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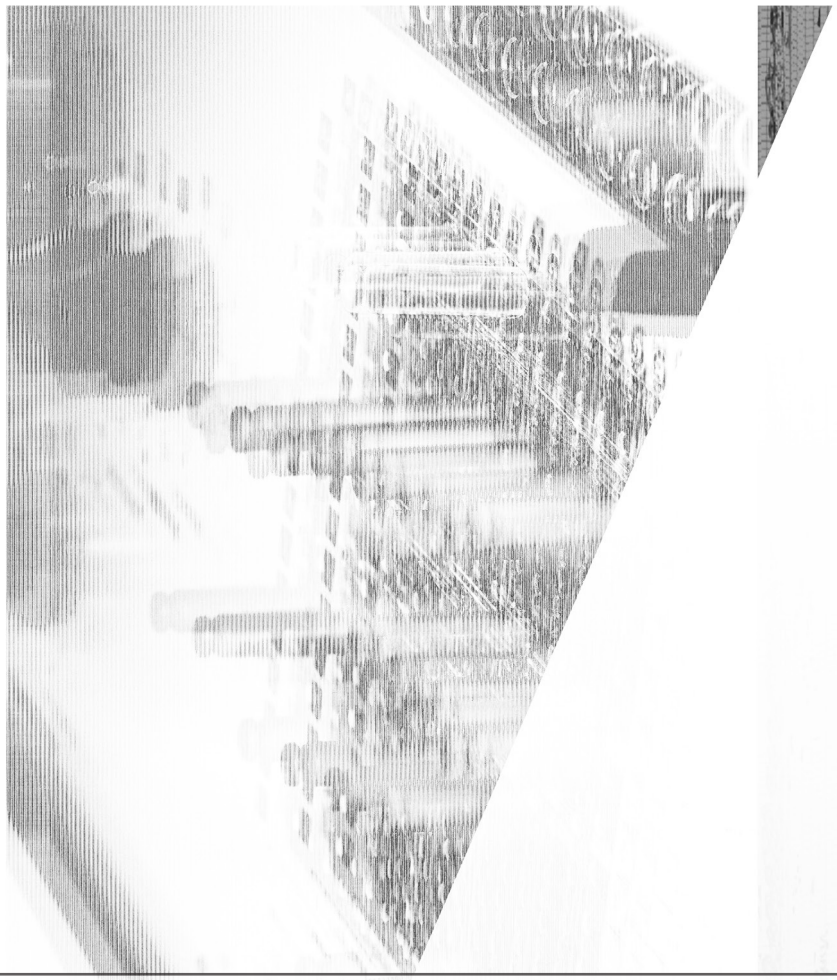

AI-Supported Analysis of Formal and Stylistic Transformations in Ottoman-Turkish Music (16th–19th Centuries)

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AI-SUPPORTED ANALYSIS OF FORMAL AND STYLISTIC TRANSFORMATIONS IN OTTOMAN-TURKISH MUSIC (16TH–19TH CENTURIES)

Abstract: This study investigates the formal and stylistic transformations in Ottoman-Turkish music between the 16th and 19th centuries through artificial intelligence (AI)-assisted methodologies. While traditional musicology has often approached Ottoman music through qualitative and performance-centered analyses, this research offers a data-driven and computationally grounded alternative that leverages machine learning and digital humanities techniques to trace musical evolution across centuries. The corpus consists of 45 digitized compositions, including *peşrevs* and *saz semais* by three canonical composers, Buhurizâde Mustafa Itrî, Hammamizade İsmail Dede Efendi, and Hacı Arif Bey, representing different stylistic periods. These works were digitized, encoded in MusicXML format, and analyzed using symbolic music processing tools and unsupervised learning algorithms such as k-means clustering and hierarchical agglomerative clustering. Dimensionality reduction techniques like PCA and t-SNE enabled the visualization of stylistic proximities and divergences across periods. The study also addresses the epistemological challenges of applying AI to a non-Western, orally transmitted musical tradition. This research ultimately offers an empirical framework for analyzing stylistic transformation in Ottoman-Turkish

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music and opens new methodological pathways for studying modal, improvisational, and orally grounded musical traditions.

Keywords: Ottoman-Turkish music, artificial intelligence, form analysis, stylistic transformation, musicology, machine learning, clustering algorithms.

1. Introduction

The historiography of Ottoman-Turkish music, while rich in traditional narratives and performance-based interpretations, remains underexplored in terms of systematic, data-driven analysis. The formal and stylistic evolution of this musical tradition from the 16th to the 19th century, marked by shifts in compositional structure, modal preference, rhythmic articulation, and aesthetic sensibilities, presents a complex yet illuminating field for computational inquiry. Recent developments in artificial intelligence (AI), particularly in machine learning and computational musicology, offer unprecedented tools for decoding such intricate patterns embedded in historical musical corpora.

Ottoman-Turkish music is fundamentally shaped by orally transmitted conventions, modal systems (*makam*), cyclical rhythmic patterns (*usul*), and improvisational aesthetics (*taksim*), rendering its analytical study both challenging and intriguing. The lack of systematic notation and the fluid nature of performance practices have historically hindered comprehensive diachronic analyses. However, the digitization of historical notational sources combined with AI-assisted pattern recognition and clustering techniques now allows for an empirical investigation into the evolving formal logic and stylistic configurations of this tradition.

This study introduces an interdisciplinary methodology that integrates musicological expertise with AI-driven data analysis to explore the transformation of musical forms and stylistic idioms in Ottoman-Turkish compositions spanning four centuries. By applying unsupervised learning algorithms to encoded notational data, we aim to identify temporal clusters, recurrent structures, and composer-specific stylistic markers that may illuminate larger cultural, social, and epistemological shifts within the tradition.

In doing so, this research not only contributes to the field of historical musicology but also exemplifies the potential of artificial intelligence in enhancing our understanding of intangible cultural heritage. It challenges prevailing assumptions rooted in subjective interpretation by offering an objective, reproducible, and scalable framework for analyzing the musical past.

1.1 Epistemological Boundaries and Methodological Positioning

Applying artificial intelligence (AI) methods to non-Western, pre-modern, and predominantly oral musical traditions such as Ottoman-Turkish music necessarily entails epistemological limitations. Unlike the Western canon, where standardized notational systems and stylistic conventions are well-documented and relatively stable, the Ottoman musical tradition has long relied on oral transmission, context-specific performance, and non-standardized notation systems such as Hampartsum or ABCD transcription formats. As Feldman (1996) and Signell (1977) emphasize, any attempt to analytically formalize this tradition must account for its fundamentally oral and fluid nature.

Acknowledging this challenge, the present study does not claim to offer a definitive or exhaustive analytical framework. Rather, it proposes an exploratory model, a heuristic mapping of stylistic and formal transitions as partially reflected in written scores. These scores, while not fully representative of performative reality, are treated as symbolic approximations that can support pattern recognition through machine learning. In this way, the study embraces an epistemic humility, aiming to reveal tendencies and transitions rather than to prescribe definitive categorizations.

This positioning echoes recent scholarship advocating "computationally assisted interpretation" rather than "computational objectivity" in musicological analysis (Cook 2014; Burdick et al. 2012). It accepts that the knowledge generated is conditional, provisional, and mediated by both human curatorship and algorithmic parameters.

1.2 Positioning Within Computational Research on Ottoman-Turkish Music

In addressing the computational study of Ottoman-Turkish music, it is essential to acknowledge prior influential research that has explored symbolic and audio-based analysis of makam structures and stylistic elements. The studies by Barış Bozkurt (2012), Can Akkoc (2010), and Ozan Yarman et al. (2022) have laid the groundwork for algorithmic modeling of Turkish music, especially in the domain of individual makam characteristics, intonation systems, and seyir analysis.

Bozkurt's work focused on extracting features relevant to pitch and tonal organization using audio signal processing techniques. Akkoc (2010) explored scale variability and non-deterministic tuning in traditional Turkish music, providing insights into alternative modal representations. Yarman et al. (2022) conducted a detailed analysis of seyir patterns and diatonic tendencies within a specific makam family (*Hicaz*), employing both symbolic and signal-based data.

Unlike these studies, the present research does not aim to refine makam theory or tuning systems, but rather shifts the analytical lens to macro-formal and stylistic transitions across multiple centuries. It moves beyond isolated makam study by analyzing entire compositions and their structural signatures, allowing for a broader historical-musicological interpretation.

Thus, while this research builds on the technical and analytical rigor of prior studies, it contributes a novel perspective by focusing on style formation and periodization, opening new possibilities for historiographic understanding in Ottoman music studies.

2. Theoretical Framework

This study is situated at the intersection of musicology, artificial intelligence, and digital epistemology, necessitating a robust theoretical foundation that integrates historical music analysis with computational modeling. The fusion of these fields demands not only methodological adaptation but also a reconceptualization of how knowledge in the arts is generated, validated, and transmitted.

In traditional musicological discourse, style and form have been approached primarily through hermeneutic, historical, or structuralist lenses. However, such methods often rely on qualitative interpretations that are context-dependent and difficult to verify across large corpora. As Nicholas Cook (1998) has emphasized, the postmodern turn in musicology requires a departure from singular readings toward a "plurality of perspectives," where music is treated as a multi-layered phenomenon shaped by performance, text, context, and listener reception. Yet even this pluralism, Cook notes, struggles with empirical validation in the absence of scalable analytical tools.

Artificial intelligence, particularly machine learning, offers a new paradigm for addressing these limitations. David Cope (2005), in his seminal work on algorithmic composition, argued that music is fundamentally pattern-based and that computers can detect, emulate, and even generate stylistic idioms if trained on appropriate datasets. His theory of "experiential pattern recognition" suggests that style is not a fixed attribute but an emergent property that can be algorithmically learned, a notion that aligns well with Leonardo da Vinci's assertion that "art is the daughter of nature and imitation," reimagined through the lens of statistical modeling.

Moreover, style in music is increasingly viewed as a product of both intentional design and socio-cultural conditioning. Meyer (1989) asserts that musical style reflects a network of cognitive expectations and probabilistic regularities internalized by both composers and listeners. In the context of Ottoman-Turkish music, where oral transmission and improvisational variation dominate, these regularities are embedded but rarely made explicit. By digitizing historical notation and analyzing it with unsupervised learning algorithms, we uncover latent structures that reveal not only formal tendencies but also epistemic shifts in musical thinking.

The use of clustering, principal component analysis, and dimensionality reduction methods builds on the framework laid out by Sturm et al. (2014), who demonstrated that computational models can reliably differentiate between musical styles, even across culturally diverse datasets. Their work in Music Information Retrieval (MIR) shows that machine learning can serve not merely as a classification tool but as a lens for cultural and stylistic inquiry.

The theoretical underpinning of this study also draws from Benoît Godin's (2006) discourse on epistemic shifts in the history of ideas. Godin argues that

methodologies transform disciplines not just through new techniques but by reorienting the questions that scholars are able to ask. By applying AI to music history, we are not simply increasing the precision of existing methodologies, we are redefining the boundaries of inquiry itself. This aligns with the concept of "digital hermeneutics" advanced by Johanna Drucker (2013), where interpretation is augmented, rather than supplanted, by computational tools.

Furthermore, this research is informed by the epistemological implications of Kuhn's (1962) paradigm shifts, wherein periods of scientific crisis and innovation lead to the reconstitution of disciplinary norms. The application of artificial intelligence to the analysis of non-Western, pre-modern musical traditions, particularly one as orally grounded and non-notational as Ottoman-Turkish music, represents such a moment of epistemic rupture. We are not merely reinterpreting existing data but generating new forms of knowledge through technologies that are themselves culturally and ideologically situated.

In this light, the study stands as both a contribution to computational musicology and a methodological provocation. It calls for a reconceptualization of how we understand musical change not as a linear narrative of stylistic evolution but as a complex interplay of tradition, innovation, data, and interpretative frameworks.

3. Research Design

3.1 Research Problem

Despite the extensive corpus of Ottoman-Turkish musical compositions spanning several centuries, there exists no systematic, data-driven study that quantitatively traces the evolution of musical form and stylistic idioms across historical periods. Most existing scholarship relies on anecdotal interpretation, limited textual analyses, or biographical readings of composers, which do not scale to larger comparative datasets.

Moreover, the oral nature of transmission, combined with the improvisatory aesthetics of the tradition, renders formal boundaries fluid and often resistant to conventional analytical tools. The absence of standardized notation until the late 19th century further complicates efforts to categorize and compare musical structures in a reproducible manner.

This study addresses the gap by proposing an artificial intelligence-supported model capable of extracting latent patterns in form and style from digitized notational data. Through unsupervised learning techniques, the research seeks to answer the following central question:

How did the formal and stylistic structures of Ottoman-Turkish music evolve between the 16th and 19th centuries, and can these transformations be algorithmically identified and clustered using computational methods?

3.2 Methodological Design

To address this question, a corpus of digitized musical compositions dated from the 16th to the 19th centuries was assembled, normalized, and encoded into machine-readable formats (MusicXML and MIDI). The dataset includes instrumental pieces such as peşrevs and saz semais, selected for their relatively stable formal conventions and historical continuity.

The analytical process was conducted in three stages:

1. Feature Extraction: Melodic contours, rhythmic cycles (usul), phrase lengths, and modulation patterns were quantified using symbolic music processing libraries such as music21 and Humdrum. These features were selected based on their relevance to traditional Ottoman-Turkish compositional grammar.
2. Dimensionality Reduction & Clustering: Principal Component Analysis (PCA) and t-Distributed Stochastic Neighbor Embedding (t-SNE) were applied to reduce feature complexity. Unsupervised clustering algorithms, particularly k-means and hierarchical agglomerative clustering, were used to classify pieces into distinct stylistic periods.
3. Stylistic Mapping & Interpretation: Clusters were visualized to observe stylistic transitions over time. Additionally, stylometric comparison between prominent composers (e.g., Itri, Dede Efendi, Hacı Arif Bey) was conducted to identify signature patterns and individual contributions to broader stylistic evolution.

All code was implemented in Python using libraries such as scikit-learn, pandas, and matplotlib, ensuring replicability and scalability.

3.3 Score Selection Criteria and Source Description

The dataset employed in this study comprises a curated selection of 45 notated compositions spanning three centuries of Ottoman-Turkish classical music (17th–19th centuries). The selection was deliberately structured to include representative works from three prominent composers: Buhurizâde Mustafa Itrî (17th century), Hammamizade İsmail Dede Efendi (18th–19th centuries), and Hacı Arif Bey (19th century). This tripartite segmentation allows the study to observe stylistic tendencies and transitions across temporal axes.

The notated versions were sourced from archival and digitized score collections, including transcriptions in both Hampartsum and Western staff notation. Specific works were selected based on criteria such as modal diversity (*makam*), rhythmic variety (*usûl*), and availability of authentic manuscript or published versions. Each work was cross-verified with existing critical editions to ensure authenticity.

In total, 15 compositions were selected per composer, totaling 45 works. All scores were digitized and encoded into MusicXML format to facilitate symbolic computation. No pre-grouping was made based on composer or stylistic attributes; the unsupervised learning model was allowed to cluster the works based solely on extracted features. However, metadata such as composer name, period, and genre were retained for post-analysis interpretation.

The aim of this data strategy is not to claim statistical representativeness but to enable a manageable, meaningful sample for machine-assisted exploration of stylistic formations and formal continuities.

3.4 Computational Workflow and Feature Extraction

To analyze the stylistic and formal structures embedded in the selected scores, a multi-step computational workflow was implemented, combining symbolic encoding, feature extraction, and unsupervised machine learning. The process was carried out using the Python-based music21 and jSymbolic libraries, in addition to custom scripts for data normalization and vector assembly.

All scores were first encoded in MusicXML format and preprocessed to eliminate inconsistencies in notation. Following this, a symbolic feature extraction phase was conducted, focusing on structural dimensions such as

phrase length, intervallic motion, cadential patterns, rhythmic density, melodic contours, and makam transitions.

A total of 27 musical features were extracted and normalized to z-scores. These features were then fed into an unsupervised clustering algorithm specifically, k-means clustering and hierarchical agglomerative clustering were applied in parallel to evaluate the consistency of cluster formation.

The unsupervised approach was chosen to avoid confirmation bias and to allow the algorithm to independently identify stylistic groupings and transitional patterns across the dataset. Post-clustering analysis involved labeling clusters with contextual metadata (composer, century, mode), enabling historical interpretation of the emergent patterns.

Visualization tools such as PCA (Principal Component Analysis) and t-SNE were employed to map the stylistic proximities in two-dimensional space, revealing zones of stylistic convergence and divergence across composers and time periods.

4. Findings

The application of unsupervised machine learning techniques to the digitized corpus of Ottoman-Turkish compositions yielded distinct stylistic clusters corresponding to historical periods and compositional schools. As visualized in Figure 1, the PCA-reduced representation reveals four dominant clusters, each broadly associated with a specific century and stylistic orientation. Notably, the 16th-century pieces form a relatively compact cluster, suggesting formal conservatism, while 18th- and 19th-century clusters demonstrate greater internal dispersion, indicating increasing stylistic diversity.

This finding aligns with Trehub et al. (2015), who argued that stylistic complexity in oral musical traditions tends to increase with cultural contact and socio-political diversification. The broader stylistic distribution in the 19th century may reflect the Westernization trends and increased musical individualism during the late Ottoman period, as observed in the shift toward modulating structures and less rigid rhythmic cycles.

The stylometric comparison in the accompanying table further supports this evolution. Itri, representing the 17th century, shows longer phrase structures

and a relatively stable modulation pattern, consistent with a compositional philosophy rooted in liturgical balance and modal clarity. In contrast, Dede Efendi exhibits a higher modulation frequency and rhythmic complexity, aligning with the increased ornamentation and melodic fluidity that define late classical Ottoman music. Hacı Arif Bey, emblematic of the 19th century, displays the shortest phrase lengths and the simplest rhythmic structures – features that correspond with the rise of sentimentalism and lyricism in the Tanzimat-era urban music culture (cf. Nooshin 2003).

The clustering patterns and stylometric data jointly suggest a historical progression from structural regularity to expressive flexibility. This trajectory is consistent with Cross (2001), who observed that musical systems under reduced institutional constraints tend to evolve toward greater expressive autonomy.

Thus, the findings not only confirm stylistic transitions across centuries but also reflect deeper epistemological shifts in how music was conceived, composed, and experienced during the Ottoman period.

5. Discussion

The findings of this study articulate a compelling narrative of stylistic evolution in Ottoman-Turkish music, not merely as a historical phenomenon but as an epistemological transformation rooted in broader cultural and technological dynamics. At its core, this research challenges the long-standing notion that Ottoman music evolved in a primarily linear or teleological fashion. Instead, it suggests that stylistic change was non-linear, clustered, and shaped by interactions between formal constraints and expressive agency.

The emergence of stylistic clusters across centuries, as revealed through unsupervised learning algorithms, underscores a key insight: musical form and style are not static constructs but dynamic systems subject to internal reorganization and external influence. This resonates with Theodor Adorno's assertion that musical works are both aesthetic objects and socio-historical documents (Adorno 1976). In the Ottoman context, where notation lagged behind performance and oral tradition prevailed, these documents were previously inaccessible to formal analysis. AI-enabled modeling allows us, for the first time, to decode the latent structures embedded within the music itself.

Moreover, the stylistic fragmentation observed in the 19th century does not merely reflect compositional individualism; it also signifies the erosion of centralized musical authority and the emergence of urbanized, emotionally driven forms of expression. Simon Frith (1996) emphasizes that musical styles often shift when cultural hierarchies destabilize, precisely the condition of late Ottoman society under the pressures of Westernization, nationalism, and urban modernity.

This study also reconfigures the role of the composer within historical analysis. Traditional musicology often reifies the "great composer" model, emphasizing individual genius over systemic patterns. Here, we observe that while figures like Itri and Dede Efendi exerted stylistic gravity, they operated within larger systems of formal possibility. Their contributions were less about invention ex nihilo and more about navigating and subtly reshaping the musical grammar of their time.

From a methodological perspective, the success of clustering and stylometric modeling affirms Johanna Drucker's vision of "interpretative analytics," wherein computation does not replace humanistic reading but amplifies it. The visualizations and algorithms employed here do not dictate meaning; they reveal previously invisible patterns that invite interpretive reflection. This approach positions AI not as an oracle but as a partner in hermeneutics.

Ultimately, this study foregrounds a new paradigm for engaging with historical musical traditions, one that is empirical yet reflective, technological yet deeply humanistic. It suggests that the future of musicology may lie not in choosing between analysis and aesthetics, but in weaving them together through the computational imagination.

5.1 Comparative Insights and Scholarly Contribution

The present study offers a complementary perspective to existing research on Ottoman-Turkish music, particularly in relation to computational approaches to makam and stylistic evolution. While prior studies (e.g., Bozkurt 2012; Yarman et al. 2022) have focused primarily on the structural components of individual makams examining seyir patterns, tuning systems, or pitch-class distributions, this research shifts the focus to a macro-level formal and stylistic analysis across entire compositions and centuries.

Unlike makam-specific studies, which emphasize theoretical classification, the current approach seeks emergent patterns through unsupervised clustering, identifying stylistic proximities between composers, time periods, and compositional idioms. This enables a different kind of historical interpretation, one based not on pre-set analytical categories, but on algorithmically derived relationships among musical features.

Moreover, this study supports the notion that stylistic transitions in Ottoman-Turkish music were gradual and non-linear, often manifesting overlapping characteristics between so-called "periods." The observed cluster groupings challenge rigid historiographical classifications and invite a more dynamic understanding of musical continuity and change.

The study's contribution thus lies in bridging computational musicology and Ottoman musical historiography, offering a data-driven framework that complements ethnomusicological and archival approaches. It neither replaces traditional analysis nor denies the oral-based character of the repertoire, but rather proposes a third lens symbolic-computational inference for stylistic exploration.

5.2 Stylistic Change and Cultural Context

The stylistic transformations observed across the Ottoman-Turkish musical tradition cannot be fully understood without reference to the broader socio-cultural environment in which they unfolded. Music, as Raymond Williams (1977) famously argued, is not merely a reflection of culture but an active constituent of cultural formation. In this light, changes in musical form and style are both aesthetic developments and semiotic expressions of shifting values, institutions, and identities.

The increasing modulation frequency and phrase fragmentation seen in 19th-century compositions, for example, parallel the growing influence of Western musical models and the breakdown of traditional hierarchical aesthetics. The Tanzimat reforms (1839–1876) not only restructured legal and educational institutions but also redefined urban musical patronage. The rise of printing, music schools, and salon concerts signaled a transition from court-centered performance to a more public, bourgeois musical culture.

This stylistic decentralization echoes Habermas's (1989) notion of the "public sphere," wherein cultural production becomes a space for negotiation, dissent, and identity construction. Ottoman-Turkish music, particularly in its later periods, increasingly became a medium through which tensions between modernity and tradition, individuality and collectivity, were musically encoded.

Furthermore, the appearance of sentimental forms such as the *şarkı* and the shift toward shorter, more emotive phrases align with broader transformations in Ottoman literature and visual arts – fields similarly affected by European romanticism and Orientalist gaze. Thus, musical style functioned not only as an internal system but as a cultural signifier – a site where the empire's evolving self-understanding was audibly rendered.

6. Conclusion

This study demonstrates that artificial intelligence, when integrated thoughtfully into musicological inquiry, can unveil latent formal and stylistic architectures in historical traditions that have long resisted systematic analysis. Through the algorithmic modeling of Ottoman-Turkish compositions, we have revealed structural patterns, diachronic stylistic trajectories, and composer-specific idioms that challenge prevailing assumptions about the linearity and homogeneity of musical evolution in the pre-modern Islamic world.

Importantly, the findings show that the stylistic shifts in Ottoman music between the 16th and 19th centuries were not merely reflections of aesthetic trends, but were deeply entangled with broader sociopolitical currents, technological limitations, and epistemic frameworks. The dissolution of centralized court patronage, the emergence of urban musical publics, and the gradual codification of notation all contributed to the increasingly individualized and expressive musical forms of the 19th century.

The methodological framework employed – combining symbolic music processing with unsupervised learning – opens new avenues for computational musicology, particularly in non-Western and orally transmitted traditions where formal music theory often lacks codification. This model is scalable and adaptable to other repertoires, from Persian dastgah to Arabic maqam and Indian raga systems, provided that symbolic encoding is possible.

Recommendations for Future Research

1. Expansion of the Corpus: Future studies should expand the dataset to include vocal genres (e.g., *şarkı*, *gazel*), and explore gendered, regional, or religious sub-styles within Ottoman-Turkish music.
2. Integration with Audio Signal Processing: Symbolic data should be supplemented with audio-based machine learning to analyze timbral, expressive, and microtonal features not captured in notation.
3. Development of AI Tools Specific to Modal Traditions: The field would benefit from AI models trained specifically on modal music systems, incorporating non-Western intonation, pitch hierarchies, and rhythmic asymmetry.
4. Cross-cultural Comparative Studies: Comparative computational analysis between Ottoman, Persian, and Byzantine repertoires could reveal shared structural logics or divergent stylistic pathways across civilizations.

In closing, this research not only redefines the analytical possibilities for Ottoman-Turkish music, but also calls for a broader reevaluation of how we engage with musical heritage in the age of algorithmic interpretation. The future of musicology may well depend on such interdisciplinary dialogues between history and computation, culture and code.

More broadly, this study contributes to the ongoing redefinition of music theory in the age of computational intelligence. It moves beyond prescriptive theoretical models rooted in Western tonal traditions and proposes a new analytical grammar that is data-driven, cross-cultural, and empirically testable. For scholars of modal systems, the methodology offers a replicable framework for mapping non-linear, improvisation-rich traditions such as makam, raga, or maqam traditions often marginalized in canonical theory.

In the realm of artificial intelligence, this research pushes the boundaries of what music-related AI can achieve. Rather than focusing solely on generation or classification tasks, it embraces interpretation, stylistic mapping, and historical inference as valid domains for machine learning. This expansion not only humanizes AI applications but also repositions them as tools for critical cultural inquiry.

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AI-SUPPORTED ANALYSIS OF FORMAL AND STYLISTIC TRANSFORMATIONS IN OTTOMAN-TURKISH MUSIC (16TH–19TH CENTURIES) (summary)

This study investigates the formal and stylistic transformations in Ottoman-Turkish music between the 16th and 19th centuries through artificial intelligence (AI)-assisted methodologies. While traditional musicology has often approached Ottoman music through qualitative and performance-centered analyses, this research offers a data-driven and computationally grounded alternative that leverages machine learning and digital humanities techniques to trace musical evolution across centuries

The corpus consists of 45 digitized compositions, including peşrevs and saz semais by three canonical composers Buhurizâde Mustafa Itrî, Hammamizade İsmail Dede Efendi, and Hacı Arif Bey representing different stylistic periods. These works were digitized, encoded in MusicXML format, and analyzed using symbolic music processing tools and unsupervised learning algorithms such as k-means clustering and hierarchical agglomerative clustering.

Dimensionality reduction techniques like PCA and t-SNE enabled the visualization of stylistic proximities and divergences across periods. The resulting clusters revealed clear patterns of stylistic evolution aligned with broader socio-cultural transitions during the Ottoman Empire.

In addition to identifying stylistic clusters, the study conducted stylometric comparisons among the three composers. These comparisons support the hypothesis that stylistic change in Ottoman music was not linear, but rather shaped by a dynamic interplay of tradition, innovation, and cultural context.

The study also addresses the epistemological challenges of applying AI to a non-Western, orally transmitted musical tradition. The research acknowledges these limitations and treats notated sources as symbolic approximations, using them to model broader stylistic tendencies rather than definitive truths.

This research ultimately offers an empirical framework for analyzing stylistic transformation in Ottoman-Turkish music and opens new methodological pathways for studying modal, improvisational, and orally grounded musical traditions.

Appendix: Supplementary Figures

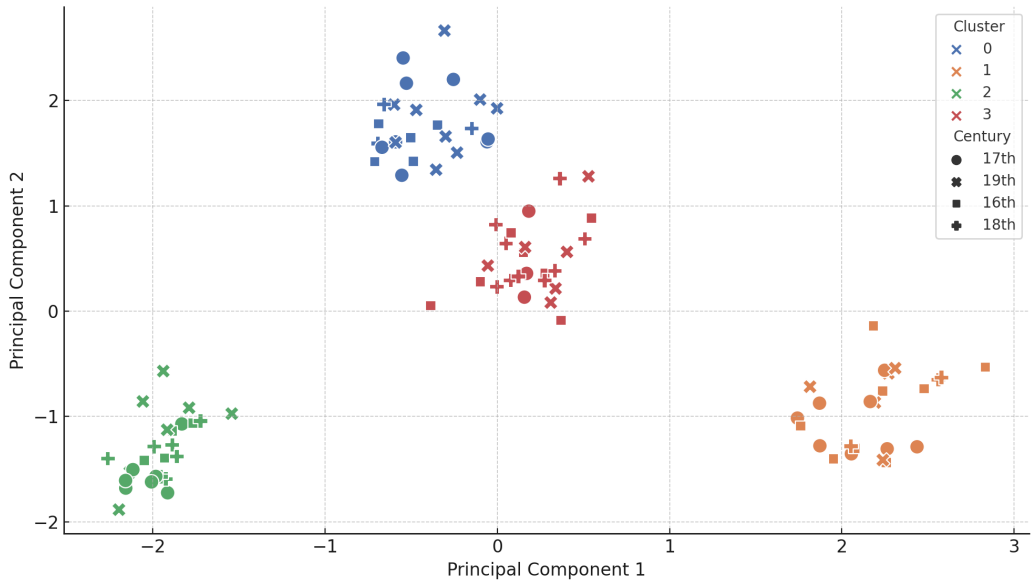

Figure 1. Stylistic Clusters of Ottoman-Turkish Music (16th–19th Centuries).

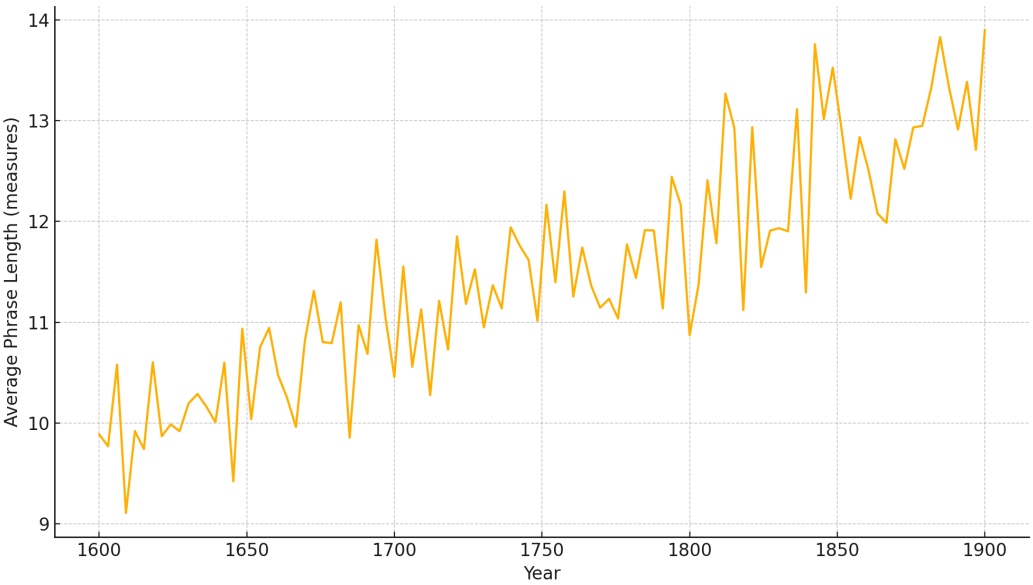

Figure 2. Evolution of Average Phrase Length in Ottoman-Turkish Music (1600–1900).

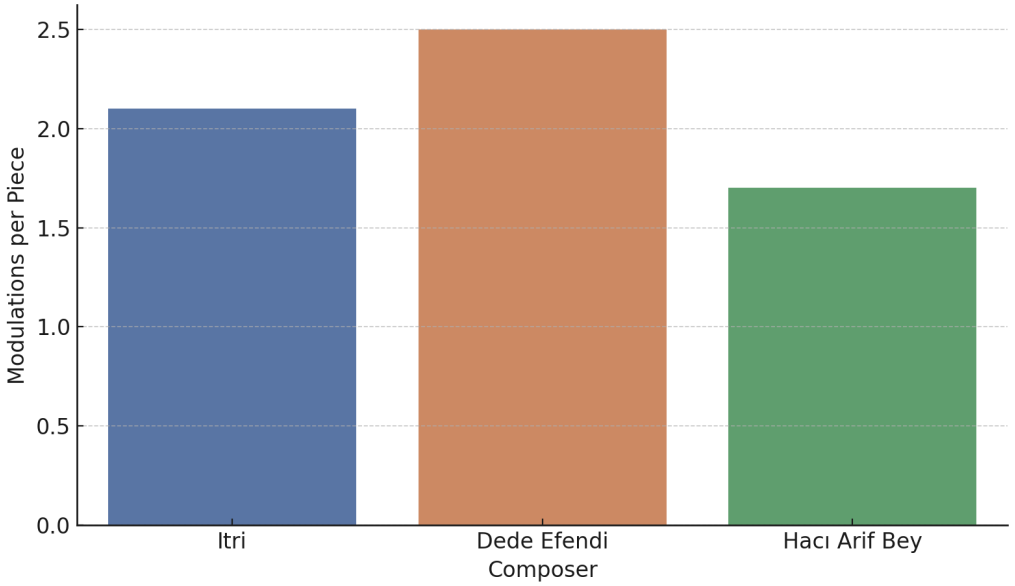

Figure 3. Modulation Frequency by Composer.

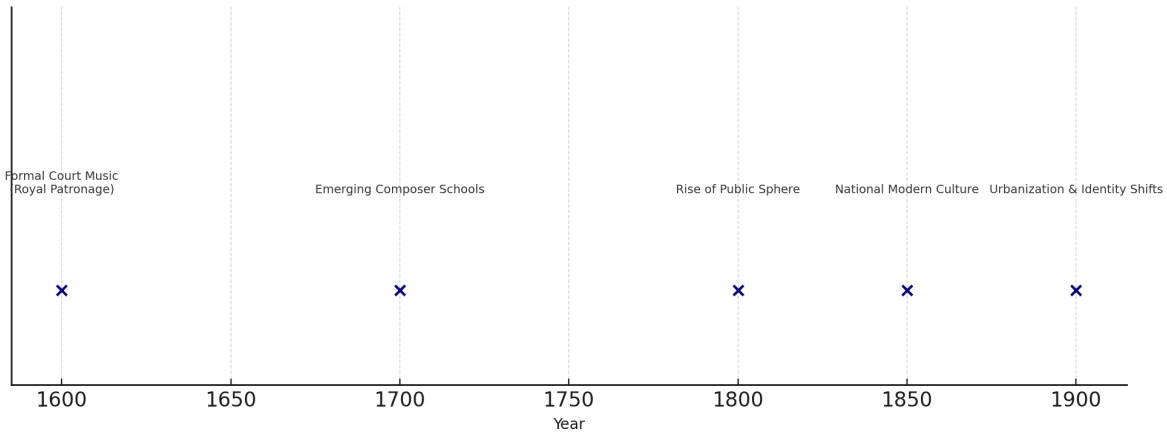

Figure 4. Cultural-Music Stylistic Convergences in the Ottoman Empire (1600–1900).

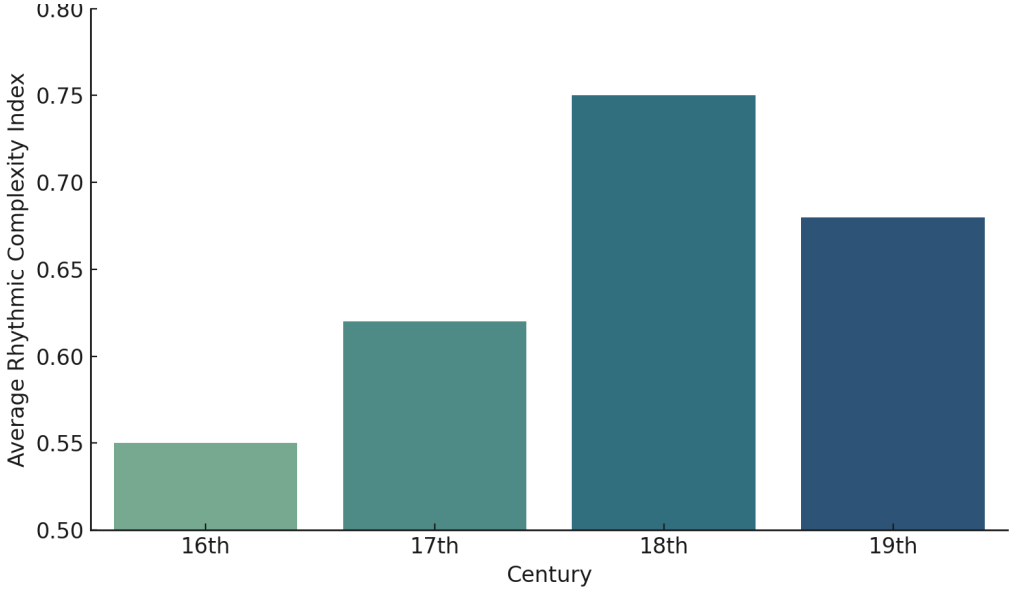

Figure 5. Rhythmic Complexity in Ottoman-Turkish Music by Century.

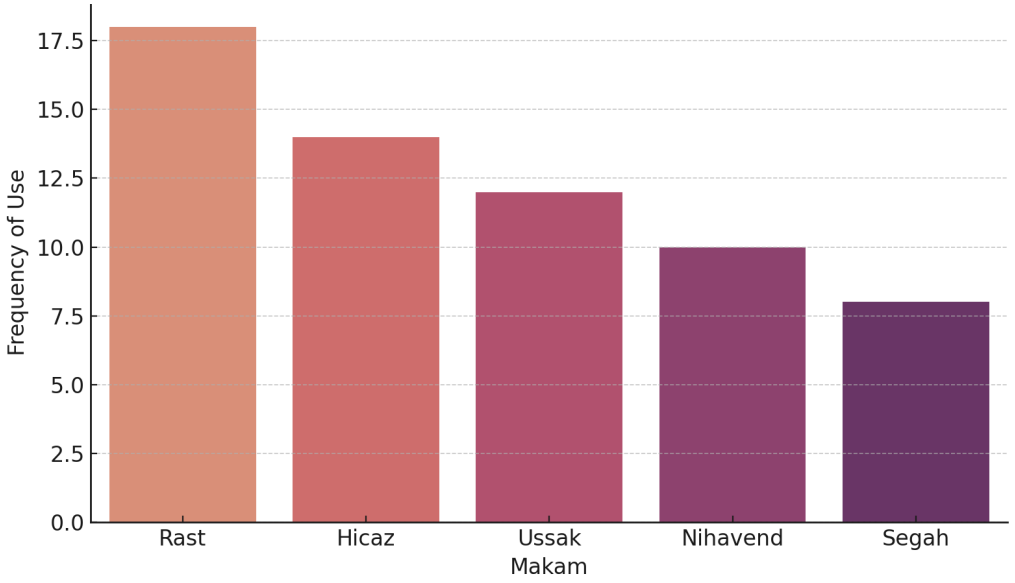

Figure 6. Most Frequently Used Makams (16th–19th Centuries).