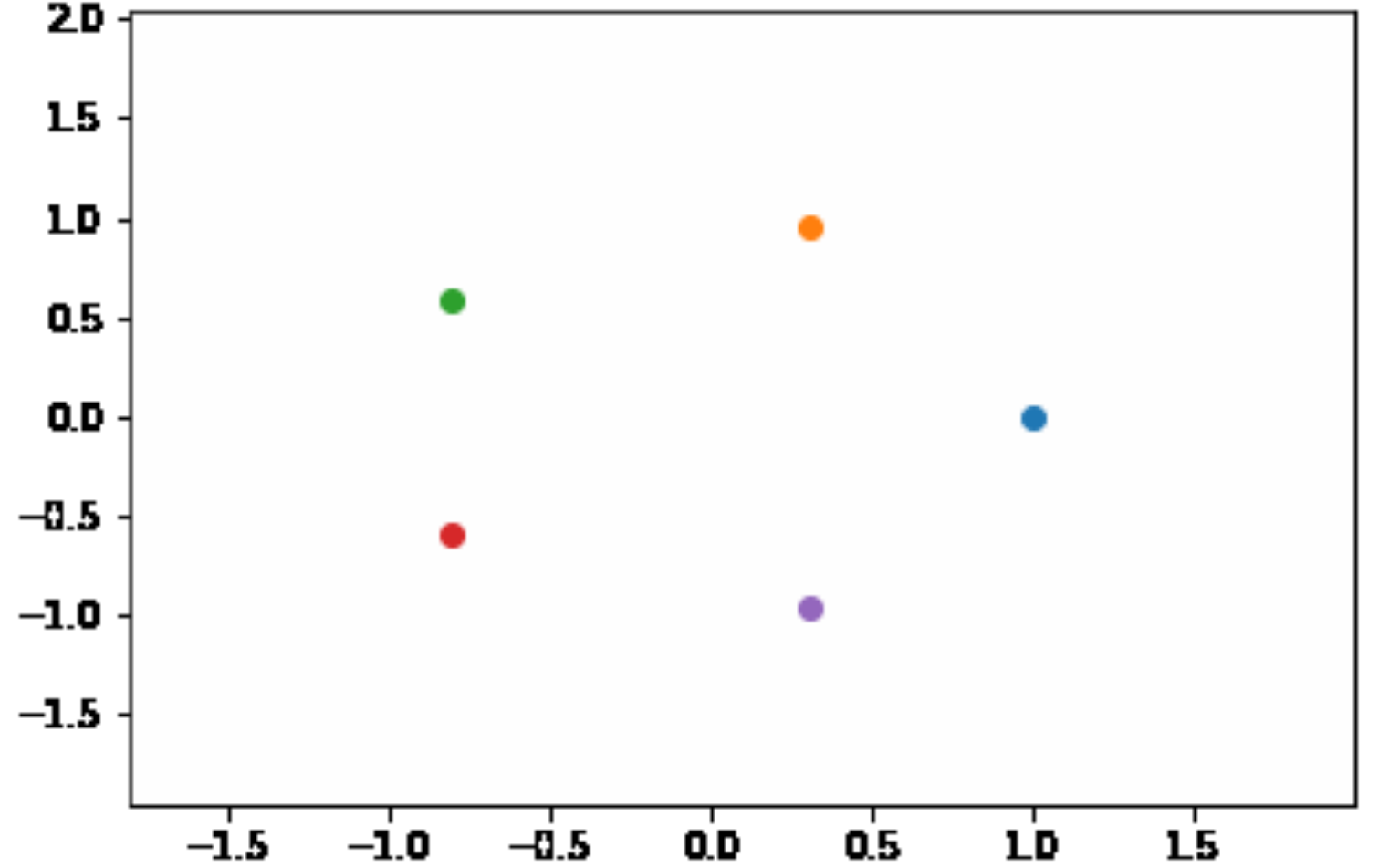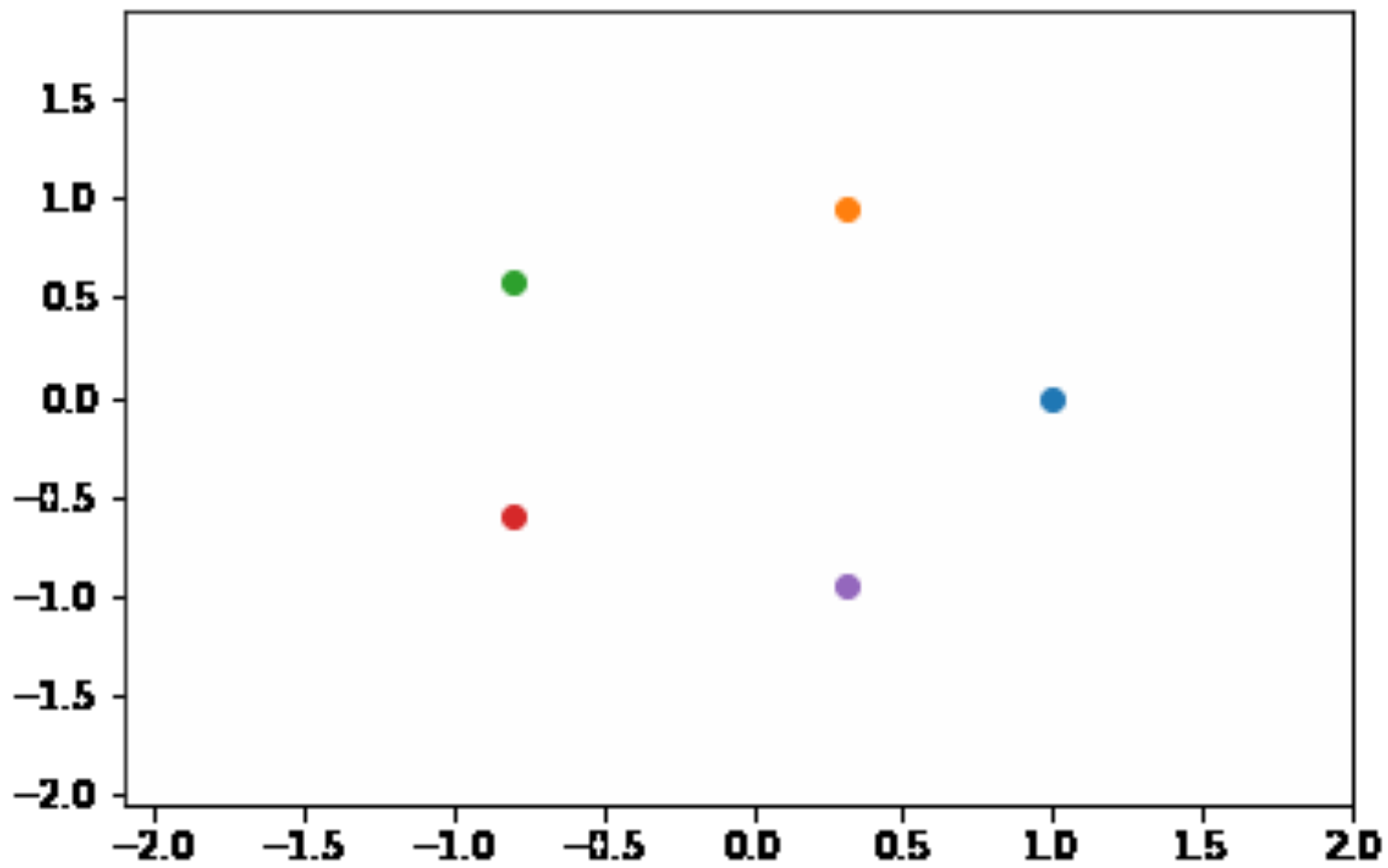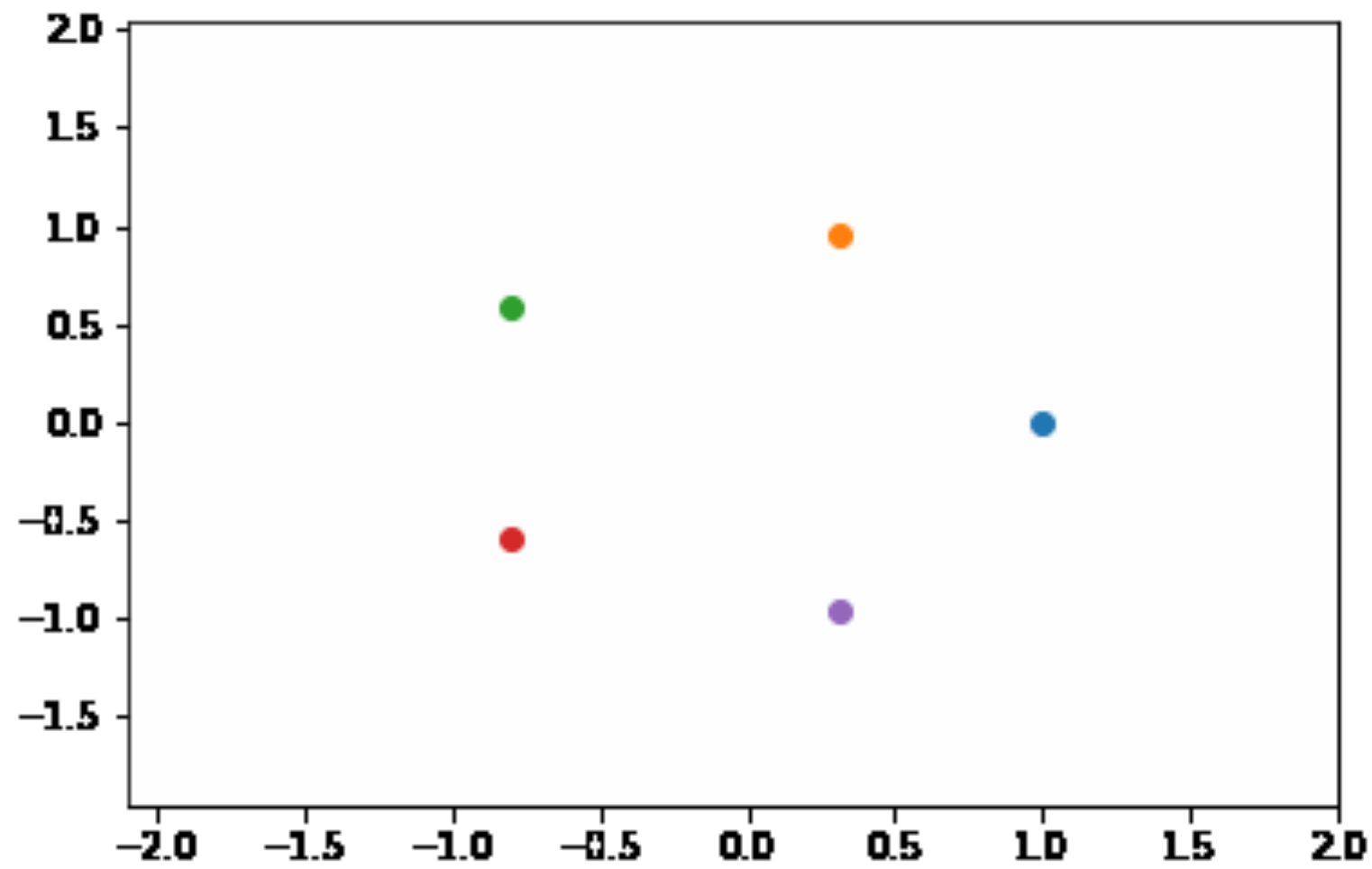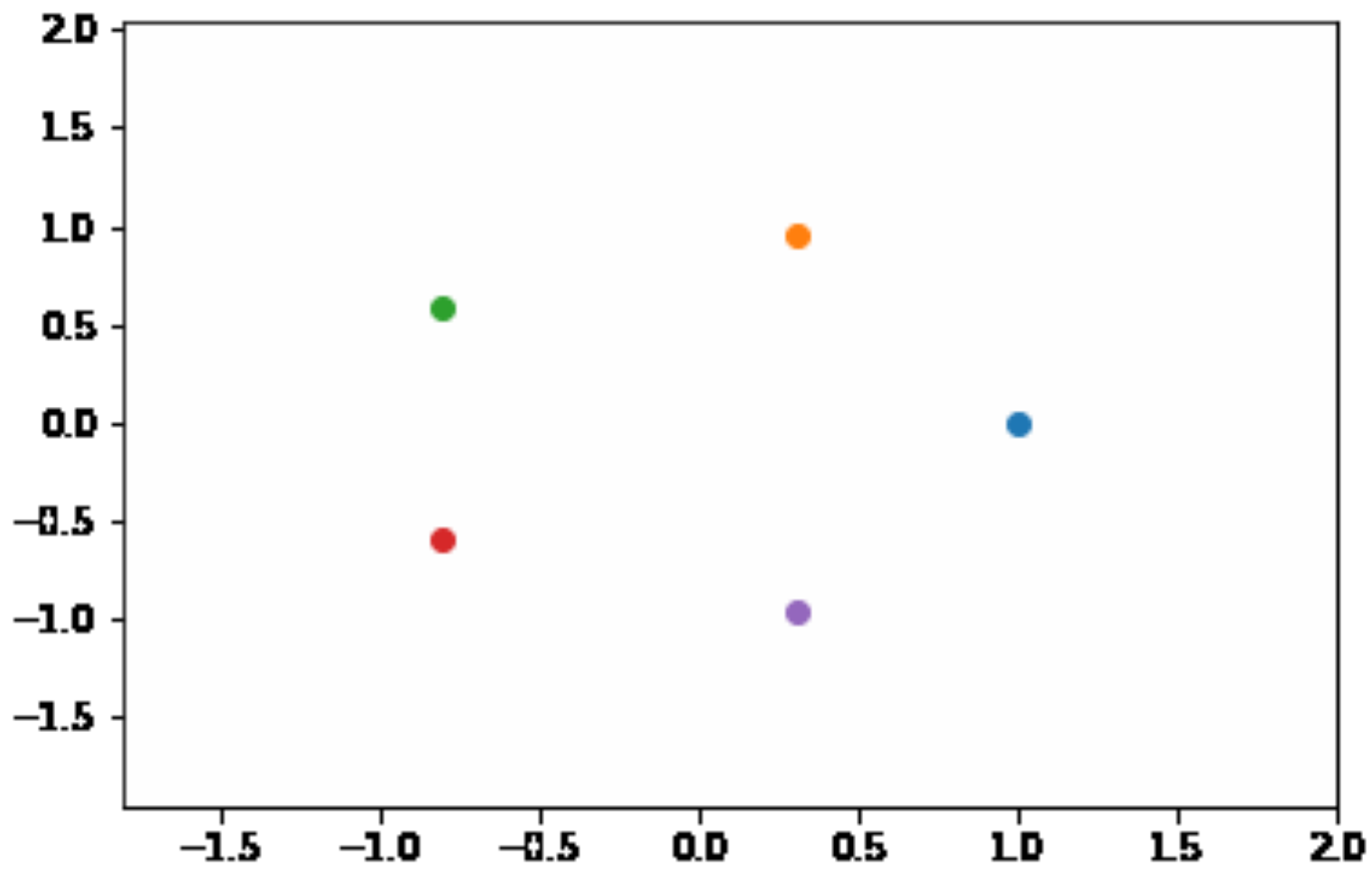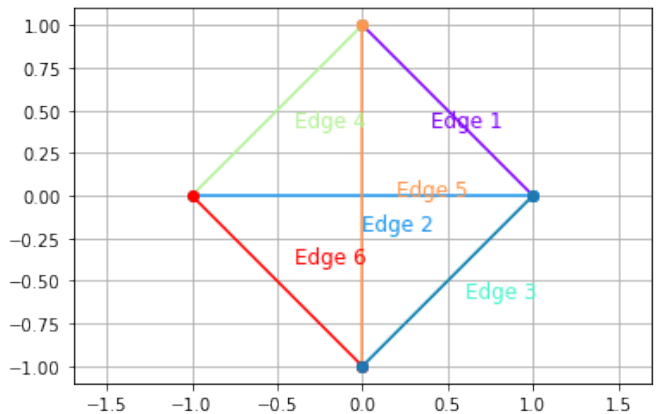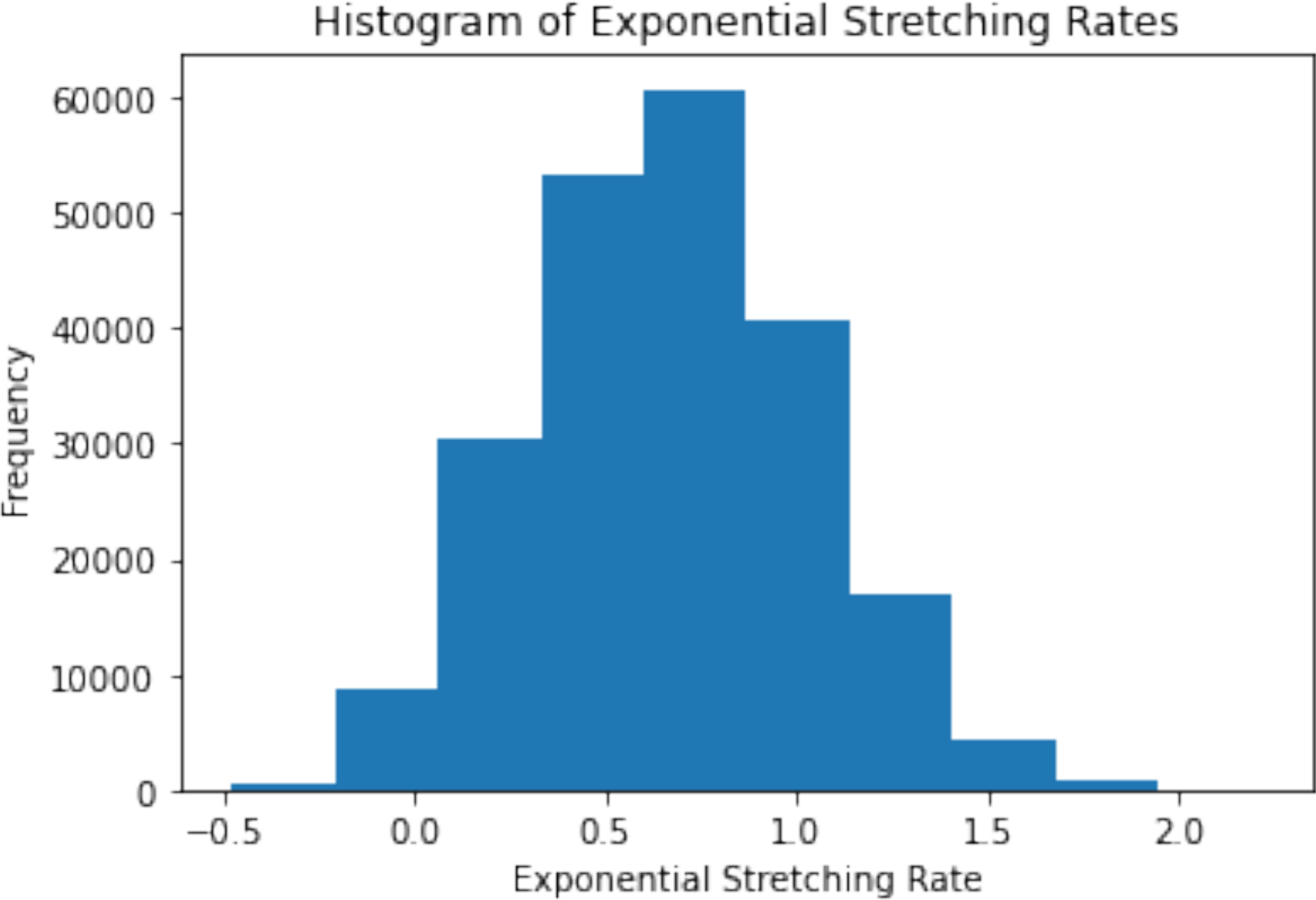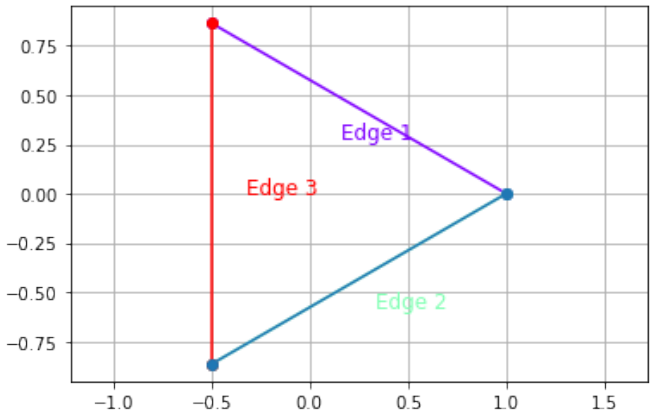
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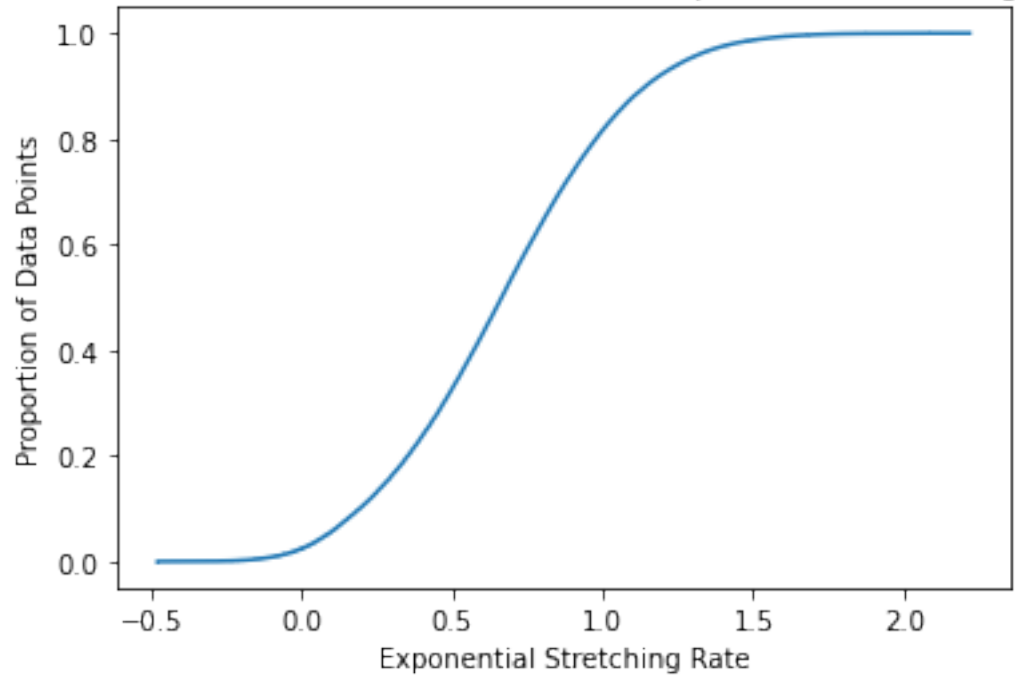
Kernel Density Estimate Plot of Exponential Stretching Rates
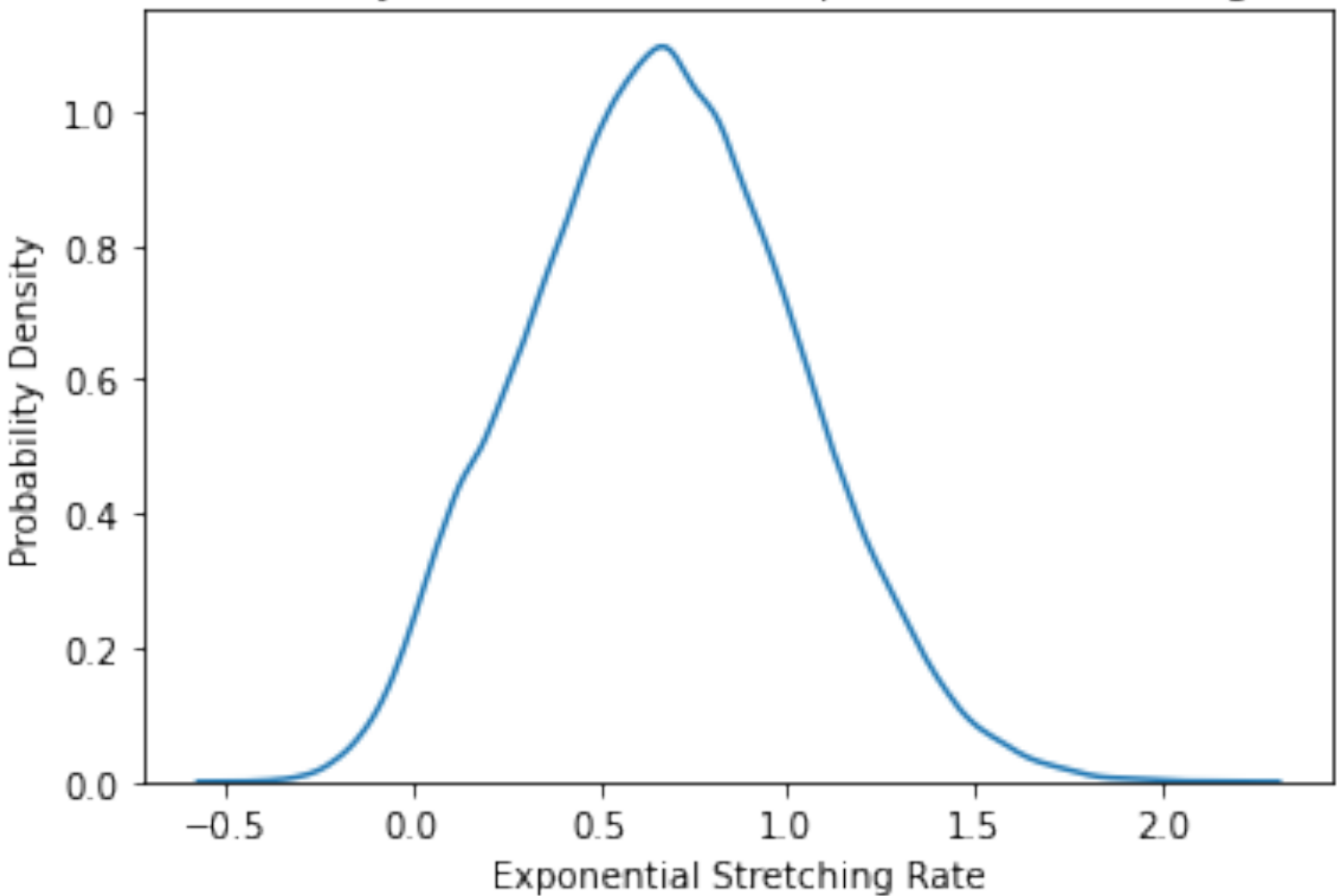
6-Rod Mixing

Computation Failed
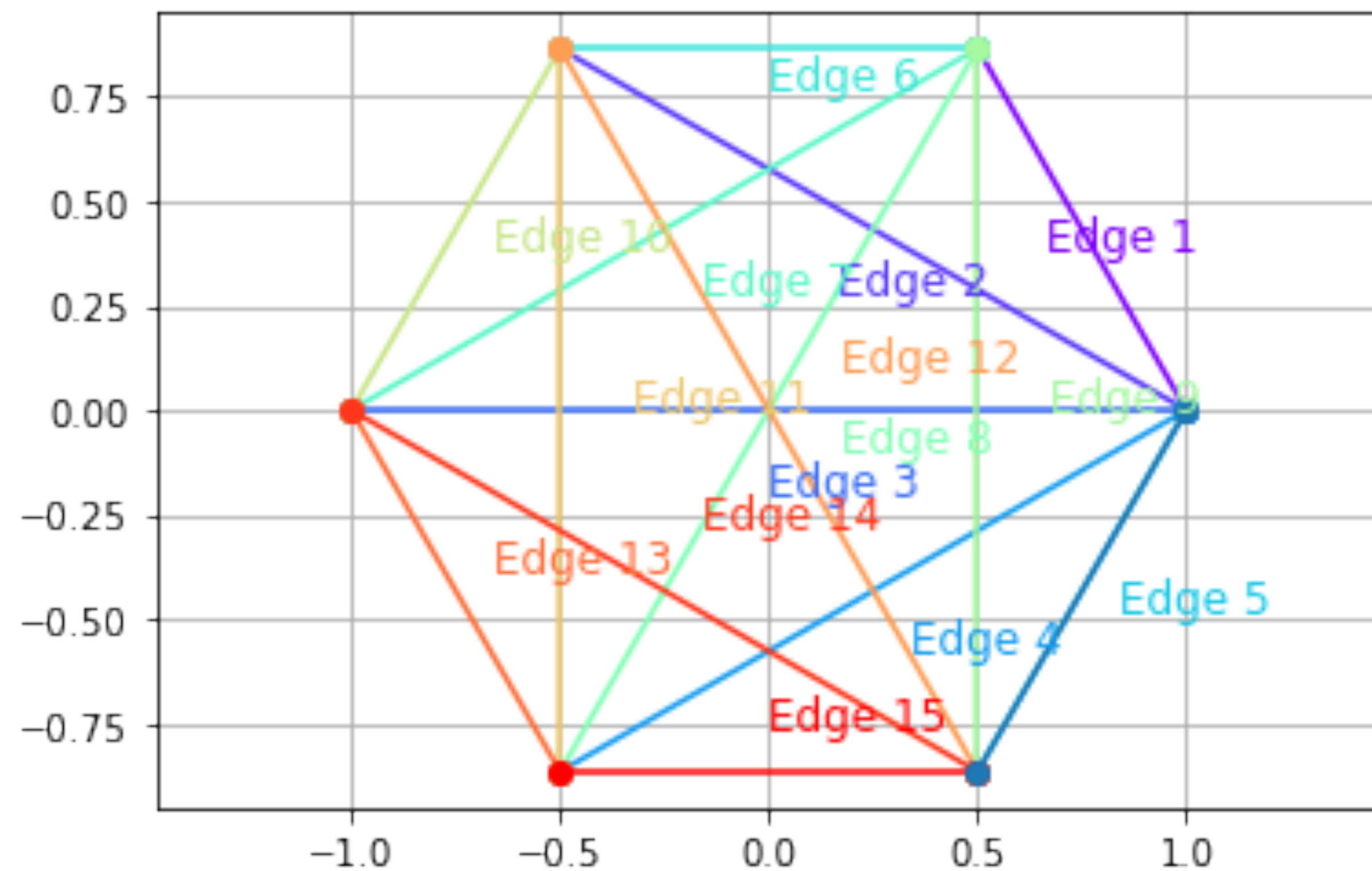
3-Rod Mixing

Length 4
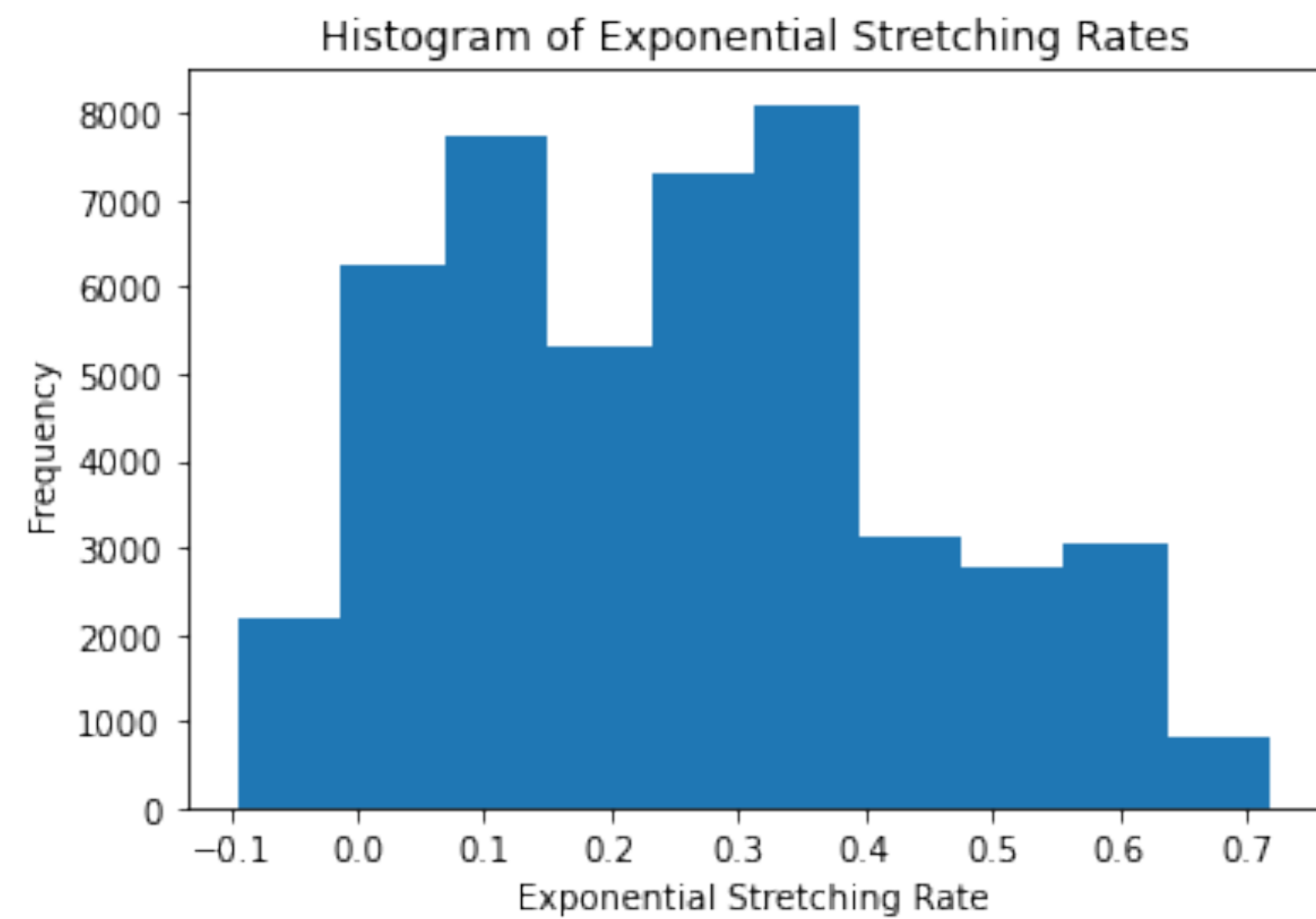
4-Rod Mixing

Length 4
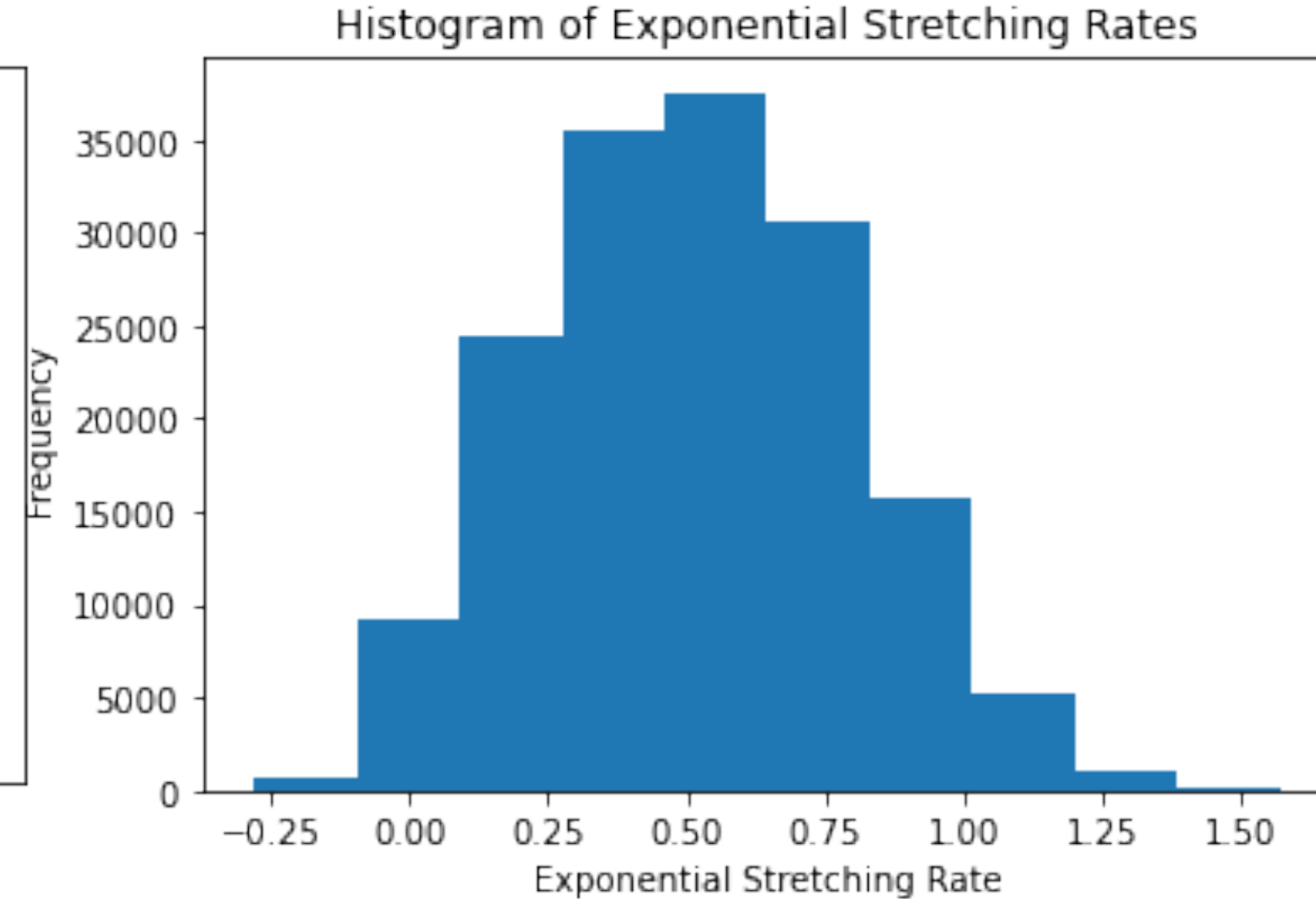
5-Rod Mixing

Length 3
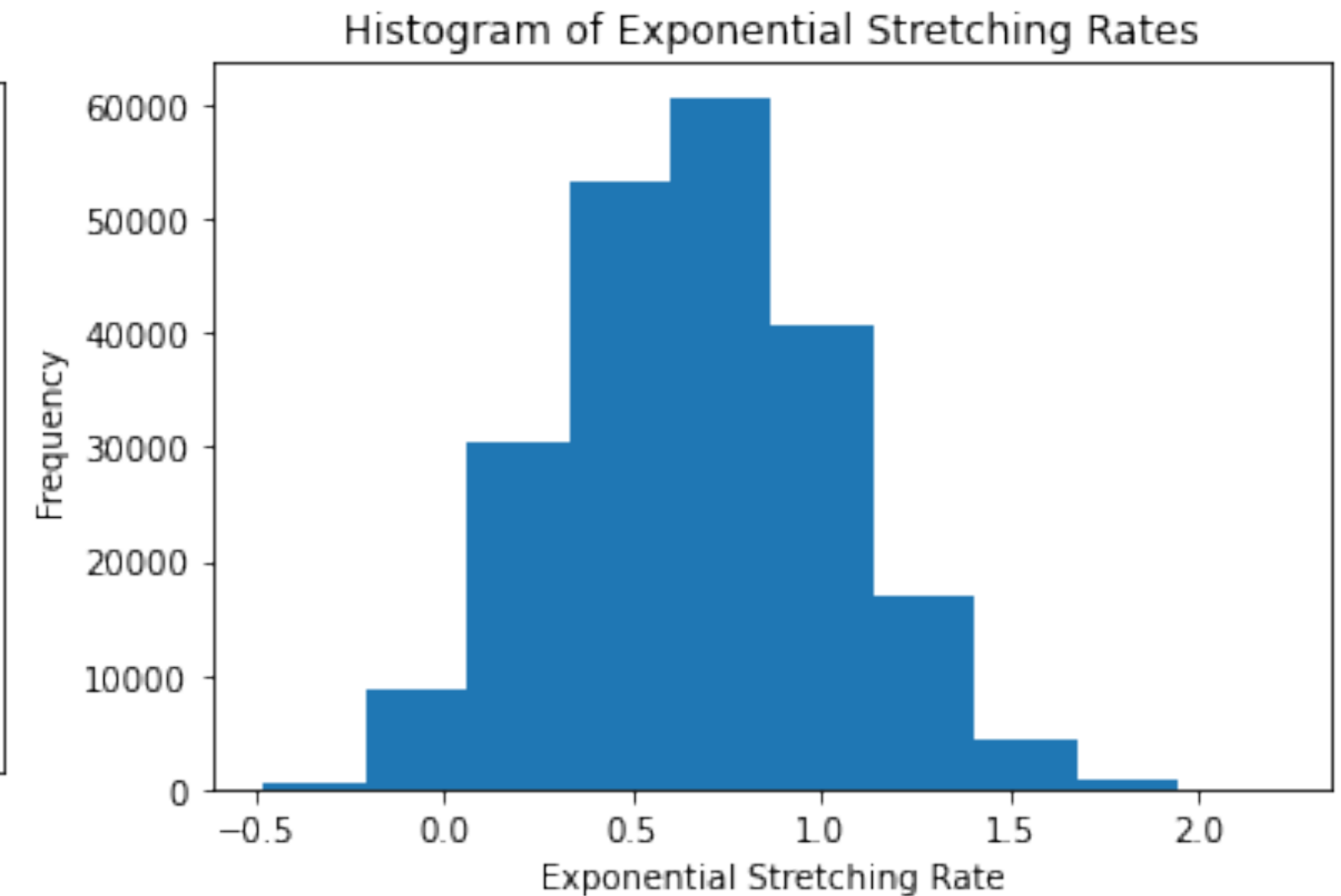
Future Steps

- Remove degeneracy

- Run for larger N and L

- Compare to experimental data

Future Steps

- Remove degeneracy

- Run for larger N and L

- Compare to experimental data

200 µm

Brownian Motion Mixing

Complete Random Motion

Jagged vs Spline Smooth

Brownian Motion Mixing

Rotational Diffusion

Translational Diffusion

Position

Velocity

Number of Walkers

Boundary Conditions

Brownian Motion Mixing

Rotational Diffusion
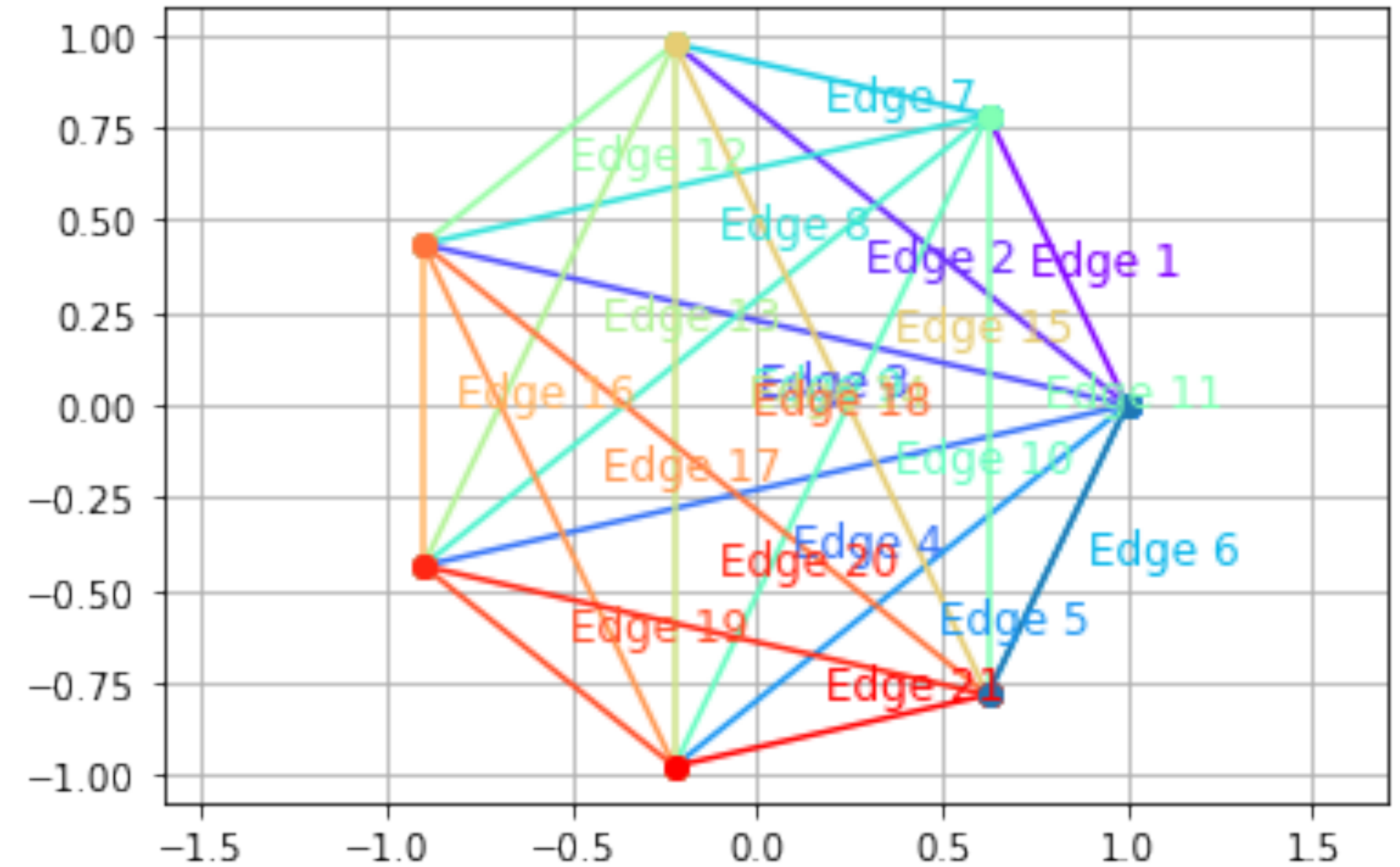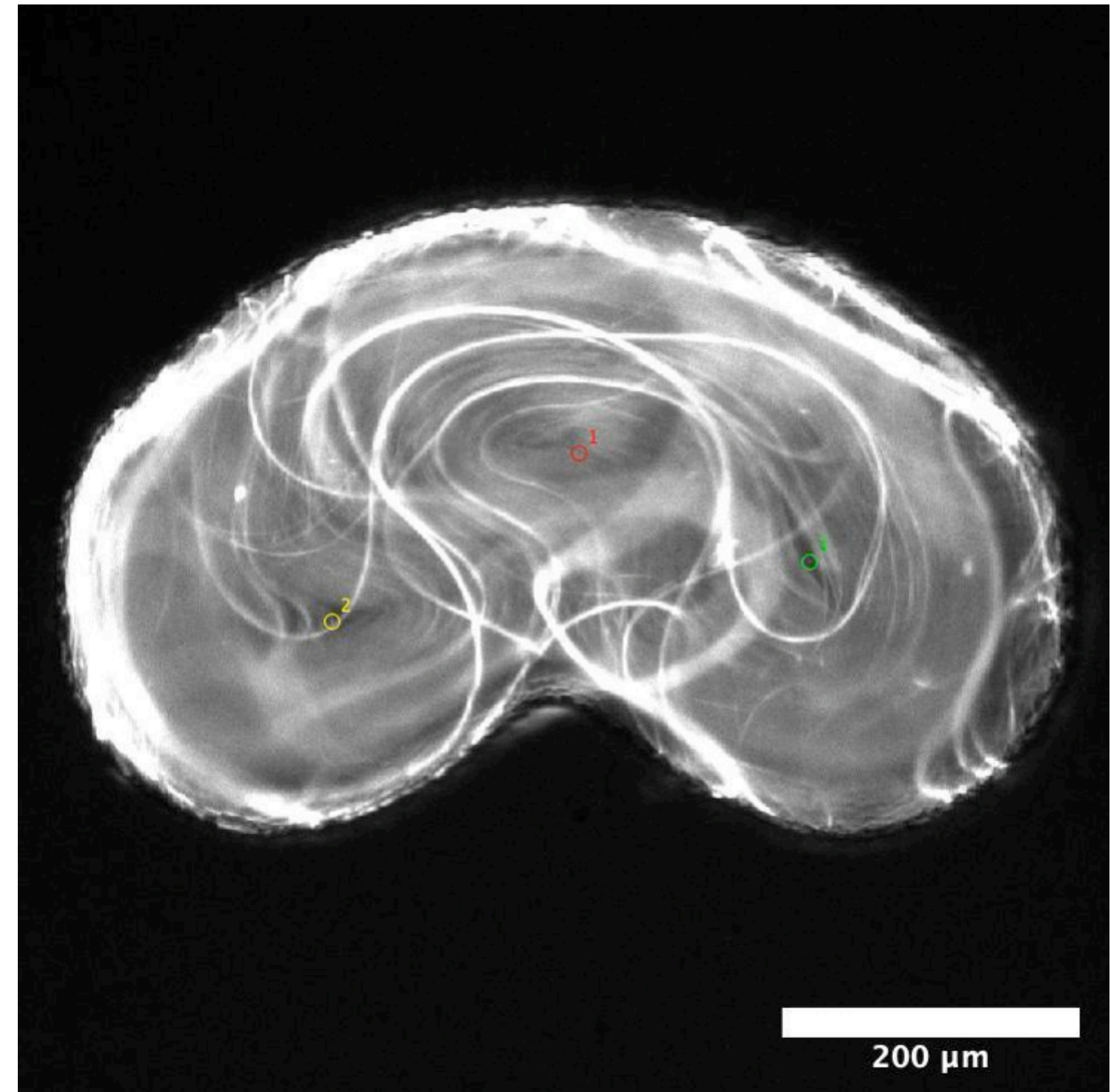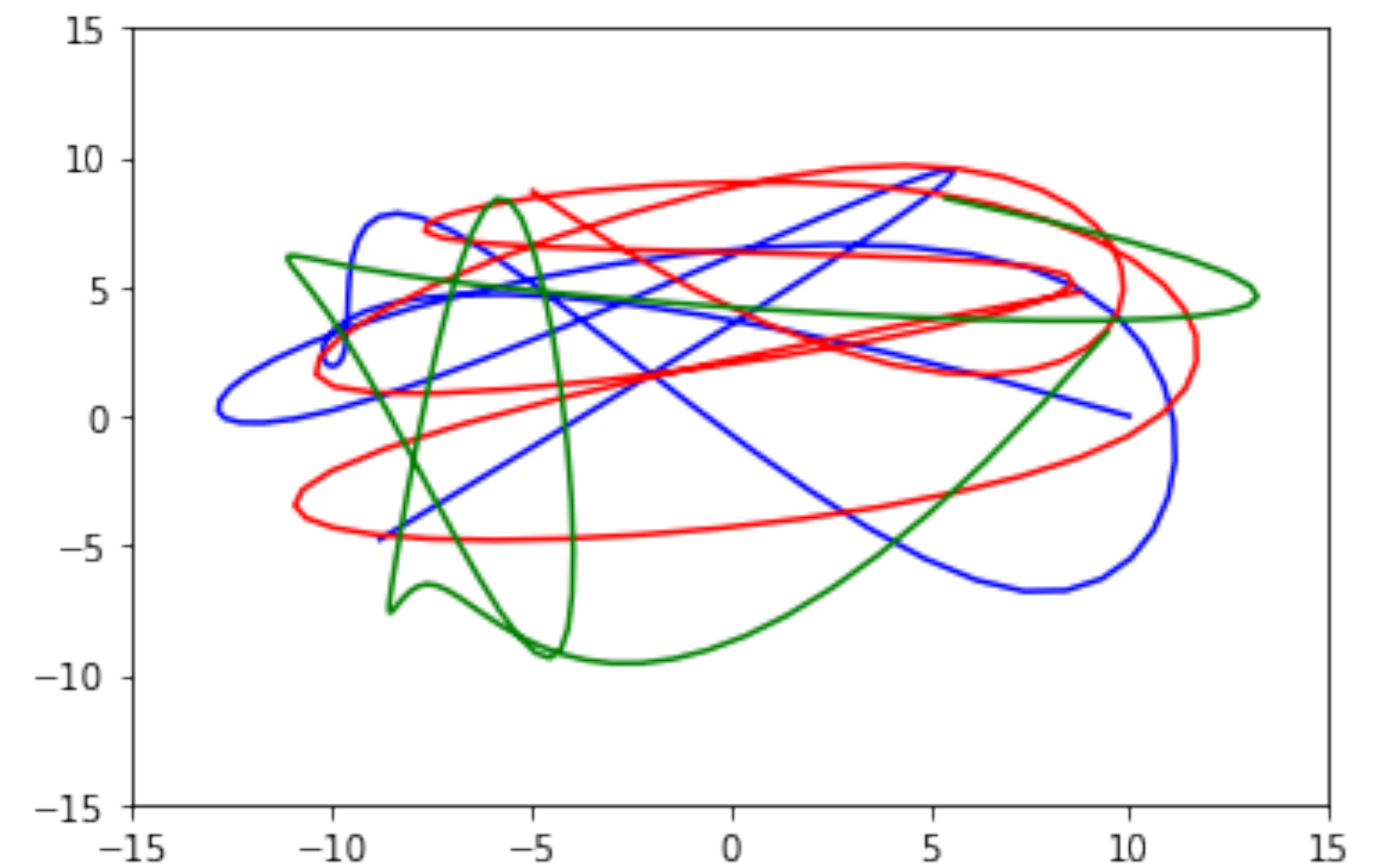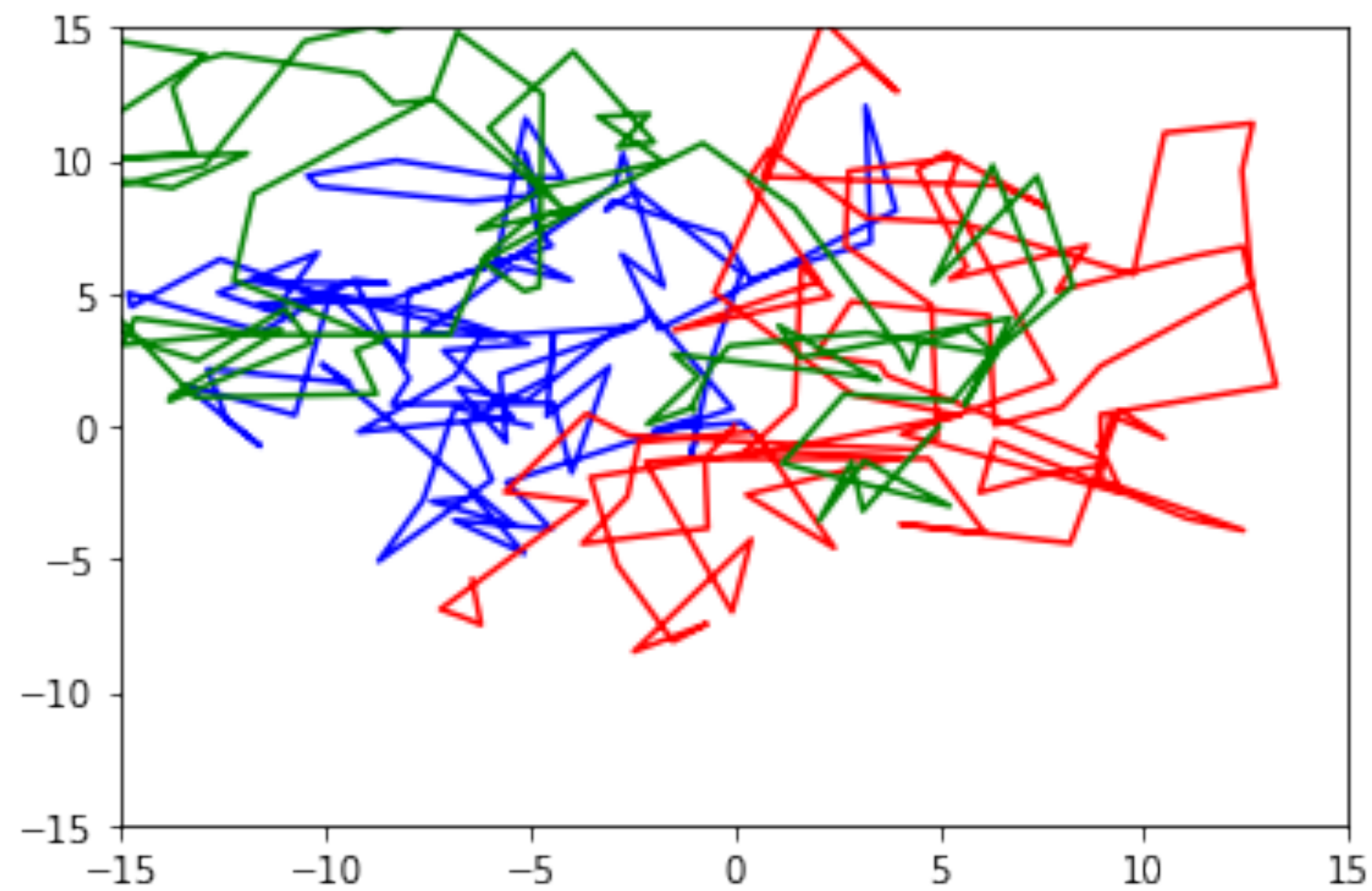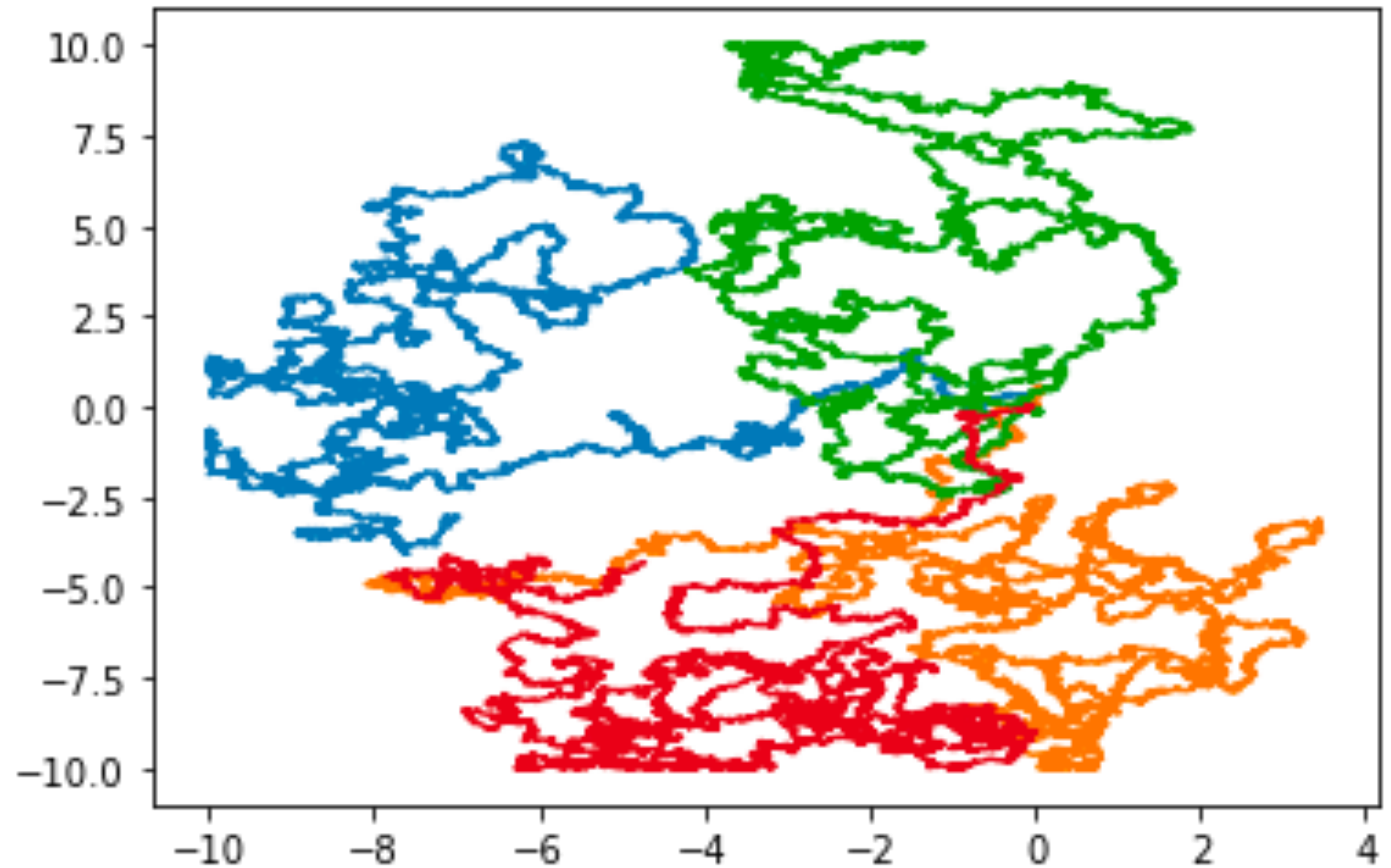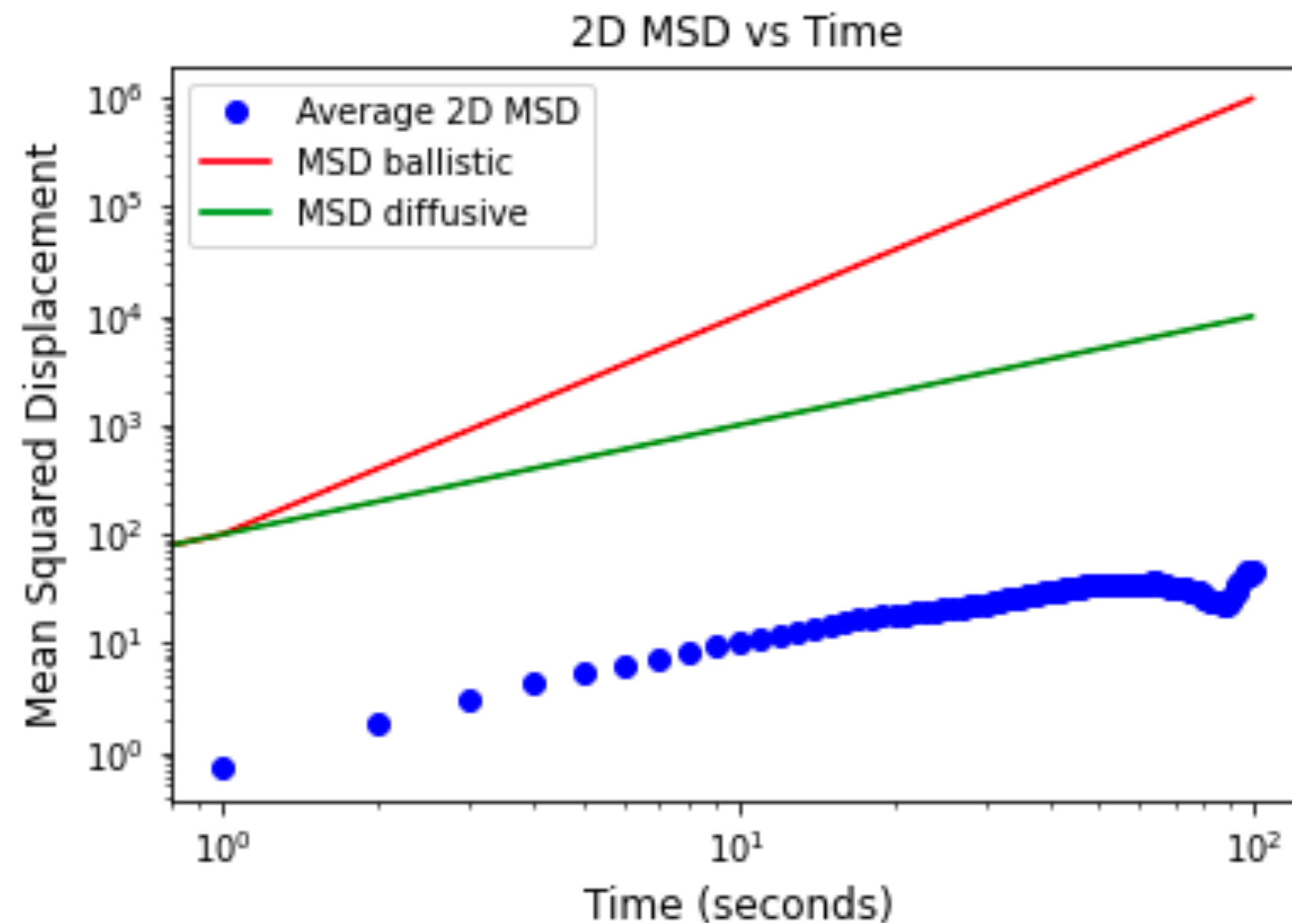
Translational Diffusion

Position

Velocity

Number of Walkers

Boundary Conditions

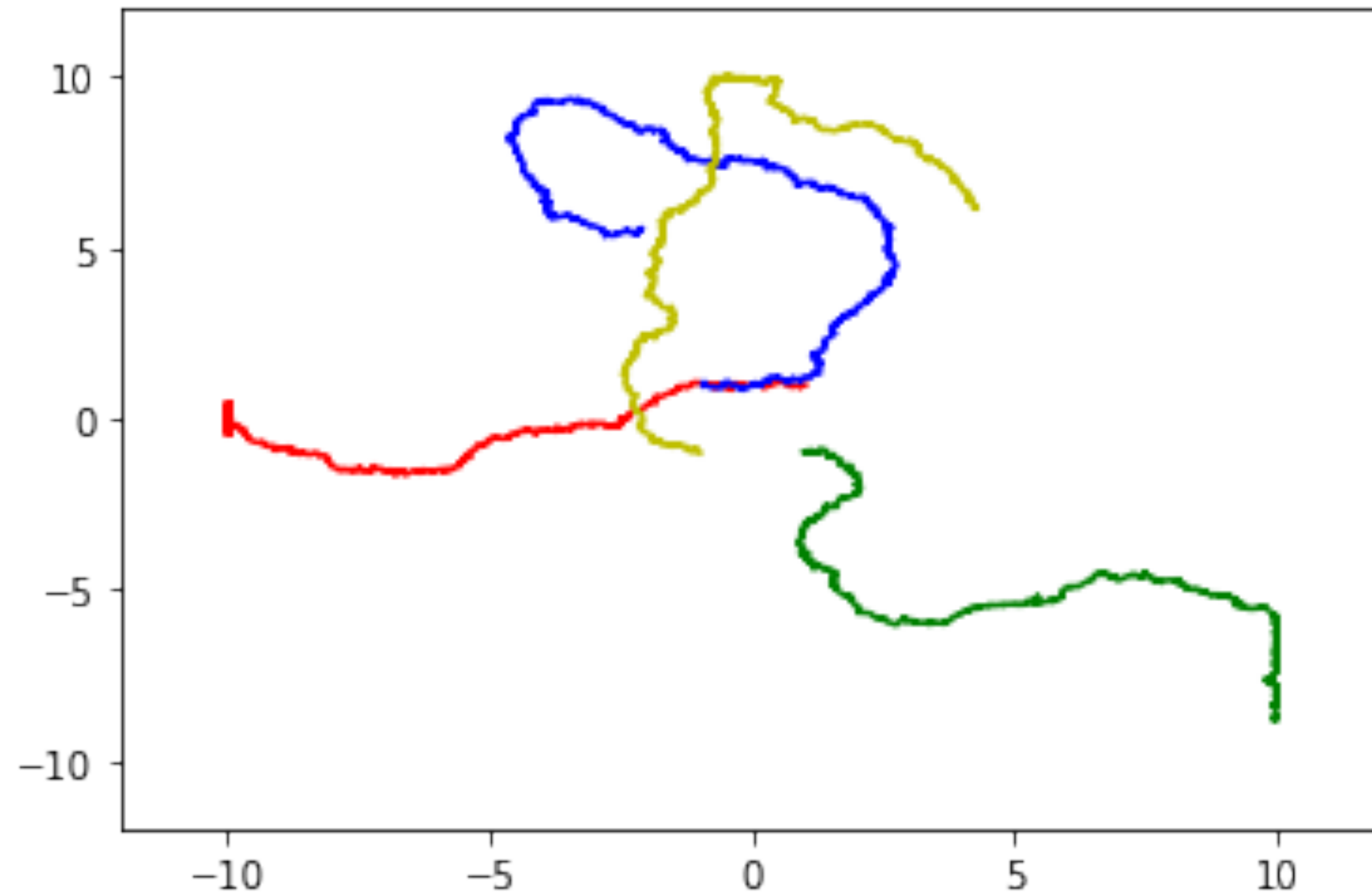# Brownian Motion Mixing

Rotational Diffusion

Translational Diffusion

Position

Velocity

Number of Walkers

Boundary Conditions

Future Steps

- Make Robust for Varying Walkers

- Calculate Mixing Entropy on Sets

- Determine what step count is comparable to braid length