From Theory to Topology: Modeling Turkish Makam Complexity with Multiplex Networks and Deep Learning

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Abstract

Modeling Turkish Makam Music (TMM) has long posed a challenge at the intersection of music theory and computation (Bozkurt et al., 2014; Moysis et al., 2023). Most cited traditional approaches, which have been established at the beginning of the 20th century by Arel, Ezgi and Uzdilek, often adopt a Euclidean framework in which an octave is divided into uniform intervals (*koma*), aligning pitches on a geometric grid (Kutluğ, 2000; Özkan, 2006). Most computational models extend this scalar logic to classification and pitch-related tasks (Atlı et al., 2014; Karaosmanoğlu, 2012).

This research departs from these assumptions by adopting a dual methodology grounded in topological and data-driven modeling. First, we incorporate *MakamNetz*, a recent multiplex network model of *çeşni* (melodic substructures) derived from historical theoretical sources (Baysal et al., 2024). Rather than treating *çeşni* as homogeneous, fixed units, *MakamNetz* (Baysal et al., 2024; MakamNetz Web App, 2024) defines them as internally heterogeneous, interconnected through intervallic and axis-based relations such as transference and axis transformation. While the model offers a novel topological map of the makam universe, questions remain regarding progression patterns, structural centrality, and link weighting.

To address these gaps, we curated a *çeşni*-level audio dataset performed by expert musicians (Yalçın & Şeftali, 2024), segmented into 8-second clips. We trained a deep classifier combining Bi-LSTM with self-attention and MobileNetV3-based CNN layers, achieving 97% test accuracy. Latent features were projected into a 2D space via t-SNE and compared with theoretical relationships. An analysis based on selected *çeşni* structures showed a significant correspondence with both *MakamNetz* model and our practical experience (see Fig. 1).

We modelled *çeşni* transitions using Markov chains whose probabilities were derived from Gaussian sampling in the latent embedding space, constrained by the *MakamNetz*

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topology as a prior. The temperature (τ) and kernel width(σ) parameters were tuned using entropy, self-transition rates, and class diversity metrics, guided by empirical analyses of *MakamNetz* (Baysal et al., 2024; Yalçın, 2024; Kesgin, 2025). Performance was evaluated by comparing sequences from three configurations—an Erdős–R'enyi null model, *MakamNetz* without weights, and the latent-space model—against empirical network statistics and expert assessments of musical plausibility.

This framework contributes a scalable and explainable methodology for modeling TMM and offers a foundation for broader computational analysis of non-Western modal systems.

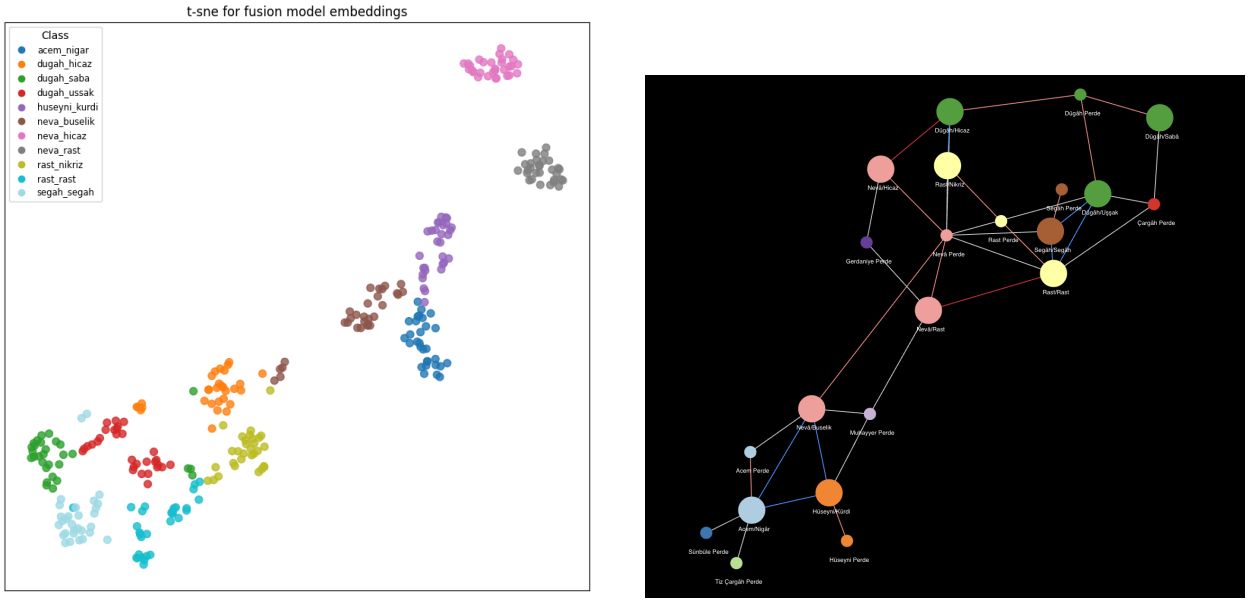

Figure 1 – Comparison of MakamNetz topology and t-SNE projection of latent embeddings. Both representations highlight clustering and structural proximity among selected *çeşni* types.

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