data

MDPI

Article

DNA of Music: Identifying Relationships among Different Versions of the Composition Sadhukarn from Thailand, Laos, and Cambodia Using Multivariate Statistics

Sumetus Eambangyung [1,*], Gretel Schwörer-Kohl [1] and Witoon Purahong [2]

[1] Institut für Musik, Medien- und Sprechwissenschaften (IMMS) Abteilung Musikwissenschaft, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany; gretel.schwoerer@musikwiss.uni-halle.de

[2] Department of Soil Ecology, UFZ-Helmholtz Centre for Environmental Research, 06120 Halle (Saale), Germany; witoon.purahong@ufz.de

* Correspondence: sumetus.eambangyung@student.uni-halle.de

Abstract: Sadhukarn, a sacred music composition performed ritually to salute and invite divine powers to open a ceremony or feast, is played in Thailand, Cambodia, and Laos. Different countries have unique versions, arranged based on musicians' skills and en vogue styles. This study presents the results of multivariate statistical analyses of 26 different versions of Sadhukarn main melodies using non-metric multidimensional scaling (NMDS) and cluster analysis. The objective was to identify the optimal number of parameters for identifying the origin and relationships among Sadhukarn versions, including rhyme structures, pillar tone, rhythmic and melodic patterns, intervals, pitches, and combinations of these parameters. The data were analyzed using both full and normalized datasets (32 phrases) to avoid biases due to differences in phrases among versions. Overall, the combination of six parameters is the best approach for data analysis in both full and normalized datasets. The analysis of the 'full version' shows the separation of Sadhukarn versions from different countries of origin, while the analysis of the 'normalized version' reveals the rhyme structure, rhythmic structure, and pitch as crucial parameters for identifying Sadhukarn versions. We conclude that multivariate statistics are powerful tools for identifying relationships among different versions of Sadhukarn compositions from Thailand, Laos, and Cambodia and within the same countries of origin.

Keywords: Sadhukarn; non-metric multidimensional scaling; cluster analysis; multivariate statistics; Na Phat music; Mekong-Chao Phraya River basin

Citation: Eambangyung, S.; Schwörer-Kohl, G.; Purahong, W. DNA of Music: Identifying Relationships among Different Versions of the Composition Sadhukarn from Thailand, Laos, and Cambodia Using Multivariate Statistics. *Data* **2024**, *9*, 50. https://doi.org/10.3390/data9040050

Academic Editors: Changseok Bae, Dong-Oh Kang and Vera Yuk Ying Chung

Received: 2 February 2024
Revised: 14 March 2024
Accepted: 22 March 2024
Published: 30 March 2024

1. Introduction

> "*Sathukar (or Sadhukarn)* is a teacher song [. . .] When people hear it in Thailand, Cambodia, or Laos, they stop talking. They listen and bow with their hands together [. . .] When you learn *Sathukar,* you need to *rieb krou* (paying respect to the teacher and teacher spirits) [. . .] And, you're supposed to learn *Sathukar* from a teacher. It's not right to learn it another way [. . .] I can't say that *(Sathukar* has a special power), because I can't prove that. But I think that, if you believe it, it's true. If you don't believe it, that's fine too. But, yeah, I believe it".
>
> Chum Ngek: 2004 [1]

Thailand, Cambodia, and Laos, the three countries in Mainland Southeast Asia located in the lower Mekong River basin, share many similarities in their physical environment, culture, and society. Throughout history, the people from these lands have had a rich tapestry of cultural, linguistic, and traditional intermingling through successive migratory movements, often caused by war and trade [2]. In addition, their music is also particularly

shared and interchangeable. The traditional music of Thailand, Cambodia, and Laos exhibits many similarities in ensemble, instrumentation, repertoire, as well as musical raw material [3,4]. These triplet-sister musical cultures have developed a rich and diverse musical tradition that reflects their unique histories and cultural identities [3].

Sadhukarn (or Sathukar in Khmer) is the first piece of *Homrong*, a series of sacred music repertoires to be played as a suite. Sadhukarn is part of *Phleng Na Phat*, a sacred music repertoire used for both ceremonial and entertainment purposes. One of the purposes of playing Sadhukarn is to entertain people, while also paying homage to the divinity and spirit of ancestor musicians [4–6]. Generally, the piece was composed and played by *Wong Phi Phat* (or *Pin Peat* in Khmer and *Phin Phat* in Lao), the traditional wind and percussion ensemble. This kind of ensemble is located particularly in the Chao Phraya and Mekong River basins that encompass most of present-day Thailand, Laos, and Cambodia [4].

Music teachers in the past composed music with their beliefs for a ceremony or a specific ritual by ordering the importance of sanctity. The first piece in a ceremony is always performed as a sign of the highest respect. Whenever the *Phi Phat* ensemble is performed, in Thai music culture, Sadhukarn is always played first to pay the highest respect to Buddha, the founder of Buddhism. Apart from being played in a ceremony as *Na phat* music, Sadhukarn takes on an important role in Thai music culture in various contexts such as ordering music pieces in performance, music pedagogy, composing music, changing melody, forms of ensembles, beliefs in the supernatural in Thai music culture, etc. [7]

Sadhukarn is popular on various occasions of auspiciousness such as religious ceremonies, general auspicious ceremonies, and royal ceremonies, including being accompanied by dancing and theatrical performances. Furthermore, ancient music teachers also related Sadhukarn to holiness in ancient religious legend until it became a constant belief handed down. As a result, Sadhukarn is widely played and has become popular among Thai, Lao, and Cambodian musicians. Sadhukarn's melody transmission has been passed down directly from teacher to student by oral tradition. Normally, the composition is relatively inflexible, and performers usually do not have the liberty to make variations spontaneously [7].

Although Sadhukarn is highly valued in the music communities of Thailand, Laos, and Cambodia, it is often overlooked. Furthermore, Sadhukarn is often transmitted orally by senior musicians or music masters to selected followers in their school, rather than being notated. It is important to note that Sadhukarn is not widely recognized despite its significance. Thus, Sadhukarn is a precious hidden gem that has yet to be discovered. If there are no efforts made in data collection and study, in the future, there may be musicians who know only how to play but do not know the Sadhukarn background, which is an important foundation of Thai music. There are several factors that influence changes in Sadhukarn: teaching in the context of oral tradition without written musical notation, self-learning, and remaking. These led to changes in the original Sadhukarn into diverse versions, specifically the changes in the main melody played in the *Khong Wong Yai* (Circle of Gongs). There are at least 25 versions of Sadhukarn occurring in Thailand, Laos, and Cambodia, and each country has its own version. Among these 25 versions, Thailand owns the majority of Sadhukarn variations (16), followed by Laos (4), Cambodia (3), and Thai-Cambodia border areas (Thai site) (2) [7].

Sadhukarn versions have been studied by Thai music scholars in terms of a comparative study of melodic and rhythmic structure [8,9]. The results from those studies show that Sadhukarn versions from different countries have both similar and different music structures [9]. Nevertheless, statistical approaches have not yet been applied to systematically analyze Sadhukarn versions in these three countries. Although it has been assumed that different lineages of Sadhukarn within the same country are more similar to one another than from different countries, this still has never been proven.

The reason behind this is that there are still limitations in the methods available for analyzing music composition from Southeast Asia. This is due to the lack of suitable

techniques [7]. Western music compositions are generally analyzed using music elements such as rhythm, melody, forms, structure, etc. For Southeast Asian music, i.e., Na Phat music in Thailand, Laos, and Cambodia, however, the analyses are still traditionally based on oral traditions, and it appears that almost no standard methods can be used to quantify the similarity among different versions of the music compositions.

Therefore, we applied multivariate statistics based on non-metric multidimensional scaling (NMDS) and clustering methods to visualize and quantify similarities among different versions of Sadhukarn. These approaches have been used to visualize and quantify similarities among different complex data such as animal, plant, and microbial communities; thus, they also have potential in the analysis of complex music compositions. NMDS requires few assumptions about the nature of the data (i.e., linear relationships and reciprocal averaging assume modal relationships are not required), thus it is suitable for a wide variety of data [10]. Unlike other ordination approaches, which require specific dissimilarity measures, NMDS allows the use of any distance measure of the samples [10].

Recently, NMDS has been applied to analyze music data in terms of musicological data visualization [11]. The study used NMDS based on composer similarity indices to generate an ordination map representing the relative position of 500 classical music composers while preserving the pairwise distances. The result showed the classification and separation of 500 composers by 10 musical historical time periods. Apart from NMDS, there are other multivariate statistical analysis techniques used to analyze music in several ways, i.e., the dimensional reduction in Korean pop music audio features performed by principal component analysis paired with K-means clustering [12], Web-based music listening studies using Goodness-of-fit test and subgroup analysis to identify, evaluate, and validate variations of 16 compositional elements of relaxation [13], etc.

Nevertheless, none of these studies used NMDS to analyze music composition considering different music elemental parameters [11–13]. Sadhukarn can be manually converted into Thai and Western music notations without additional expensive devices and software. Data including Look Tok (pillar tone), rhythmic structure, melodic structure, intervals, and pitches can be derived from the music notation and used for music structure analysis [7]. Furthermore, rhyme structure can be extracted from Thai and Western notations and can also be used for music structure analysis. In this study, we aimed to use multivariate statistics including NMDS and cluster analysis based on the Euclidean distance for analysis of the music composition of Sadhukarn. Rhyme structure, Look Tok, rhythmic structure, melodic structure, intervals, pitch, and a combination (the mixture of all music elemental parameters used in this study) were used for multivariate analysis.

The results were compared to identify the best parameters that can be used to separate different versions of Sadhukarn music structure according to their countries of origin. Although different parameters can be used to identify the origin and/or relationship among Sadhukarn versions, the results can be different. Time, effort, and expertise are needed to generate data for these six parameters. When we can identify the best parameter, we can save time in the analysis of Sadhukarn. We hypothesize that (i) different versions of Sadhukarn form clusters in the ordination plots where those with similar origins stay close to each other, while those from different origins are far apart. We also hypothesized that (ii) Sadhukarn versions originating from Thai and Cambodian border areas form a separate cluster located between Sadhukarn versions from Thailand and Cambodia in the ordination plots as they are influenced by the cultures of both countries. Finally, we hypothesized that (iii) the combination of rhyme structure, Look Tok, rhythmic structure, melodic structure, intervals, and pitch for multivariate analyses is the best approach to separate different versions of Sadhukarn music structure according to their countries of origin. We expected that the combination of such diverse important parameters could positively influence the stability and reliability of the multivariate analyses used in this study.

The multivariate analysis implemented in this study allows us to objectively validate the non-Western music composition consisting of distinctive characteristics of musical elements, which is presumed by most research in music analysis. The organization is as

follows: first, a description of data preparation and the methodology used is presented; second, the results of NMDS and clustering analysis of 26 Sadhukarn versions are shown; and finally, a discussion and the application of this study are presented.

2. Material and Method

2.1. Data Collection

The data collection consists of 25 versions of Sadhukarn main melodies collected from Thailand, Laos, Cambodia, and their border areas. All Sadhukarn versions were transcribed into Western and Thai music notation and rhyme music structure. We used data from our own data descriptor, in which all information on musical data (i.e., version name, location and graphical coordinates, source types, and collected/published date) and the procedure was previously published by Eambangyung et al. [7]. Furthermore, one version of Sadhukarn recently discovered in Siem Rieb (Thai–Cambodian border areas, Cambodian site) was included in this study (Table S1, Appendix I, Supplementary Materials).

2.2. Thai and Western Notation and Their Transcription to Different Music Element Parameters for Multivariate Statistical Analysis

Because our method (multivariate statistical analysis) required isolating music attributes as parameters in multiple dimensions, we determined our dataset with four elemental music parameters following the musical meta-features and notational dimensions that specify characteristics of music composition in detail [14], including rhythm, melody, interval, and pitch. To take advantage of the cross-cultural analogies of Thai-Laos-Cambodian and Western music, we also applied the Look Tok or pillar tone and rhyme music structure as fixed-elemental music parameters in analyzing the data at the hyper-deep structure level [15]. Following this procedure, six elemental music parameters consisting of rhyme structure, pillar tone, rhythmic pattern, melodic pattern, interval, and pitch were extracted from all 26 Sadhukarn main melodies and then recorded in the dataset.

2.3. Normalization of Sadhukarn Datasets

Due to the difference in the number of phrases and keys in the Sadhukarn main melody version, normalization was considered at this point to avoid bias. There are 5, 19, 30, 32, and 55 phrases, but 32 phrases are played most often, which could be the so-called "32 shared phrases". For the normalization procedure, thus, we selected only the 32 shared phrases and the G note as the tonic of the pieces.

2.4. Statistical Analysis

In order to analyze 26 different versions of Sadhukarn's main melodies, we applied the microbial community analytical approach in music analysis based on multivariate statistical techniques [16–18]. In principle, microbial communities are interacting groups of different microorganism species with varying abundances in a common environment [16,19]. Similarly, the different versions of Sadhukarn main melodies appearing in Thailand, Laos, and Cambodia are comparable to microbial communities as a music composition of various characteristics with multidimensional music elements in detail in similar surroundings [7]. We analyzed using melodic phrases, identities, and distinctive characteristics of music elements including the rhyme structure, Look Tok (pillar tone), rhythm, melody, intervals, and pitches. We employed cluster analysis and NMDS as multivariate statistical techniques for music composition analysis. Using hierarchical cluster analysis with NMDS based on the Euclidean distance is useful to represent the dissimilarity between versions based on values of multiple variables (i.e., elemental music parameters) associated with them so that similar versions are depicted from each other, and different versions are found further apart from each other. NMDS plots and cluster analysis were [performed on Euclidean distance coefficients with the program PAST (Paleontological Statistics, version 4.11) [20].

The dissimilarity measure between a pair of versions is determined by the square root of the sum of the square of differences between each pair of music phrases [20]:

$$d_{jk} = \sqrt{\sum_{i=1}^{n} \left(X_{ji} - X_{ki}\right)^2} \quad (1)$$

where:

d_{jk} = the dissimilarity measure between a pair of Sadhukarn versions j and k.
j, k = two points in Euclidean n-space.
X_{ji}, X_{ki} = Euclidean vectors (scores), starting from the origin of the space (initial unit).
n = n-space (unit).

The quality of NMDS ordination can be determined using the goodness of fit of the regression, which is measured based on the sum of squared differences between ordination-based distances and the distances predicted by the regression. Such goodness of fit is called stress, which is commonly calculated using Kruskal's Stress. Stress values ranging from 0 to 0.20 are considered acceptable. The clustering algorithm used in this study is based on the unweighted pair-group average (UPGMA) [20]. Specifically, clusters are joined based on the mean distance between all members in the two groups [20]. Other clustering algorithms (i.e., single linkage (nearest neighbor) and ward's method) are also available in PAST; however, there are some limitations related to such algorithms as compared with the UPGMA. Nevertheless, one method is not necessarily better than the other, and the clustering results from different algorithms should be compared [20]. We indeed compared and found that the results were relatively consistent among different algorithms. Each Sadhukarn version consists of different numbers of phrases ranging from 5 to 54. Depending on the considered parameters, each phrase consists of different units ranging from 1 (interval and pitch), 2 (rhythmic and melodic structures), 4 (Look Tok), and 16 (rhyme structure). Different scores were assigned to each unit depending on the degree of the note and interval ratio (rhyme structure and Look Tok [1 to 10]), the intensity and origin of the rhythm (rhythmic pattern [1 to 15]), increasing pitch of the musical mode (melodic pattern [1 to 7]), the interval size and ratio (interval [1 to 9]), and increasing pitch range (pitch [1 to 10]). Detailed data used for score assignment were published in our recent article [7]. The method used for score assignment is described in Appendix II.

3. Results

3.1. Which Parameters Should Be Used for Music Composition Analyses?

NMDS and cluster analyses based on the Euclidean distance were successfully applied with six music elemental parameters including rhyme structure, Look Tok, rhythmic structure, melodic structure, interval, and pitch to analyze the composition of 26 different versions of Sadhukarn main melodies. The average degrees for each phrase of all six elemental music parameters are provided in Appendix III. Overall, different music elemental parameters showed consistent results for NMDS and cluster analyses that almost all full Sadhukarn versions from Thailand (except TTD) were grouped tightly and clearly separated from other Sadhukarn versions from Laos, Cambodia, and the border areas (Figures 1a–f and 2a–f). TTD was isolated from other Sadhukarn versions. In contrast, the Sadhukarn versions from Laos, Cambodia, and the border areas of Cambodia-Thailand were grouped together or dispersed in NMDS ordination plots depending on the music elemental parameters considered (Figure 1a–f). Three out of the six music elemental parameters (rhyme structure, interval, and pitch) showed that Sadhukarn versions from Laos (LB1, LB2, LB3, and LY) and border areas (IP, IN, and KW), as well as KR from Cambodia, were clustered together and/or located nearby in the NMDS ordination plots and were separated from the Sadhukarn version from Cambodia (KS1 and KS2) (Figures 1a,e,f and 2a,e,f). Based on Look Tok, KS1 and KS2 were clustered together with LB1 and LB2 from Laos whereas KR formed a group with Sadhukarn versions from border areas (IP and IN) and LB3 and LY from Laos (Figures 1b and 2b). When only the rhythmic structure was consid-

ered, KS1 was completely separated from a large cluster of Sadhukarn versions from Laos, Cambodia, and border areas (Figures 1c and 2c).

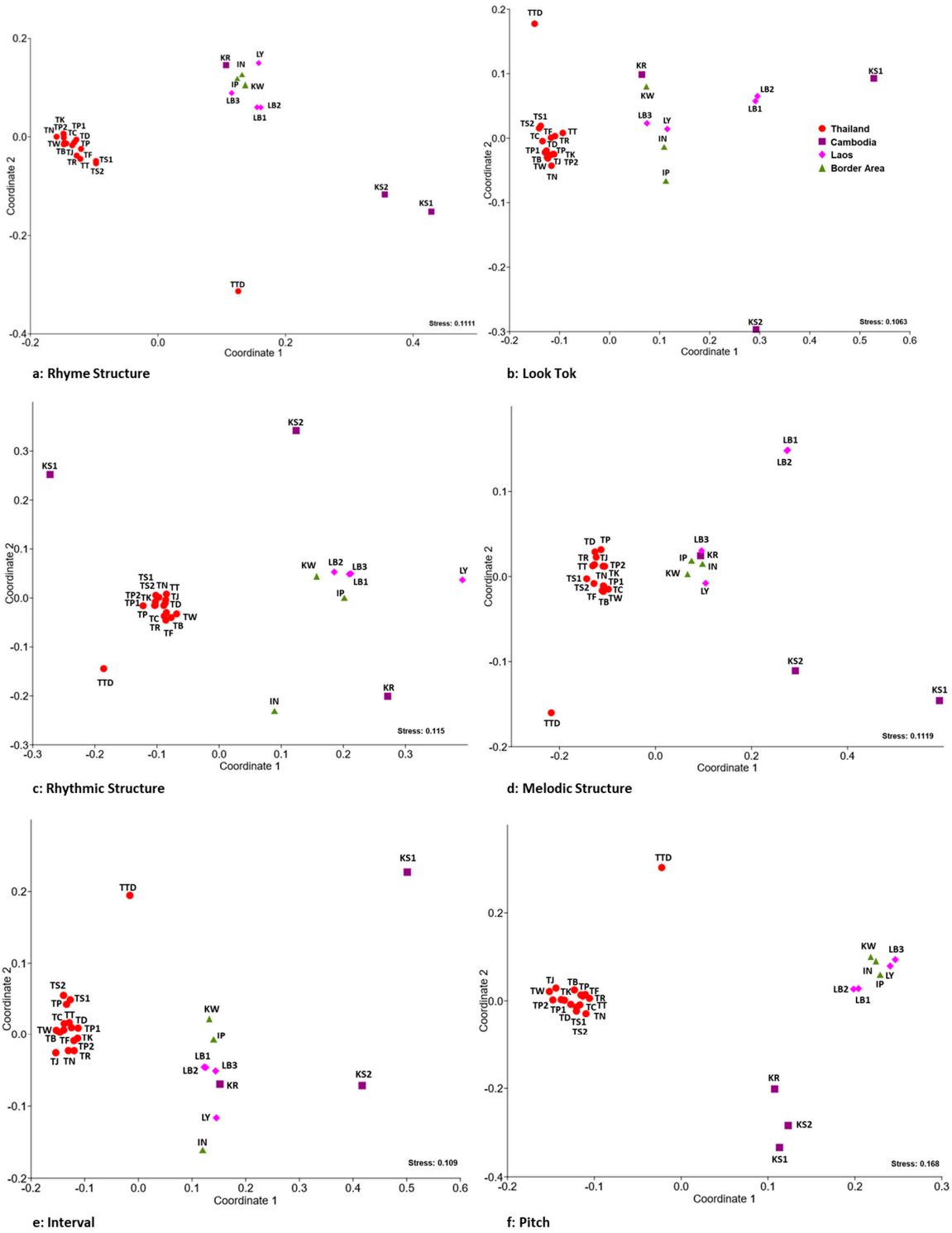

Figure 1. (**a**–**f**) Non-metric dimensional scaling (NMDS) ordination plots of 26 different versions of Sadhukarn's main melody [full version] generated by six parameters consisting of rhyme structure (**a**), Look Tok (**b**), rhythmic structure (**c**), melodic structure (**d**), interval (**e**), and pitch (**f**). All abbreviations are explained in Supplementary Materials and can be found in our previous study [7].

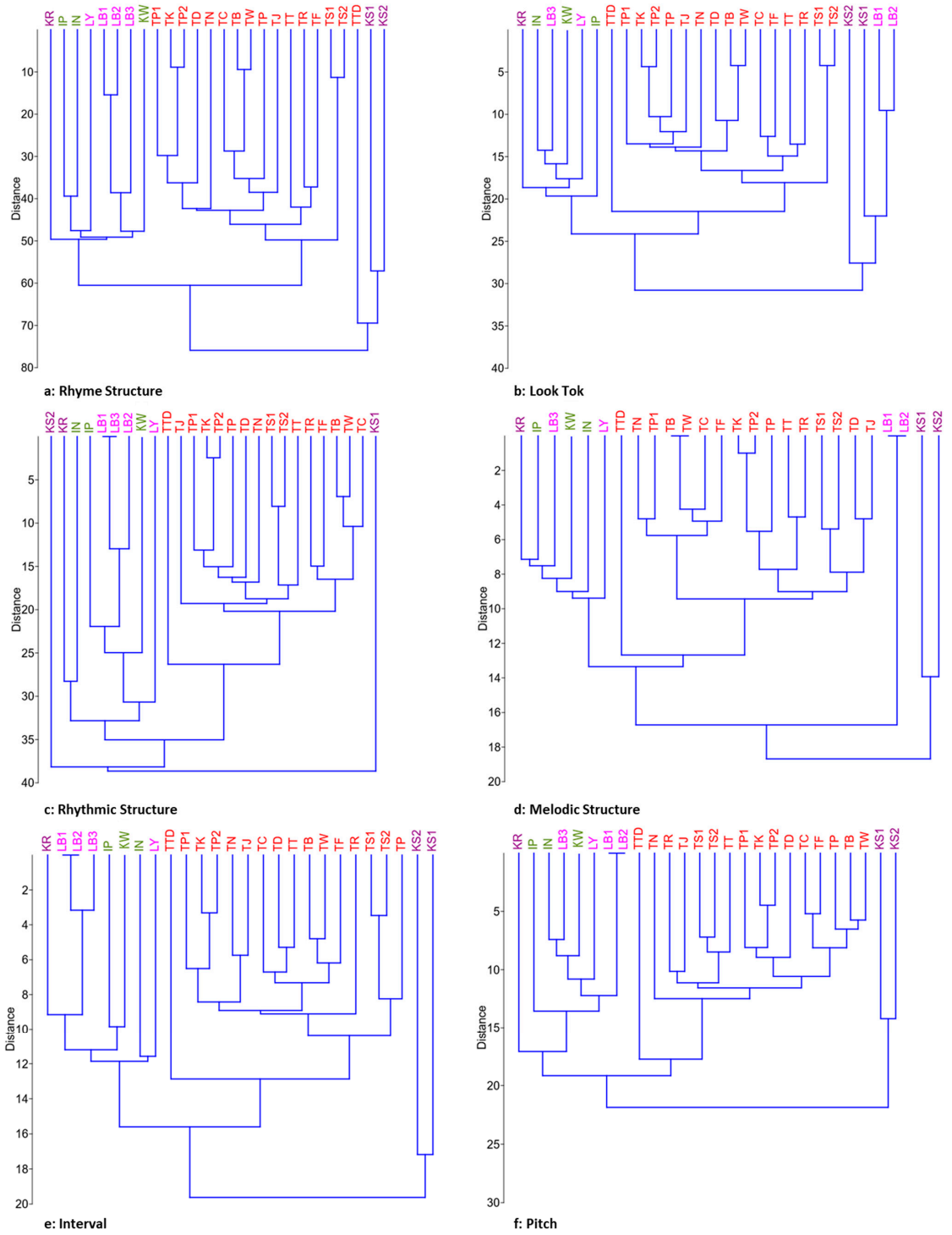

Figure 2. (**a**–**f**) Hierarchical cluster analysis diagrams of 26 different versions of Sadhukarn's main melody [full version] generated by six single parameters consisting of rhyme structure (**a**), Look Tok (**b**), rhythmic structure (**c**), melodic structure (**d**), interval (**e**), and pitch (**f**).

When all six music elemental parameters were combined together, all Sadhukarn versions from Thailand, except TTD, were grouped together and isolated from Sadhukarn versions of Laos, Cambodia, and the border areas (Figure 3). KR from Cambodia formed a large group with Sadhukarn versions from border areas (IP, IN, and KW) and LB1, LB2, LB3, and LY from Laos (Figure 3), which were separated from KS1 and KS2. These results were similar to the results obtained from the rhyme structure, interval, and pitch.

Furthermore, regarding the clustering configuration of all six music elemental parameters, Thai Sadhukarn versions were identified as four sub-groups (Figure 3): (1) group 1 was associated with TK, TP2, TP1, TD, and TN; (2) group 2 joined Thai Sadhukarn versions of TB, TW, TC, TP, and TJ; (3) group 3 incorporated Thai Sadhukarn versions of TR, TF, and TT; and (4) group 4 joined TS1 and TS2.

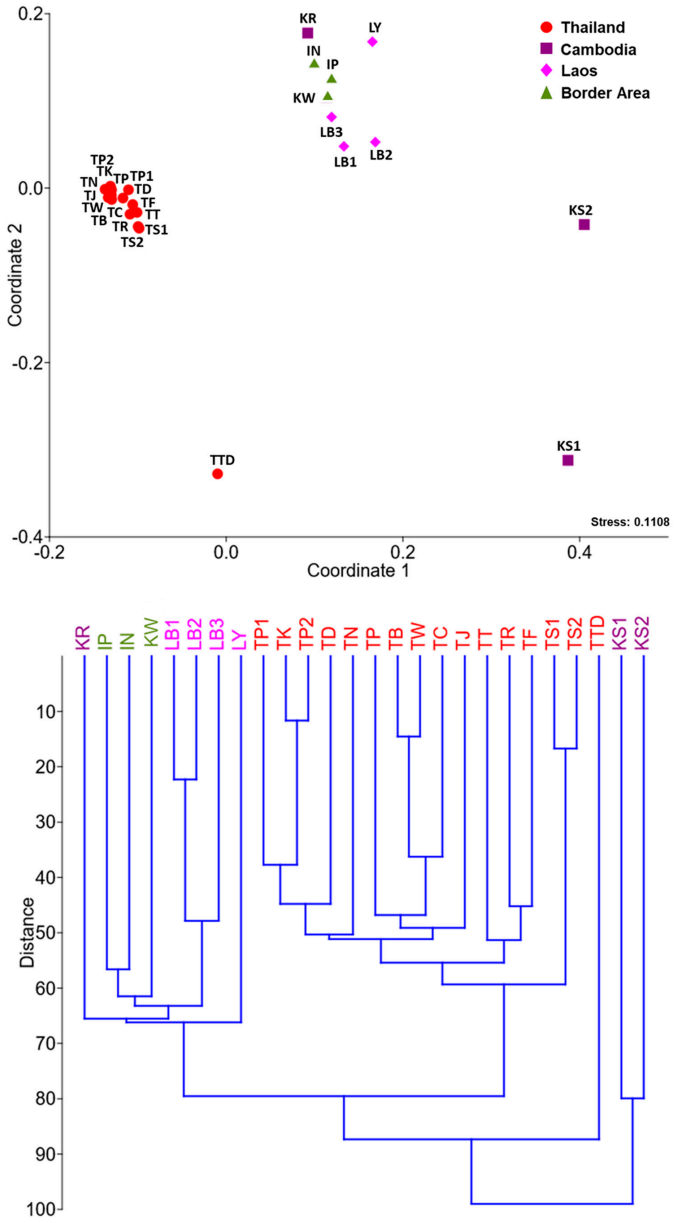

Figure 3. Non−metric dimensional scaling (NMDS) ordination plots and hierarchical cluster analysis diagrams of 26 different versions of Sadhukarn's main melody [full version] generated by the combination of six parameters.

3.2. Normalization of Music Phrase and Key: Does Normalization Impact the Results of Multivariate Statistics to Analyses Sadhukarn Composition?

After normalization for the number of music phrases and keys, 20 versions of Sadhukarn remained for further analysis. The results showed that three out of the six music elemental parameters (rhyme structure, rhythmic structure, and pitch) could separate versions of Thai Sadhukarn from other versions from Laos, Cambodia, and the border areas (Figures 4a,c,f and 5a,c,f). It is noteworthy that among these three music parameters, rhythmic structure was identified as the best parameter to use for NMDS and cluster analy-

sis as it tightly grouped and completely separated Thai versions of Sadhukarn from other versions of the other locations (Figures 4a–f and 5a–f). When considering only Look Tok, the Sadhukarn version from Laos (LB3) clustered together with Thai versions, which were completely separate from both Cambodia (KR) and Thai-Cambodian border areas (Thai site) (IP and IN), except KW (Cambodian site) (Figure 5b). When the melodic structure was used, both Sadhukarn versions from Cambodia and Laos (KR and LB3) were grouped with the Thai versions, which were separated from the border areas (Thai site) (IP and IN) (Figure 5d).

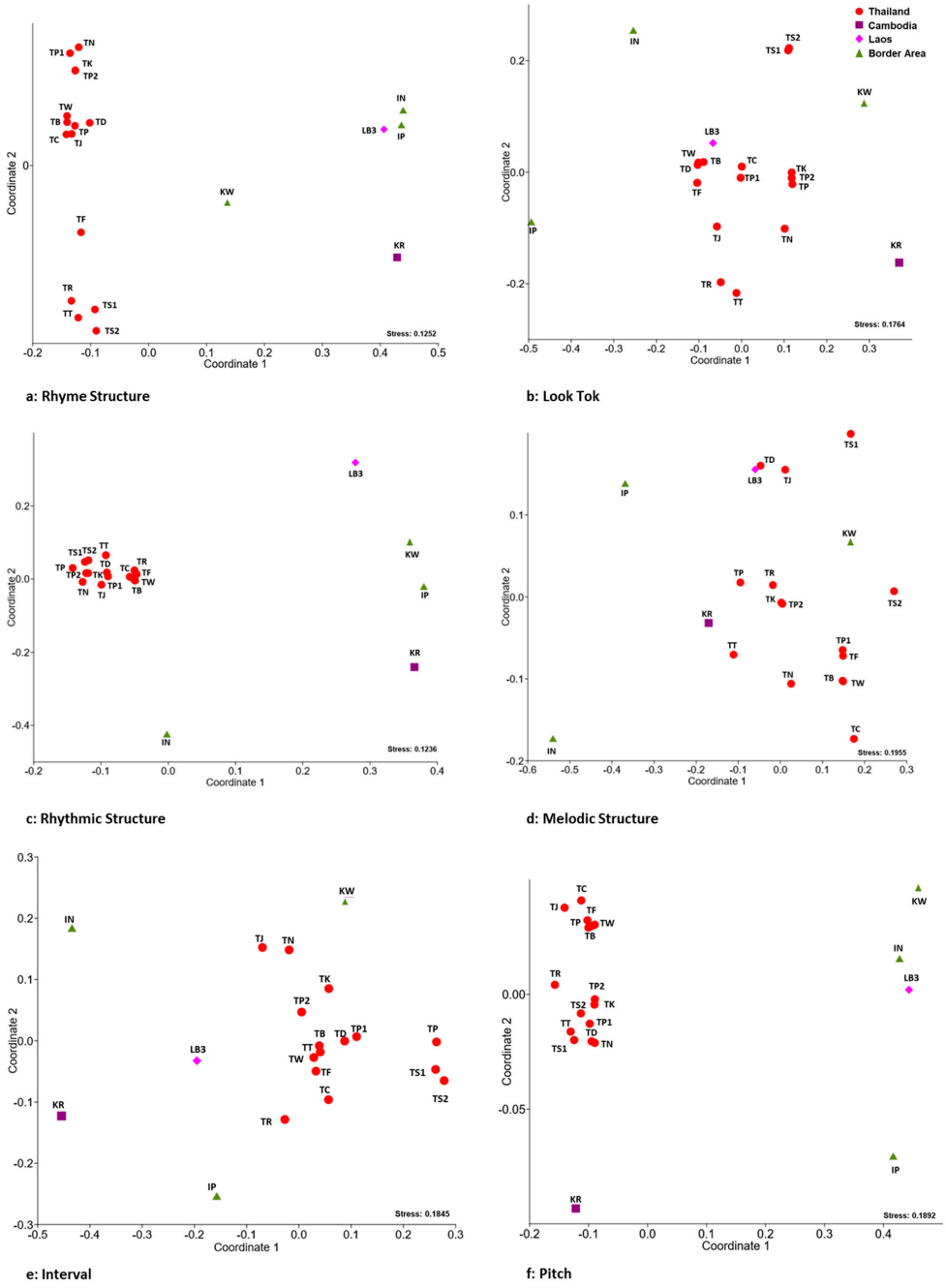

Figure 4. (**a**–**f**) Non-metric dimensional scaling (NMDS) ordination plots of 20 different versions of Sadhukarn's main melody [Normalized version] generated by six single parameters consisting of rhyme structure (**a**), Look Tok (**b**), rhythmic structure (**c**), melodic structure (**d**), interval (**e**), and pitch (**f**).

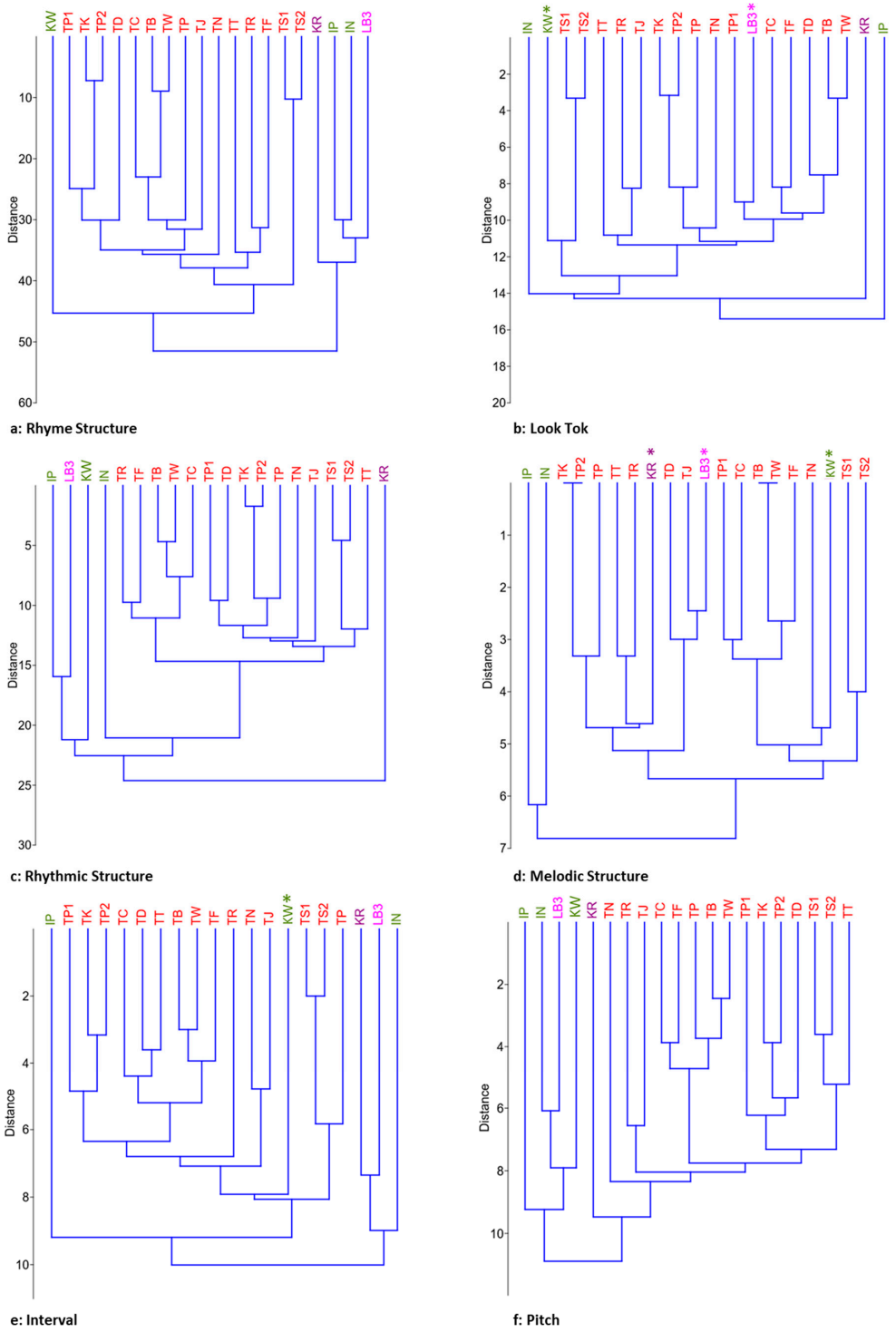

Figure 5. (**a**–**f**) Hierarchical cluster analysis diagrams of 20 different versions of Sadhukarn's main melody [Normalized version] generated by six single parameters consisting of rhyme structure (**a**), Look Tok (**b**), rhythmic structure (**c**), melodic structure (**d**), interval (**e**), and pitch (**f**).

When all six music elemental parameters were combined, we could separate Thai Sadhukarn versions from the Sadhukarn versions of Cambodia (KR), Laos (LB3), and border areas (IP, IN, and KW), which were all separated in the NMDS ordination plot and clustering diagram (Figure 6). Although IP, LB3, KW, IN, and KR seemed to be clustered together in the cluster ordination, their distances were between 41 and 50 Euclidean units, which may be considered different clusters. Furthermore, regarding the clustering configuration

of all six music elemental parameters, Thai Sadhukarn versions were identified as four sub-groups (Figure 6): (1) group 1 was associated with TK, TP2, TP1, and TD; (2) group 2 joined Thai Sadhukarn versions of TR and TT; (3) group 3 incorporated Thai Sadhukarn versions of TB, TW, TC, and TF; and (4) group 4 joined TS1 and TS2. In addition, there were three versions, namely TP, TN, and TJ, that were separate from the others.

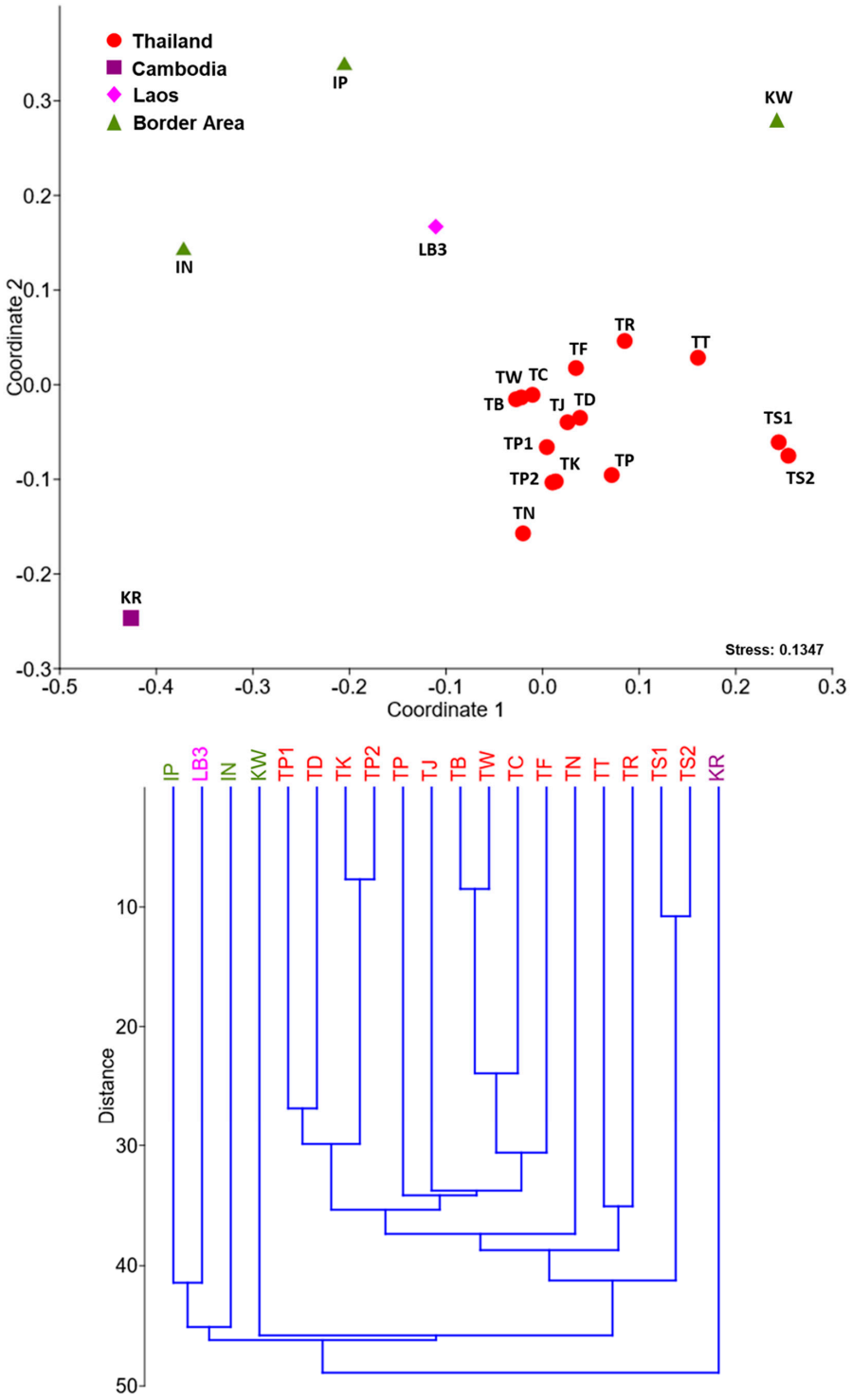

Figure 6. Non−metric dimensional scaling (NMDS) ordination plots and hierarchical cluster analysis diagrams of 20 different versions of Sadhukarn's main melody [Normalized version] generated by the combination of six parameters.

4. Discussion

4.1. Clear Separation of Different Versions of Sadhukarn in Thailand, Laos, and Cambodia (Hypotheses): Why?

Our results demonstrate that multivariate statistics by means of NMDS and cluster analysis are powerful tools for identifying relationships among different versions of the composition of Sadhukarn from Thailand, Laos, and Cambodia. We show that six music elemental parameters, including rhyme structure, Look Tok, rhythmic structure, melodic structure, interval, and pitch, and their combination can be used to analyze and identify the composition of 26 different versions of Sadhukarn main melodies with their countries of origins (hypothesis i). This finding can be explained by the fact that Sadhukarn main melodies in different countries contain unique features and musical structures [8,9,21]. In addition, our result based on cluster analysis shows that Sadhukarn versions originating from Thai and Cambodian border areas form a separate cluster together with Sadhukarn versions from Laos and/or Cambodia, which were separated from Sadhukarn versions from Thailand. This may be related to the stronger influence of Cambodian and Lao cultures in these border areas as compared with central Thai culture [2]. However, the unequal number of phrases in different Sadhukarn versions can highly contribute to such changes observed in this study. The number of phrases in different Sadhukarn versions varies greatly between five phrases in KS1 and 54 in all Thai versions. Sadhukarn versions from Laos and some parts of Cambodia have 30–32 phrases. The differences in the number of phrases among Sadhukarn versions are the result of imperfect oral transmission, as well as self-modification or even changes in melodies independently [8]. Nevertheless, such different numbers of phrases may introduce biases into the result analysis using multivariate statistics. To solve this problem, we normalized the different Sadhukarn versions into 32 shared phrases. The results from normalized data show some degrees of difference as compared to the full version. Specifically, the combination of all six parameters still successfully separated Sadhukarn versions into different countries (hypothesis iii). However, only three out of the six individual parameters can be used to identify Sadhukarn versions into different countries; that is, rhyme structure (cut-off value = 41 Euclidean units), rhythmic pattern (cut-off value = 14.5 Euclidean units), and pitch (cut-off value = 8.5 Euclidean units). The melodic structure can be considered the worst parameter for identifying Sadhukarn versions with different countries based on NMDS and cluster analyses. Specifically, KR, KW, and LB3 were clustered closely together with other Sadhukarn versions from Thailand. This can be explained by the fact that melody can be easily diffused and transformed from one country to another. The melodic transformation process can be categorized into four steps: (1) melodic reduction, (2) forward cross-cultural transformation, (3) melodic elaboration, and (4) backward cross-cultural transformation [15]. Although the normalized dataset may be a useful method to eliminate potential biases due to different numbers of phrases, we cannot normalize the Sadhukarn version with low phrase numbers.

4.2. Relationships between Sadhukarn Versions in Thailand Analyzed Using Combination of 6 Parameters in Normalize Dataset

In this study, we categorized Thai Sadhukarn into four subgroups and three individual versions. Such groupings are the result of locations and the relationships between the composers. Group I (TK, TP2, TP1, and TD) is in Ayutthaya and Bangkok. TK, TP2, and TP1 belong to maestro Phinij Chaisuwan, while TD belongs to maestro Chue Dontrirot. Both are Thai national artists who were born in Ayutthaya and worked together as musicians in Thai music ensembles in Bangkok. In addition, they also learned music with maestro Prieng Dontrirot, the head of the Thai music ensemble in Bangkok around the 1950s. Group II (TR and TT) and Group III (TB, TW, and TC) are also located in Bangkok and Ayutthaya. We can explain these relationships by the fact that they are all patrons of the Siam royal family and work relatively closely together. Group IV (TS1 and TS2) is in Ayutthaya. These Sadhukarn versions belong to the same musician (maestro Samran Kerdphol) who

developed and released them in different years. The other three individual versions (TP, TN, and TJ) are not clustered with any other sub-groups. They are individual versions and are not located in Ayutthaya or Bangkok. Specifically, TP is located in Phetchaburi, TN in Samut Songkhram, and TJ in Sing Buri.

4.3. Application of Multivariate Statistics for Music Structure Analysis

Apart from the composition of Sadhukarn, multivariate statistics by means of NMDS and cluster analysis based on the Euclidean distance can potentially be used to analyze the structure of general and traditional music. Traditional music that shares some similarity to Sadhukarn and/or Thai traditional music structure, such as Gamelan music from Indonesia [22], Burmese music [23], and other music traditions in Southeast Asia that use a skeleton note as a pillar tone in composition, can be analyzed using a similar approach to the present work. Perhaps other music genres, especially music from Western cultures, can also be analyzed using multivariate statistics considering rhythmic, melodic, and pitch parameters. Moreover, the results can be used to infer the origin of a musical piece and its uniqueness. Such statistical analysis can also be an alternative approach for tracking copyright.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data9040050/s1, Appendix I: Information on the 26 versions of the Sadhukarn main melody (Table S1); Appendix II: Degree of note and interval ratio in Khong Wong Yai (Table S2); Appendix III: Average degree for each phrase of all six elemental music parameters (Figures S1–S6). Data on different parameters (rhyme structure, pillar tone, rhythmic and melodic patterns, intervals, pitches, and combinations) of 25 different versions of Sadhukarn main melodies from Thailand, Laos, and Cambodia can be derived from Western notation, Thai notation, and rhyme structure which were published and freely available at https://www.mdpi.com/2306-5729/7/11/150, (accessed on 31 October 2022).

Author Contributions: Conceptualization, S.E., W.P. and G.S.-K.; methodology, S.E.; validation, S.E., W.P. and G.S.-K.; formal analysis, S.E.; investigation, S.E.; resources, S.E.; data curation, S.E.; writing—original draft preparation, S.E.; writing—review and editing, S.E. and W.P.; visualization, S.E.; supervision, W.P. and G.S.-K.; project administration, W.P. All authors have read and agreed to the published version of the manuscript.

Funding: Open-Access funding was enabled and organized by Martin-Luther-Universität Halle-Wittenberg under the program "Open Access Publishing".

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data on different parameters (rhyme structure, pillar tone, rhythmic and melodic patterns, intervals, pitches, and combinations) of 25 different versions of Sadhukarn main melodies from Thailand, Laos, and Cambodia can be derived from Western notation, Thai notation, and rhyme structure which were published and are freely available at https://www.mdpi.com/2306-5729/7/11/150 (accessed on 31 October 2022). Western notation, Thai notation, and rhyme structure of the recently discovered version of Sadhukarn in Siem Rieb (Wat Reach Bo Pinpeat ensemble [KW]) is included in Table S1, Appendix I, Supplementary Materials.

Acknowledgments: We would like to thank all music teachers from Thailand, Cambodia, and Laos for their help in providing different versions of the Sadhukarn main melody. We also acknowledge the financial support from the program "Open Access Publishing" of Martin-Luther-Universität Halle-Wittenberg.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Pecore, J.T. *Sounding the Spirit of Cambodia: The Living Tradition of Khmer Music and Dance-Drama in a Washington, DC Community*; University of Maryland: College Park, MD, USA, 2004; ISBN 0-496-62209-9.
2. Pawakapan, P.R. Warfare and Depopulation of the Trans-Mekong Basin and the Revival of Siam's Economy. In *Warring Societies of Pre-Colonial Southeast Asia: Local Cultures of Conflict within a Regional Context*; Charney, M.W., Wellen, K., Eds.; NIAS Press: Copenhagen, Denmark, 2017; pp. 21–46, ISBN 978-87-7694-228-1.
3. Morton, D. Thai Traditional Music: Hot-House Plant or Sturdy Stock. *J. Siam Soc.* **1970**, *58*, 44.
4. Wisuttipat, M. Pipat Traditions in Music Culture in the Mekong River Basin: Practice and Phenomena in the Early 21st Century. *Fine Arts J. Srinakharinwirot Univ.* **2014**, *18*, 12–22.
5. Wong, D. *Sounding the Center: History and Aesthetics in Thai Buddhist Performance*; The University of Chicago Press: Chicago, IL, USA, 2001; ISBN 0-226-90585-3.
6. Srikongmuang, D. Character and Expressivity in the Sacred Naphat Music of Thailand. Ph.D. Thesis, University of York, York, UK, 2019.
7. Eambangyung, S.; Schwörer-Kohl, G.; Purahong, W. Manual Conversion of Sadhukarn to Thai and Western Music Notations and Their Translation into a Rhyme Structure for Music Analysis. *Data* **2022**, *7*, 150. [CrossRef]
8. Pidokrajt, N. Sadhukarn: Analysis of Gong Wong Yai Melody. Master's Thesis, Mahidol University, Nakhon Prathom, Thailand, 1991.
9. Sapphut, M. Khong Wong Yai Melody of Thai, Lao, and Cambodian Song of Sathukarn: A Comparative Study. *J. Lib. Arts Ubon Ratchathani Univ.* **2019**, *15*, 184–200.
10. Holland, S.M. *Non-Metric Multidimensional Scaling (MDS)*; Department of Geology, University of Georgia: Athen, GA, USA, 2008.
11. Georges, P.; Seckin, A. Music Information Visualization and Classical Composers Discovery: An Application of Network Graphs, Multidimensional Scaling, and Support Vector Machines. *Scientometrics* **2022**, *127*, 2277–2311. [CrossRef]
12. Solomon, M. *Multivariate Analysis of Korean Pop Music Audio Features*; Bowling Green State University: Bowling Green, OH, USA, 2021; ISBN 9798516075520.
13. Conrad, C.; Wagner, C.; Nathan, E.; Xu, X.; Frazier, T.; Rui, M. Identification and Multivariate Analysis of 16 Compositional Elements of Relaxation. *medRxiv* **2023**, 2023-08. [CrossRef]
14. Miller, M.; Häußler, J.; Kraus, M.; Keim, D.; El-Assady, M. Analyzing Visual Mappings of Traditional and Alternative Music Notation. *arXiv* **2018**, arXiv:1810.10814.
15. Huang, C.-Z.A. Melodic Variations: Toward Cross-Cultural Transformation. Master's Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2008.
16. Ramette, A. Multivariate Analyses in Microbial Ecology. *FEMS Microbiol. Ecol.* **2007**, *62*, 142–160. [CrossRef]
17. Hammer, Ø.; Harper, D.A.; Ryan, P.D. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontol. Electron.* **2001**, *4*, 9.
18. Purahong, W.; Wubet, T.; Lentendu, G.; Schloter, M.; Pecyna, M.J.; Kapturska, D.; Hofrichter, M.; Krüger, D.; Buscot, F. Life in Leaf Litter: Novel Insights into Community Dynamics of Bacteria and Fungi during Litter Decomposition. *Mol. Ecol.* **2016**, *25*, 4059–4074. [CrossRef] [PubMed]
19. Konopka, A. What Is Microbial Community Ecology? *ISME J.* **2009**, *3*, 1223–1230. [CrossRef] [PubMed]
20. Hammer, Ø.; Harper, D. *PAST. Paleontological Statistics. Version 4.11. Reference Manual*; Natural History Museum, University of Oslo: Oslo, Norway, 2022.
21. Pidokrajt, N. *Encyclopedia of Thai Music*, 1st ed.; Mahidol University Press: Nakhon Prathom, Thailand, 2014; ISBN 978-616-279-514-5.
22. McPhee, C. The Five-Tone Gamelan Music of Bali. *Music. Q.* **1949**, *35*, 250–281. [CrossRef]
23. Lu, H.T. The Burmese Classical Music Tradition: An Introduction. *Fontes Artis Music.* **2009**, *56*, 254–271.