Bipartite Entanglement Entropy

Aditya Chincholi

June 28, 2021

Quasiperiodic Kicked Rotor

What I did earlier

- Constructing the full floquet operator in a single basis.

What I did earlier

- Constructing the full floquet operator in a single basis.
- Using a density matrix the whole time for calculations.

What I did earlier

- Constructing the full floquet operator in a single basis.
- Using a density matrix the whole time for calculations.
- This has the drawback of increasing computational complexity of each individual step and the memory used at any given time is large.

What I have done now

- Separate the floquet operator into momentum space and position space parts.

What I have done now

- Separate the floquet operator into momentum space and position space parts.
- Use a single pure state for calculations.

What I have done now

- Separate the floquet operator into momentum space and position space parts.
- Use a single pure state for calculations.
- Fourier transform the state at each time step and apply both parts of the floquet operator in their resp. basis.

What I have done now

- Separate the floquet operator into momentum space and position space parts.
- Use a single pure state for calculations.
- Fourier transform the state at each time step and apply both parts of the floquet operator in their resp. basis.
- This is better as the memory used is less but computation increases. Since fourier transforms are computationally cheap anyway, so it's fine.

What I have done now

- Separate the floquet operator into momentum space and position space parts.
- Use a single pure state for calculations.
- Fourier transform the state at each time step and apply both parts of the floquet operator in their resp. basis.
- This is better as the memory used is less but computation increases. Since fourier transforms are computationally cheap anyway, so it's fine.
- Peak memory required scales the same way but we have reduced it by a constant factor and it is not used in all calculations.

Results

We use $\hbar = 2.85, \omega_2 = 2\pi\sqrt{5}, \omega_3 = 2\pi\sqrt{13}$, the momentum ranges from -10 to 10

$$H = \frac{p_1^2}{2} + p_2\omega_2 + p_3\omega_3 + Kcos(\theta_1)(1 + \alpha cos(\theta_2)cos(\theta_3))\sum_n \delta(t-n)$$

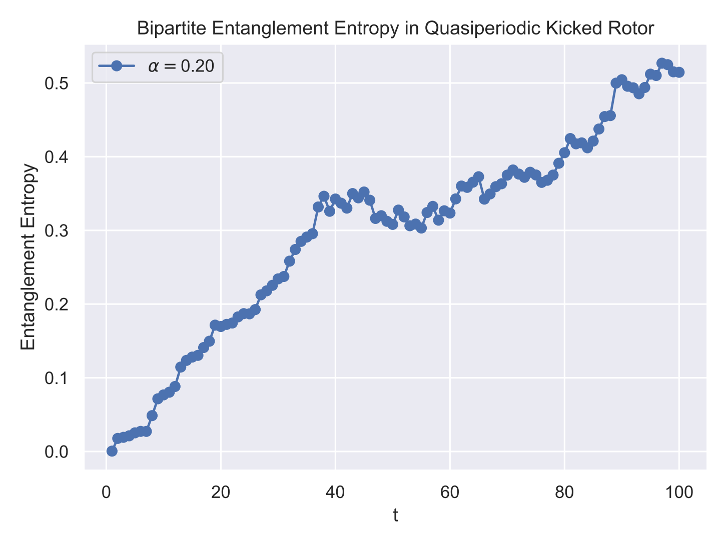

Figure 1: Precritical (Insulator): $K = 4, \alpha = 0.2$

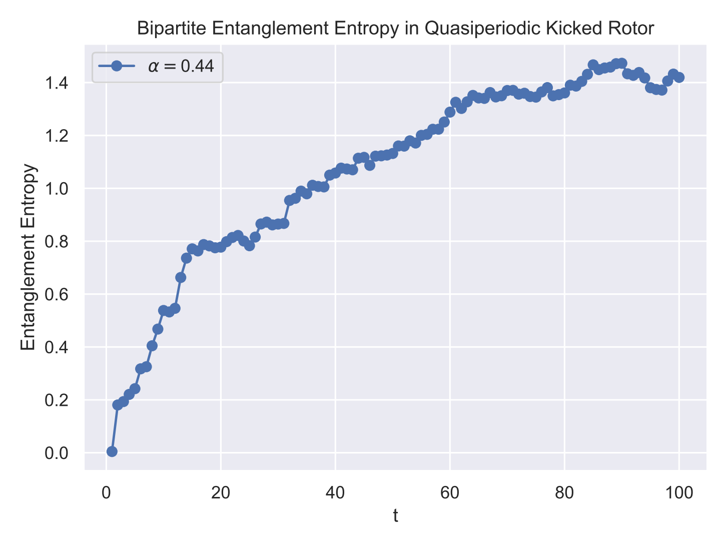

Figure 2: Critical: $K = 6.36, \alpha = 0.4375$

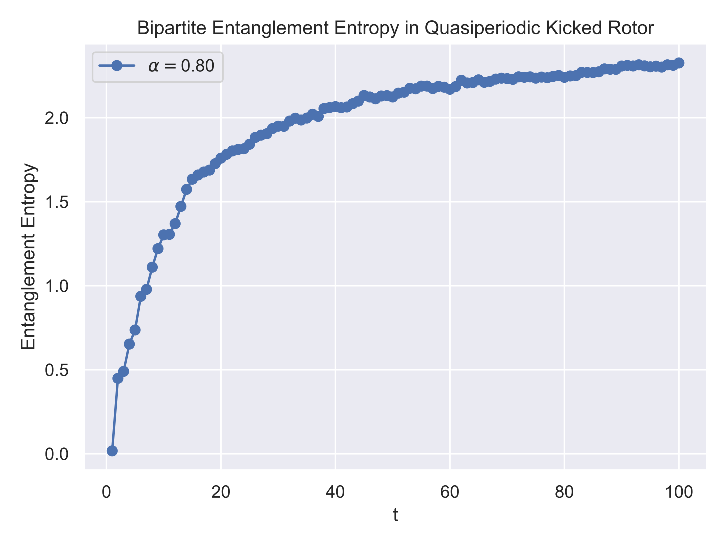

Figure 3: Post-critical (Metal): $K = 8, \alpha = 0.8$

- I don't see much of a trend here. The entanglement grows faster and higher with higher K values i.e. more diffusive the regime higher the entanglement for the same number of time steps but other than that, I don't see anything here.

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \rightarrow \rho \rightarrow \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \to \rho \to \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.
- What I realized: $|\psi\rangle \to \rho_1 = Tr_{2,3}[\rho]$ This gives a really high speedup and allows me to check if localisation is happening properly or not.

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \to \rho \to \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.
- What I realized: $|\psi\rangle \to \rho_1 = Tr_{2,3}[\rho]$ This gives a really high speedup and allows me to check if localisation is happening properly or not.
- I used these params to generate the following results: p-basis = [-100, 100], 80 timesteps, $\omega_2 = 2\pi\sqrt{5}$, $\omega_3 = 2\pi\sqrt{13}$, $\hbar = 2.85$.

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \to \rho \to \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.
- What I realized: $|\psi\rangle \to \rho_1 = Tr_{2,3}[\rho]$ This gives a really high speedup and allows me to check if localisation is happening properly or not.
- I used these params to generate the following results: p-basis = [-100, 100], 80 timesteps, $\omega_2 = 2\pi\sqrt{5}$, $\omega_3 = 2\pi\sqrt{13}$, $\hbar = 2.85$.
- We plot the following quantities:

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \to \rho \to \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.
- What I realized: $|\psi\rangle \to \rho_1 = Tr_{2,3}[\rho]$ This gives a really high speedup and allows me to check if localisation is happening properly or not.
- I used these params to generate the following results: p-basis = [-100, 100], 80 timesteps, $\omega_2 = 2\pi\sqrt{5}$, $\omega_3 = 2\pi\sqrt{13}$, $\hbar = 2.85$.
- We plot the following quantities:
  - $P(p_1 = m\hbar)$

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \to \rho \to \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.
- What I realized: $|\psi\rangle \to \rho_1 = Tr_{2,3}[\rho]$ This gives a really high speedup and allows me to check if localisation is happening properly or not.
- I used these params to generate the following results: p-basis = [-100, 100], 80 timesteps, $\omega_2 = 2\pi\sqrt{5}$, $\omega_3 = 2\pi\sqrt{13}$, $\hbar = 2.85$.
- We plot the following quantities:
  - $P(p_1 = m\hbar)$
  - $E = p_1^2/2 + p_2\omega_2 + p_3\omega_3$

Bypassing The Density Matrix

- What I was doing: $|\psi\rangle \to \rho \to \rho_1 = Tr_{2,3}[\rho]$. This is a memory bottleneck as the full density matrix ρ still requires the $O(N^6)$ memory.
- What I realized: $|\psi\rangle \to \rho_1 = Tr_{2,3}[\rho]$ This gives a really high speedup and allows me to check if localisation is happening properly or not.
- I used these params to generate the following results: p-basis = [-100, 100], 80 timesteps, $\omega_2 = 2\pi\sqrt{5}$, $\omega_3 = 2\pi\sqrt{13}$, $\hbar = 2.85$.
- We plot the following quantities:
  - $P(p_1 = m\hbar)$
  - $E = p_1^2/2 + p_2\omega_2 + p_3\omega_3$
  - $S = -\rho_1 ln(\rho_1)$

Momentum (p_1) distributions

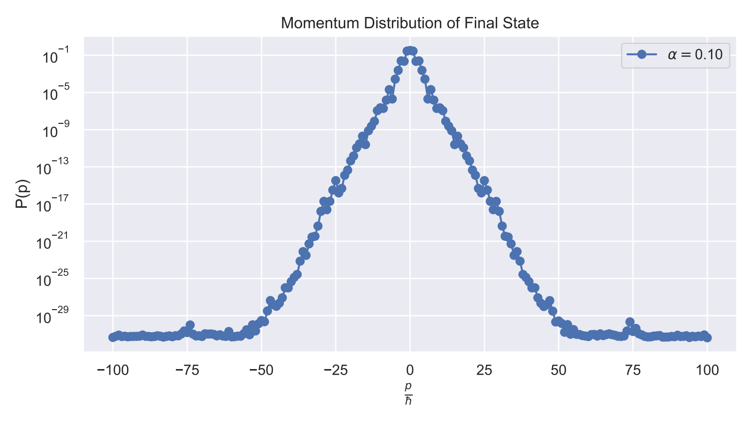

Figure 4: $\mathrm{K} = 3$, $\alpha = 0.1$

Momentum (p_1) distributions

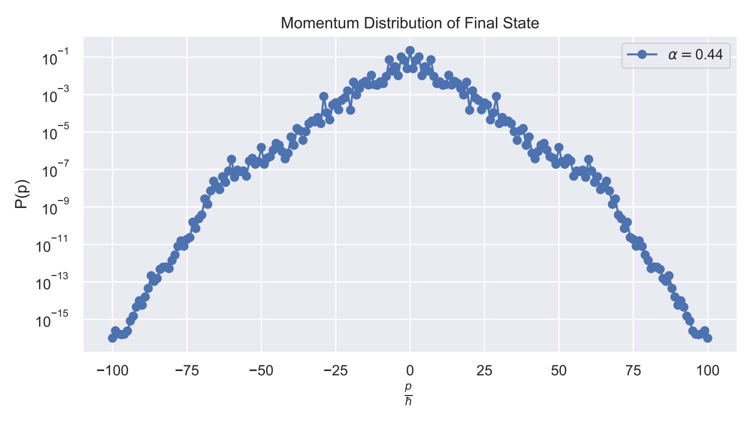

Figure 5: K $= 6.36$, $\alpha = 0.4375$

Momentum (p_1) distributions

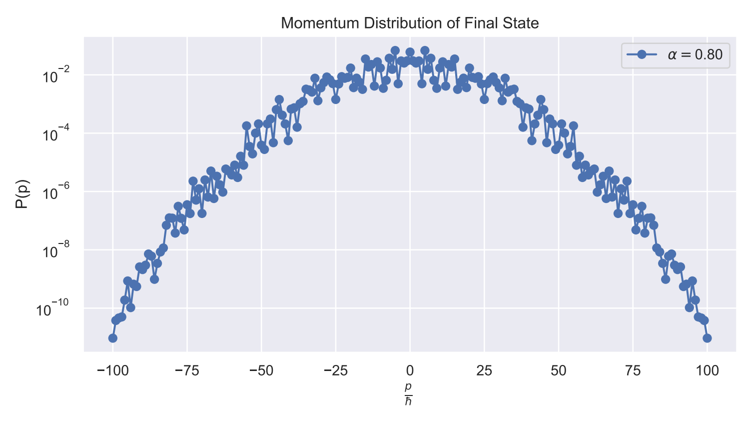

Figure 6: K $= 7$, $\alpha = 0.8$

Energy

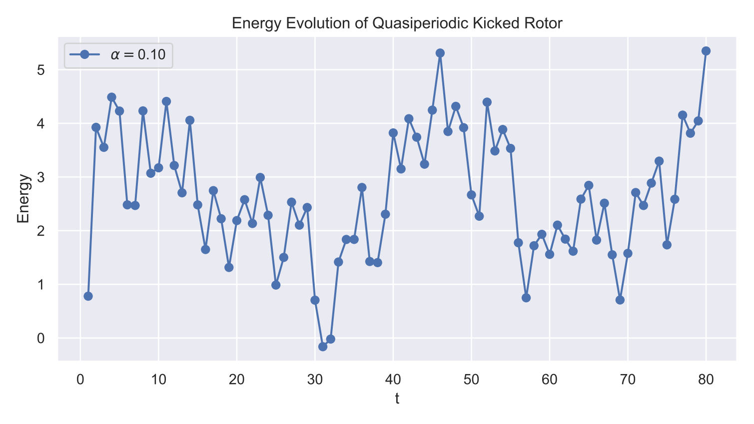

Figure 7: K $= 3$, $\alpha = 0.1$

Energy

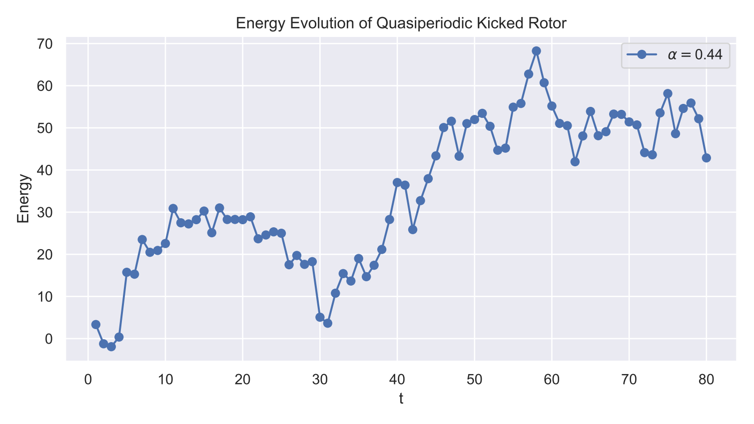

Figure 8: K $= 6.36$, $\alpha = 0.4375$

Energy

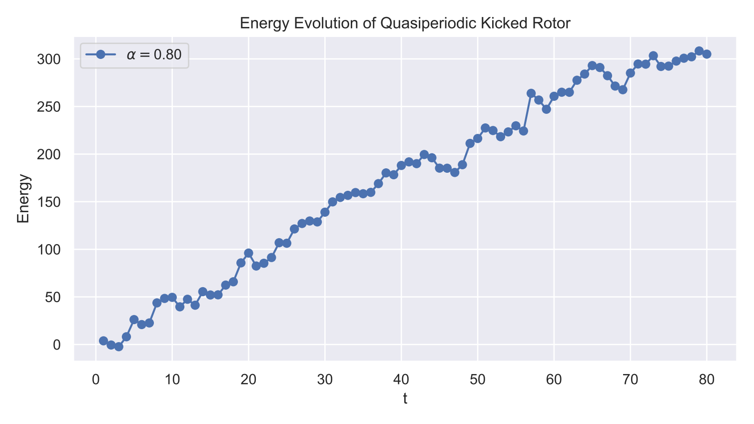

Figure 9: K $= 7$, $\alpha = 0.8$

Entropy

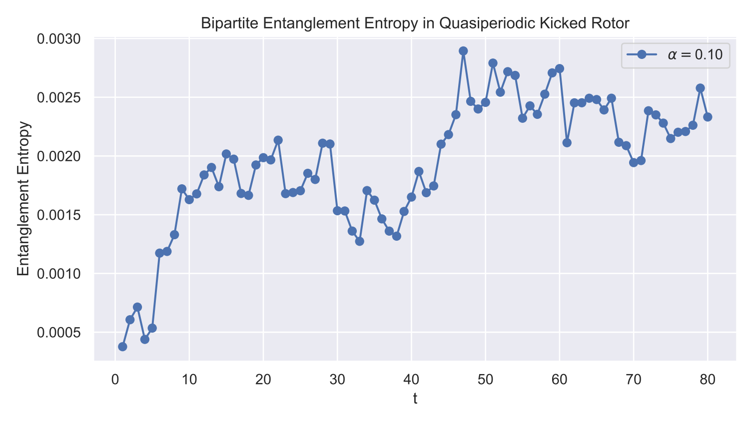

Figure 10: K $= 3$, $\alpha = 0.1$

Entropy

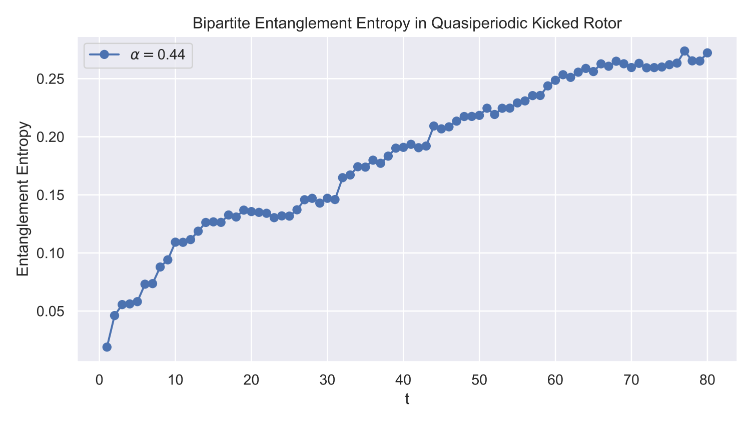

Figure 11: K $= 6.36$, $\alpha = 0.4375$

Entropy

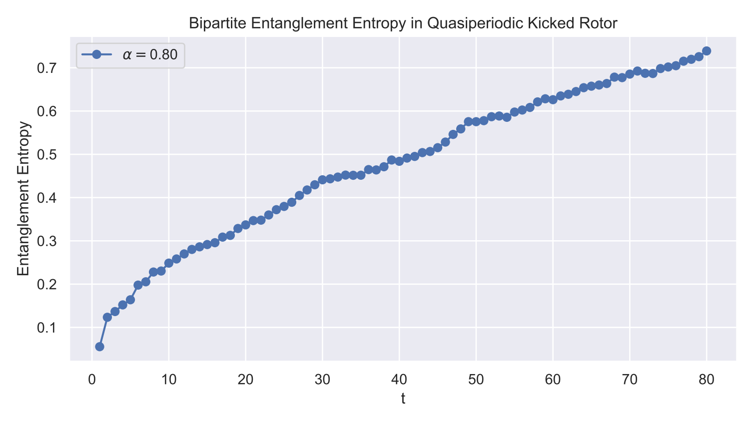

Figure 12: $K = 7$, $\alpha = 0.8$