1 Hamiltonian Construction on the Segment Compatibility Graph

Let $G = (V, E)$ denote the weighted, undirected compatibility graph constructed over the set of beat-aligned audio segments, where each node $i \in V$ corresponds to a segment and each edge weight $A_{ij} \geq 0$ encodes the similarity between segments i and j. The adjacency matrix $A \in \mathbb{R}^{N \times N}$ is symmetric by construction, ensuring real-valued spectra for all operators derived from it.

1.1 Adjacency Hamiltonian

The first Hamiltonian considered is the adjacency-based operator,

$$H_A = A, \tag{1}$$

which directly encodes pairwise segment similarities. Due to the symmetry of A, the operator H_A is Hermitian and thus generates unitary quantum evolution. However, adjacency-based dynamics are known to favor localization around highly connected nodes, potentially biasing the system toward repeated transitions among structurally dominant segments.

1.2 Graph Laplacian Hamiltonian

To promote exploratory dynamics, we also construct the combinatorial graph Laplacian. The degree matrix D is defined as

$$D_{ii} = \sum_j A_{ij}, \tag{2}$$

and the Laplacian Hamiltonian is given by

$$H_L = D - A. \tag{3}$$

The Laplacian operator is Hermitian and positive semi-definite, with at least one zero eigenvalue corresponding to the uniform eigenstate. This structure induces diffusion-like quantum dynamics that suppress trivial self-trapping and encourage traversal across the global graph topology.

1.3 Spectral Analysis

To characterize the dynamical implications of each Hamiltonian, we compute their eigenvalue spectra via exact diagonalization. For the constructed graph of $N = 64$ segments, the adjacency Hamiltonian exhibits a spectral spread of

$$\Delta\lambda_A \approx 19.33, \tag{4}$$

with a small degree of eigenvalue degeneracy, indicating partial symmetry-induced localization. In contrast, the Laplacian Hamiltonian exhibits a broader spectral spread,

$$\Delta\lambda_L \approx 25.01, \tag{5}$$

and no observable degeneracies, consistent with enhanced structural asymmetry and improved state-space exploration.

1.4 Implications for Quantum Dynamics

The narrower spectrum and mild degeneracy of H_A suggest dynamics dominated by coherent oscillations among strongly connected regions of the graph. Conversely, the broader, non-degenerate spectrum of H_L supports diffusive quantum transport, making it better suited for generating diverse and non-repetitive mashup trajectories.

Based on this analysis, the Laplacian Hamiltonian is selected as the primary operator for quantum evolution in subsequent experiments, while the adjacency Hamiltonian is retained as a baseline for comparative evaluation.