INTRODUCING MAKAMNETZ: A VIRTUAL GUIDE TO TURKISH MAKAM UNIVERSE

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ABSTRACT

This presentation introduces MakamNetz, a virtual model crafted to map the musical universe of Turkish makam based on the relations of its nuclear substructures. Through interactive applications, MakamNetz serves as a virtual cartography tool, visually delineating harmonic connections among diverse makam structures, illuminating transitional pathways. For the theoretical background, emphasis is placed on the pivotal role of perde as the primary material of makam, and tetrachordal structures called çeşni (flavor), which act as modular building blocks of makam. In brief, our model interprets makam as progressions of Perde/Çeşni structures, highlighting the melodic path (seyir) of each makam. The model utilizes shared substructures and various transformational relationships, proposing three main categories: Intraconnected, Transference, and Fixed-axis, each with subtypes as well as combinations. MakamNetz offers a comprehensive understanding of these connections, displaying diverse Perde/Çeşni networks. The application's backend module is developed using Python and the Django framework, incorporaing transformational and relationship algorithms written in Python. Utilizing force-directed network graphs, the virtual model demonstrates different makam-spaces, guides through neighboring constellations, and allows hyperjumps to seemingly remote systems.

1. INTRODUCTION

Music-theory scholars have long sought to understand the harmonic connections within different musical structures. Visual models of pitch-set relationships have emerged as a useful tool in this pursuit, offering a panoramic perspective that allows for a holistic view of the musical universe. In particular, network models can reveal previously unrecognized pathways within the web of harmonious relations, offering a broader understanding of the underlying connections and patterns that govern musical composition.

One famous example of such a model is the tone-network "tonnetz" proposed by Leonhard Euler in the 18th century. This model later became the foundational framework for many theoreticians, including Hugo Riemann, who demonstrated his principles of harmonic motion and transformational models in the 19th century through the conceptual basis provided by the "tonnetz" [1, 2]. Similar representations can be found in the theoretical corpus of Turkish makam music, such as the manuscript treatise *Tefhimu¨'l Makâmât fi Tevlidi'n Nagâmât* ('Explanation of Makams in the Generation of Melodies') from the 18th century [3]. In this treatise, one can see the linking of different *perde* and makam structures as well as their interrelationships with other systems (Figure 1).

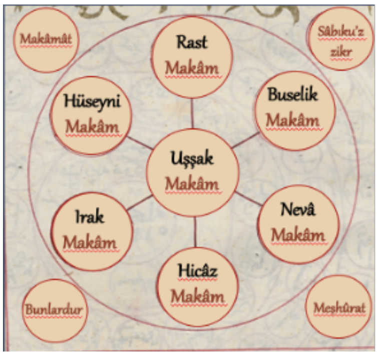

Figure 1. A reproduction of makam connections as depicted in *Tefhimü'l Makâmât* (Kemani Hızır Aga, 8A).

Recently, computer-aided tools have highlighted the gap between theory and practice in Turkish makam music. By utilizing advanced technologies such as tuning analysis, segmentation, statistical classification, and automatic transcription, researchers have developed sophisticated methods tailored to the unique elements of makam. [1]

This presentation offers a virtual model for mapping the makam universes of Turkish music according to their harmonic relations, that is, according to their common and/or related substructures. The network model presented here not only considers common substructures between different makams, but also recognize and include various relationships transformations and topographies between dif-

[1] Bozkurt (2008) [4] developed an automatic tuning analysis method, followed by Tamer and Bozkurt's (2013) [5] creation of microtonal tuners for custom tunings. Bozkurt (2014) [6] introduced automatic tonic detection and histogram-based analysis applications. The same year, Bozkurt et al. (2014a) [7] presented melodic segmentation tools using makam and usul features and published a comprehensive review of computational analysis in Turkish makam music (Bozkurt et al., 2014b) [8]. Benetos and Holzapfel (2015) [9] developed transcription systems for microtonal Turkish music, while Bozkurt (2015) [10] analyzed melodic progression in Turkish makam music. In 2016, Senturk (2016) [11] introduced Tomato, a Python toolbox for analyzing Turkish-Ottoman makam music, and Karakurt et al. (2016) [12] released MORTY, a mode recognition and tonic identification toolbox.

ferent substructures. After reviewing some basic concepts and terminology, the first part of the presentation will explain the methodology of determining the relationships between various makam systems. Here we will present common nuclear elements and certain relationship principles that mutate such elements, creating alternative bridges with other makam systems.

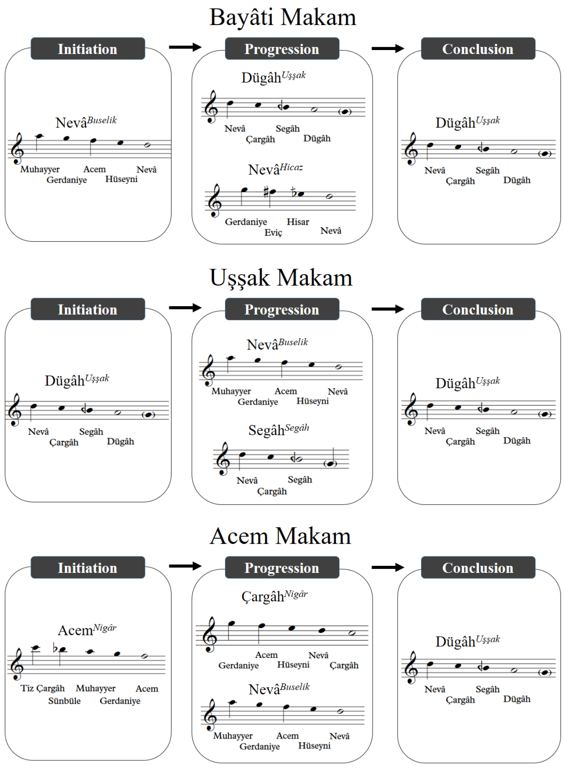

Figure 2. *Seyir* of *Bayâti*, *Uşşak* and *Acem* Makamlar as a chain of Perde$^{\text{Çeşni}}$ progressions.

2. THEORETICAL BACKGROUND AND MODEL

The primary material of makam is *perde* (pl. *perdeler*), which in some cases can refer to a specific frequency – as in the Western notion of pitch -, or can encompass a range of frequencies that can vary according to the makam it is used in and its function in the melody. Thus a *perde* can be either stable or unstable (movable/dynamic) depending on the musical context. [2] Stable *perdeler* possess melodic-axis qualities, which function either as a finalis, a reciting-tone, or a suspended cadence; all of these can be used as anchoring pivots while connecting to other substructures. These modular building blocks of makam - similar to Greek genus/genera or Arabic jins/ajna - will be referred to as it is popularly used in Turkish as; *çeşni* - meaning flavor, expressing the temporary sonorous effect of the melody. Recently, Abu Shumays (2013) proposed a clear explanation of how Arabic ajna create a network of pathways that build up a maqam and the surrounding "jins baggage" they possess, an alternative/supplement to the conventional "scalar" explanation of maqamat [14]. The proposal holds true for Turkish makam music as well. We will be using Perde$^{\text{Çeşni}}$ denotation to refer to specific *çeşni* structures built on specific perdeler. For instance, Neva$^{\text{Hicaz}}$ means Neva *perde* with Hicaz *çeşni*.

A defining element of a makam is *seyir* (the course), the basic outline and the distinct melodic path of a makam. *Seyir* distinguishes makams that have the same *perde* structures and finalis degrees, but are different in their melodic orientation. We believe this is due to the combination of different Perde$^{\text{Çeşni}}$ progressions. Thus, our model interprets makam as progressions of Perde$^{\text{Çeşni}}$ structures, highlighting the melodic path (initiation, development, closure), or *seyir*, of each makam.

In Figure 2, the basic *seyir* of *Bayâti*, *Uşşak* and *Acem* makam are demonstrated in this manner. The whole notes represent the primary axis, the *perde* on which the *çeşni* is built on. The quarter notes are secondary axes, while the unstemmed full notes, although usually being the identifiers of the *çeşni*, are less significant in connecting the structural pillars due to their unstable inclinations [3] . Realize that all three makams presented in Figure 2 share two Perde$^{\text{Çeşni}}$ structures, Neva$^{\text{Buselik}}$ and Dügah$^{\text{Uşşak}}$. Using these common substructures as pivots, one can smoothly wander within the three listed makams. However, inter-makam transitions are not solely reliant on the utilization of such common Perde$^{\text{Çeşni}}$ substructures. Indeed, each Perde$^{\text{Çeşni}}$ may uniquely be connected to another, facilitating various types of transitions.

Figure 3. Transformation examples from the repertoir.

We propose three main Perde$^{\text{Çeşni}}$ transformational relation categories;

(1)*Intraconnected*, in which the primary, the secondary, or both axes are displaced either within the same perde collection or its subsets/supersets;

[2] Recent computational research exposed this fact by various frequency-histogram analyses of makam performances, at which some perde regions are displayed as steep and narrow while some others resemble plateaus that spread over a bandwidth of nearly a semitone [13].

[3] For a discussion on the melodic inclination of different 'nuclei' substructure in makam music see Bayraktarkatal and Güray, 2023 [15]

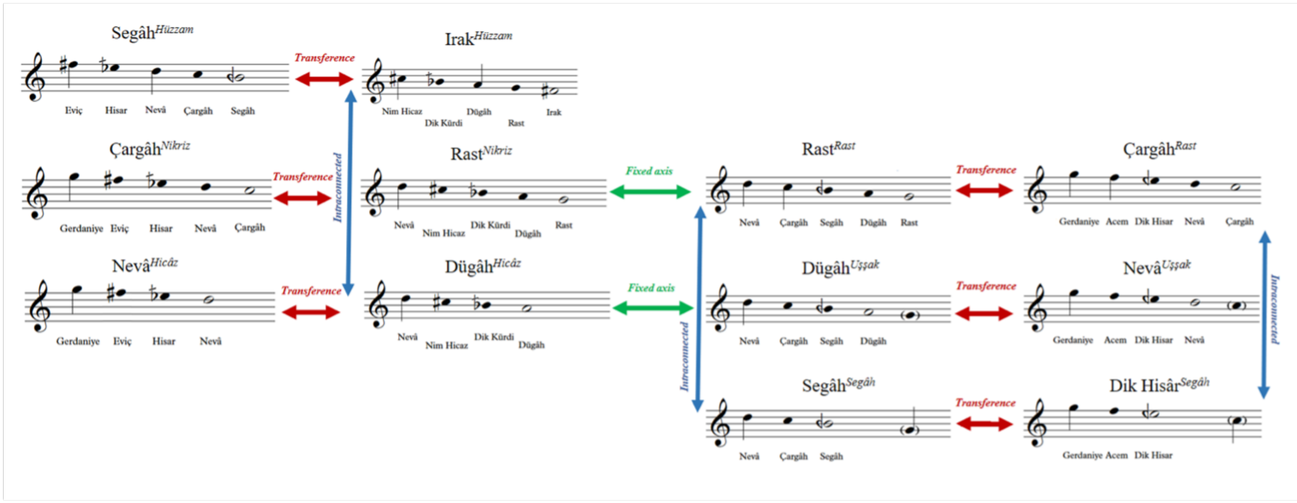

Figure 4. Three basic Perde^{Çeşni} transformations.

(2)*Transference*, in which the primary axis *perde* changes, but the *çeşni* structure remains the same (thus, the structure is basically transposed) in our model we limited the transferences with P5 and P4 (each up and down) as frequently witnessed in the repertoire;

(3)*Fixed axis*, in which one or two of the axis *perdeler* remain constant while the *çeşni* structures change.

One can come across many similar transformations and relations within the repertoire. Figure 3 provides three examples for each transformation type.

Figure 4 demonstrates examples of these three main transformations by connecting various Perde^{Çeşni} structures. Realize how Dügah^{Uşşak} is related to Neva^{Uşşak}and Dügah^{Hicaz} is related to Neva^{Hicaz} through transference, while Dügah^{Uşşak} and Dügah^{Hicaz} are related through fixed axis, similar to how Neva^{Uşşak} is linked to Neva^{Hicaz}. An important point to note is that there can be instances of double-transformations, such as the transition from Dügah^{Uşşak} to Neva^{Hicaz} , which are not directly related. Such transformations are also possible as can be seen within the progression of Bayâti Makam (Figure 2).

Based on this model we have compiled two extensive databases. The first one includes the most commonly used Perde^{Çeşni} structures in Turkish makam music and described them according to their perde content as well as the primary and secondary axes. The second one includes makam informations, in which makams are considered as Perde^{Çeşni} progressions.

3. THE MAKAMNETZ APP

3.1 Designing MakamNetz Virtually

Our data model for the pitch and intervallic content in music uses a textual approach to account for the variability of makam systems, with a focus on capturing trajectories and pathways between melodic units and makam structures. We leverage a relational database and the Django framework to effectively represent and analyze the intricate textual data structures, revealing the topological properties inherent in the makam universe.

The model's fundamental building block is "Perde," linking melodic units, while incorporating essential melodic components ("Cesnis") that establish connections within the makam network, providing insights into the evolution and complexity of the makam universe across different historical periods. The foundation of our data structures relies on Django "models," a prominent feature that empowers us to create intricate and well-defined data abstractions. This enables us to design and manage complex relationships between various entities in the system effectively.

For the frontend framework, we opted for React, a widely-used open-source framework designed for constructing single-page web applications. React's modular structure revolves around components, which are reusable building blocks. This feature facilitates the development of scalable and maintainable web applications. Additionally, React boasts efficient rendering capabilities, contributing to the creation of fast and responsive web experiences.

At the core of our application lies a graphical interface known as "react-force-graph." Leveraging the power of Three.js, this interface enables the creation of visually appealing 3D and 2D force-directed graphs. The combination of React and Three.js provides a robust platform for generating captivating visual representations of complex data structures. By harnessing the data generated through Django, we were able to craft an engaging user interface, providing users with a seamless experience in exploring and constructing the universe. The current version of the application framework exhibits versatility in handling diverse data models and generating distinct networks in accordance with our theoretical framework.

3.2 The App

Our app showcases the Çeşni Space (Figure 5), offering a visualization of different substructural units, and their interconnections. The small nodes represent individual Perde^{Çeşni} units, while the larger ones symbolize the fundamental *perde* upon which they are built. Nodes sharing the same color originate from the same perde. This visualization enables users to explore diverse pathways within

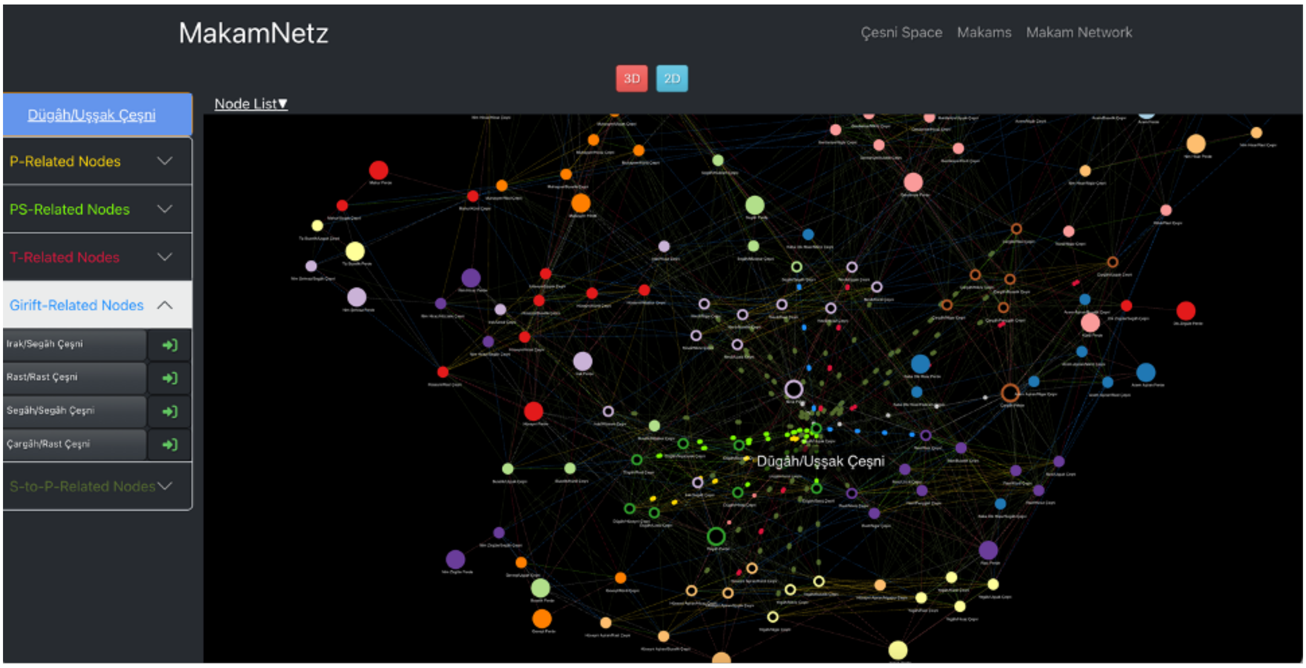

Figure 5. MakamNetz User Interface.

the network freely. Hovering over a node allows users to highlight all connected nodes and links, facilitating an in-depth analysis of transformations and relationships among different substructures. This feature aids in studying pathways in makams and gaining insights into the complex relationships between various structures.

In the 'Makams' section, users can delve into the melodic progressions within a single makam. The formal sections are color-coded, and the users can listen to how a selected makam sounds. Additionally, our app involves creating networks from multiple selected 'Makam Network. Presently, we are testing this feature with 17 makams. This subset allows us to observe and analyze relations between different makams and their sub-spaces. Our goal is to expand this functionality to encompass a larger number of makams that are currently in practice [4] .

3.3 ER Diagram and Relation Logic

MakamNetz primarily relies on the entity-relation (ER) model, which we transformed into a relational model using Django. Figure 6 displays the ER diagram, illustrating that the app is built upon four fundamental entities.

The smallest entity is Perde, where Makam pitch objects are encoded, each having a name and primary ID. The second entity, Perde/Cesni, consists of content that includes multiple Perde entities. We envisioned Perde/Cesni Content as a weak entity dependent upon Perde/Cesni. Each Perde/Cesni is related to another of its kind via a relation that relies on the content. Additionally, each Perde/Cesni is categorized within a Formal Section, which comprises three subcategories of the *seyir* (Initiation, Progression, Closure). This categorical hierarchy is encoded via an ISA relation. These formal units come together to compose a Makam, each of which has a unique ID and name. The diagram also illustrates the hierarchical relationship between each sub and superstructure through participation constraints encoded via thick lines. Each superentity has a participation constraint, as it cannot exist without the subentity. For instance, the Makam entity cannot exist without the formal section and thus relates to it via mandatory participation.

Much of relational logic is predicated on hierarchy; however, one particular configuration stands out: the self-relating Perde/Cesni entity, which constitutes one of the most crucial aspects of the application. This relationship, termed "Related to," relies on an algorithm to ascertain the nature of the relation, namely, p-axis, ps-axis, s-axis, and girift. The first three are contingent upon the common axis relation existing between two nodes under consideration, while the latter necessitates an object known as a girift chain to be formed. A girift chain embodies a predetermined scale-like structure composed of cyclically alternating cesnis. Within this framework, cesnis that can transition into one another via sliding one or two steps up or down are deemed girift-related. Given the finite number of girift chains, we have chosen to create an external JSON document rather than defining a separate entity. Formally, we can define the axis relations as follows:

Definition 1:

Let P_{MAKAM} be the set of all perdes and C_{MAKAM} be the set of all cesni sequences used in Turkish Makam.

- An axis perde in a cesni sequence is a perde that serves as a primary or secondary pivot point in the sequence.

[4] Demo videos of MakamNetz environment at work can be found in the MakamNetz YouTube page (https://www.youtube.com/@MakamNetz)

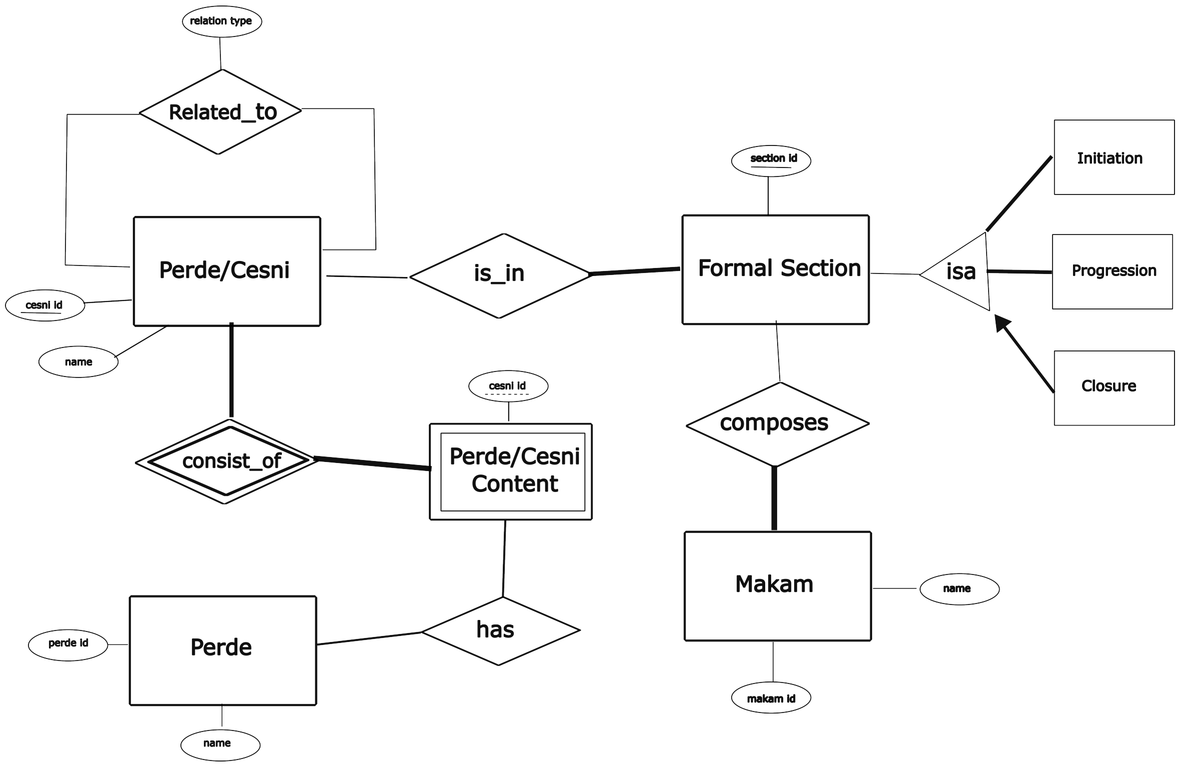

Figure 6. MakamNetz User Interface.

- A cesni sequence is a specific arrangement of perdes that define a makam's characteristic melodic progression.

$$A_P = \left\{ p \in P_{\text{MAKAM}} \mid \begin{array}{l} p \text{ is an axis perde in some cesni} \\ \text{sequence in} \\ C_{\text{MAKAM}} \end{array} \right\}$$

Thus, $A_P \subseteq P_{MAKAM}$.

We define a matrix $PerdeMatrix$, where each element X_{ij} represents the relationship between two axis perdes p_i and p_j in terms of the cesni sequences they participate in. Specifically, X_{ij} is a set of cesni sequences that use both p_i and p_j as axis perdes.

Definition 2:

Define the set P_M as:

$$P_M = \{X_{ij} \mid p_i, p_j \in A_P \text{ and } X_{ij} \subseteq C_{MAKAM}\}$$

Within this framework, we can define:

- p-axis: The set of all cesni sequences where the primary axis perde is common.
- s-axis: The set of all cesni sequences where the secondary axis perde is common.
- ps-axis: The set of all cesni sequences where both primary and secondary axis perdes are common.

These can be defined as follows:

$$ps\text{-axis} = \{X_{ij} \mid X_{ij} \in P_M \text{ and } X_{ij} \neq \emptyset\}$$

$$p\text{-axis} = \bigcup_j X_{ij} \text{ for a fixed } i, \text{ where } X_{ij} \neq \emptyset$$

$$s\text{-axis} = \bigcup_i X_{ij} \text{ for a fixed } j, \text{ where } X_{ij} \neq \emptyset$$

4. DISCUSSION

While the model represents a significant advancement in the study of Turkish makam music, it is important to acknowledge certain limitations and considerations for future development. One notable limitation is the variability in the *perde* degrees within certain *çeşni* structures, such as Hicaz, which are influenced by their melodic relationships within specific makam contexts. Several studies have addressed this issue using computational methodologies, providing case-study frequency-band measurements of perde degrees derived from live recordings. However, there has been limited progress in general theoretical models concerning this matter, and there is no universal agreement on the most effective model. Since the discussion of this theory versus practice issue is beyond the scope of this research, the model framework does not accommodate such nuances arising from frequency-band differences of *perdeler* in different contexts.

Continued refinement of the transformational and relationship algorithms, alongside enhancements to visualization features, will be crucial in augmenting the usability and effectiveness of the application as a research tool. This includes a more accurate demonstration of the distances between substructures. Although the network model offers valuable insights into the harmonic connections and melodic pathways between Perde$^{\textit{Çeşni}}$ structures, distance calculation remains an unresolved issue. Currently, there is limited research on the similarity of Perde$^{\textit{Çeşni}}$ structures, which raises questions about their potential influence on the smoothness of transformation. Thus, our model assigns equal weight to paths of equivalent total distance, irrespective of their practical applicability due to variations in frequencies. This is an area that the forthcoming phases of our research aim to address and improve in order to capture the nuances inherent in Turkish makam music.

5. CONCLUSIONS

In conclusion, MakamNetz provides a novel approach to mapping harmonic relations of Perde^{Çeşni} substructures and demonstrating transitional pathways within the makam universe, including individual spaces, neighboring constellations, and ostensibly remote systems. We believe that this work will offer a valuable tool for scholars, students, and enthusiasts of makam music alike, fostering exploration, discovery, and a deeper understanding of this rich musical tradition.

Acknowledgments

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