Cosine Similarity in the Spectral Neighbors Recommender

Cosine similarity is the central measure of song-to-song relatedness in the Spectral Neighbors Recommender. After each track is converted into a standardized numerical vector composed of aggregated audio features—such as MFCC means and standard deviations, spectral centroid, roll-off, flatness, zero-crossing rate, and tempo—similarity between two songs is computed as the cosine of the angle between their feature vectors in high-dimensional space.

Formally, for two tracks with feature vectors **A** and **B**, cosine similarity is defined as

$$\text{cosine}(A, B) = \frac{A \cdot B}{\|A\| \, \|B\|}$$

Where A.B is the dot product and ∥A∥ , ∥B∥ are their magnitudes. The value ranges from −1 to 1, with 1 indicating that both vectors point in the same direction implying the songs share nearly identical timbral and spectral characteristics and 0 indicating no relation.

In this system, the cosine metric is preferred over Euclidean distance because it focuses on the **direction** of the feature vectors rather than their scale. This makes it insensitive to differences in loudness or overall signal energy, ensuring that songs are compared by their *shape of spectral content* rather than by amplitude. After feature vectors are normalized through z-score standardization, cosine similarity becomes a direct measure of how much two tracks' relative spectral patterns align.

The resulting similarity matrix allows each seed track to retrieve its top-K nearest neighbors. Empirically, this produces high Artist@K scores, demonstrating that cosine similarity effectively clusters songs by consistent acoustic identity grouping same-artist or genre-coherent recordings together. Within the prototype, it provides a mathematically elegant yet computationally simple foundation for music retrieval, balancing interpretability, efficiency, and robustness.