Archives of Acoustics Vol. 46, No. 3, pp. 471–478 (2021), doi: 10.24425/aoa.2021.138139

Research Paper

Artificial Intelligence on the Identification of *Beiguan* Music

Yu-Hsin CHANG(1), Shu-Nung YAO(2)*

(1) *Department of Music, Tainan National University of the Arts*
No. 66, Daqi, Guantian Dist., Tainan City 72045, Taiwan; e-mail: yhchang@tnnua.edu.tw

(2) *Department of Electrical Engineering, National Taipei University*
No. 151, University Rd., Sanxia District, New Taipei City 237303, Taiwan
*Corresponding Author e-mail: snyao@gm.ntpu.edu.tw

(*received October 8, 2020; accepted June 10, 2021*)

This research determines an identification system for the types of *Beiguan* music – a historical, non-classical music genre – by combining artificial neural network (ANN), social tagging, and music information retrieval (MIR). Based on the strategy of social tagging, the procedure of this research includes: evaluating the qualifying features of 48 *Beiguan* music recordings, quantifying 11 music indexes representing tempo and instrumental features, feeding these sets of quantized data into a three-layered ANN, and executing three rounds of testing, with each round containing 30 times of identification. The result of ANN testing reaches a satisfying correctness (97% overall) on classifying three types of *Beiguan* music. The purpose of this research is to provide a general attesting method, which can identify diversities within the selected non-classical music genre, *Beiguan*. The research also quantifies significant musical indexes, which can be effectively identified. The advantages of this method include improving data processing efficiency, fast MIR, and evoking possible musical connections from the high-relation result of statistical analyses.

Keywords: artificial neural network; *Beiguan* music; music information retrieval; social tagging.

1. Introduction

As non-classical music genres gain emerging attention in the academic field in recent years, the need for tailoring the in-depth examination methods of these genres has aroused. Cultivated worldwide under distinctive ethnic traits, non-classical music genres coin unique traditions and narrative ways. Classical music genres focus on developing music motifs, interpreting harmonic structures, or relating pitches or rhythmic centers, but these factors are nonessential issues of non-classical music genres. As a result, the typical, widely adopted methods designed for analyzing classical music can be biased or insufficient when directly used to analyze non-classical music. The starting point of this research is to locate and quantify the significant musical indexes of selected *Beiguan* music pieces, a non-classical musical genre thrived in East Asia from the 17th to the 18th centuries. *Beiguan* music not only was an essential part of social events ranging from wedding ceremonies to funeral bands and religious occasions but also was regarded as a common means of entertainment for the public. The 48 *Beiguan* pieces are annotated and categorized by instrumentation. These pieces were first examined by a music specialist, and then were identified into three types, namely, wind–percussion ensemble, string ensemble, and mixed ensemble with vocal. The music specialist extracted significant qualifying facts of these pieces, and then transferred them into quantified musical indexes. The processed data were then sent for artificial neural network (ANN) training. The trained ANN is expected to correctly identify the type of a given *Beiguan* piece.

1.1. Inspirations from music information retrieval (MIR) and social tagging

Describing and differentiating the contextual meaning of music serve as the basis of any research involving music regardless of the research purpose (e.g., under-

standing aesthetic choices, structural features, or relating music to other subjects). Interdisciplinary research topics focus on MIR and social tagging, both approach music data (regardless if classical or non-classical) systematically and intuitively, sometimes topped with the aid of statistics (Tzanetakis *et al.*, 2007). A typical strategy adopted by MIR research is to break down music pieces into manageable units (e.g., labeling similar melodic patterns or extracting separate voices) (Wiering *et al.*, 2009; Rosner *et al.*, 2014). Meanwhile, social tagging involves labeling intuitive judgments or informative words on a given piece of music (e.g., one or more brief descriptions of its genre, mood, opinion, recording label, and instrumentation) (Lamere, 2008). These methods enable researchers to process massive data, measure the similarity among music pieces, and recommend music according to the input keywords, further gaining the potentiality to generate music of a given style (Briot *et al.*, 2019).

Based on the results of the interdisciplinary research mentioned above, one of the critical improving factors lies on an improved understanding of the contextual meaning of music. Therefore, this research narrows down the scope of music selection, focusing on only one non-classical music genre, *Beiguan* music. The aim of this research is to develop an efficient model of describing and differentiating the three types of the targeted genre with the aid of ANN. The result is expected to meet three criteria: accurate, effective, and objective. That is, this model is expected to be conducted by a non-music specialist, and the differentiation accuracy is expected to exceed 70% correctness.

1.2. Background of Beiguan music

Beiguan is a living-ancient music genre that has spread from China to Taiwan by immigrants who originally resided in the southern provinces hundreds of years ago (Pan, 2019). The accurate origin of *Beiguan* music cannot be rigorously defined. The compound term *Beiguan* literally means "northern pipe" probably revealing some information. This term is used to distinguish *Beiguan* from another music tradition, *Nanguan*, which literally means "southern pipe" (Yeh, 1988). The most common understanding of *Beiguan* describes it as a large combination of theatrical music and local melodies developing through time. This genre is mainly preserved and practiced by immigrants from northern to southern China, and then from southern China to Taiwan. Some of the *Beiguan* music pieces even share similar musical characteristics with the theatrical music of northern or northwestern Chinese provinces. Taiwanese *Beiguan* music absorbs the characteristics of Taiwanese music and preferences of local audience through time, gradually evolving distinguishable traits from its ancestor.

When Baroque music grew popularity in Europe, *Beiguan* music thrived in southeastern China and Taiwan approximately. During that time, people appreciated *Beiguan* music, regardless of literacy, wealth, or age. *Beiguan* music is not only a means of entertainment heard in theatrical plays but also exemplifies strong social functions, dominating religious servings, weddings, or funeral ceremonies (Lu, 2011). That is, *Beiguan* music is characterized by its flexibility and abundant repertoire, which evolved through time. Until today, although *Beiguan* music has been gradually detached from social functions, professional music institutes and *Beiguan* specialists collaborate to preserve the living legacy. *Beiguan* has developed its iconic lexicons, which have several categories according to instrumentation and context. As classical music was well-acknowledged by European people who typically lived in the 18th century, *Beiguan* music was once widely appreciated by Taiwanese people until the first half of the 20th century.

The evolution of a music genre can be a genuine mirror reflecting the trace of history. That is, identifying the changing process of musical characteristics may suggest a way of understanding the subtle side of historical current. The more popular or influential a genre is to the public, the higher relevance is indicated between musical characteristics and the major sociological phenomena. Similar to the importance of classical music in European countries, *Beiguan* is a living example of Taiwan, showing the changing history through musical traits. Taiwan situates at the middle point of the East Asian coast, the west-most boundary of the Pacific Ocean, and one of the ideal relay stations stretching through the Southern Hemisphere. Therefore, Taiwan exemplifies the confluence of multiple ethnicity and music genre. Chinese, Japanese, Portuguese, Dutch, and American people identified their innate privileges and once reached their hands toward this place. Therefore, the flexibility of Taiwanese *Beiguan* music corresponds to the inherited nature of Taiwanese people: the instant adaptations to outside changes.

2. Method

The formation background of *Beiguan* music poses significant differences from classical music on three major aspects: the lack of composer, the tendency of improvisation, and social functions. First, in *Beiguan* music, the role of a composer is absent. It mostly relies on experienced players to deliver the "changing" traditions to the next generation, whereas the ideology of a composer appears to be the critical clue for interpreting a piece of classical music. Second, the tendency of improvisation based on simple pitches makes *Beiguan* music difficult to analyze. Third, unlike classical music that possesses social and artistic functions, *Beiguan* music emphasizes on social functions. It includes many

repetitions based on simple melodies and rhythmic and harmonic aspects compared with classical music.

As a non-classical music genre, *Beiguan* music poses significant differences compared with classical music on these aspects. Therefore, we may fail to efficiently describe *Beiguan* music or any non-classical music genre by using the model used for classical music, including marking out musical motifs, phrases, cadences, harmonic progression, and rhythmic patterns. Understanding the background of these genres may bridge an insightful way of describing and differentiating these unfamiliar voices.

2.1. Describing and differentiating Beiguan music

Existing studies on *Beiguan* music are mostly approached with the discipline of ethnomusicology. Under such a discipline, *Beiguan* music is categorized into four standard types according to function and performance features. The four types of *Beiguan* including *Pai5-chi2*, *Hien5-pho2*, *Yiu2-khiek4*, and *Hi2-khiek4* (Lu, 2011) are shown in Table 1.

Literally speaking, the names of the first three types represent their notable features. The first type, *Pai5-chi2*, means short chunks of music. Therefore, a *Pai5-chi2* does not solely exist. *Pai5-chi2* is widely used in social occasions (e.g., before a religious ceremony, on a wedding, a funeral march, or between scenes of a theatrical play). It features a mixture of wind and percussion instruments, usually repeating one *Pai5-chi2* or accumulating multiple *Pai5-chi2* into long pieces under the guidance of a lead drummer. The acoustic feature of *Pai5-chi2* is loud, intensive, and transitive, being able to draw the attention of passersby and audiences.

The second type, *Hien5-pho2*, literally means a score for strings and indicates a piece mostly played by a group of plucked and bowed string instruments. Few wind and percussion instruments also play melodic and rhythmic ornamentations. The acoustic feature of *Hien5-pho2* is relaxing and flexible. Therefore, a*Hien5-pho2* piece is frequently played for entertainment, sometimes incorporating borrowed melodies from other types of *Beiguan* music (*Yiu2-khiek4* and *Hi2-khiek4*) or popular songs at that time.

The third type, *Yiu2-khiek4*, means a delicate vocal piece. The instrumentation of *Yiu2-khiek4* is the reduced version of the fourth type, *Hi2-khiek4*, meaning "theatrical music." Both feature a vocal line accompanied by instruments. Singing a *Yiu2-khiek4* usually exhibits the delicate vocal skills of a singer. Accordingly, the accompanied instruments of *Yiu2-khiek4* is reasonably fewer than those of theatrical music. Meanwhile, *Hi2-khiek4* requires a full, mixed ensemble to build a sufficient acoustic contrast. The acoustic feature of theatrical music varies depending on the content of the theatrical play. It usually employs more flexible tempos, tempo changes or instrumental alternations than other types. Some popular songs of *Hi2-khiek4* can also be extracted, tailored as a *Yiu2-khiek4*, and performed solely.

To briefly conclude, the qualifying-oriented identification method widely adopted by the field of ethnomusicology points out the most notable performance feature of every type of *Beiguan* music. However, it somewhat fails to give an insight into the relating music content between each type. Due to frequent crisscross influences between the four types, pieces with the same title may fall into different types or the opposite and pieces of different types with different names may share the same origin. The identification can be increasingly difficult when many recordings with only vague, incorrect descriptions exist or when information is completely lost – which is common in terms of early recordings. Classifying *Beiguan* music by ear may be confusing, but one can easily tell when watching a live performance of *Beiguan* music. However, the major challenge of differentiation appears when dealing with the recording form. Counting the number of players and recognizing the instrument they are playing on the stage are easier than obtaining the corresponding information from the recording. Two other factors increase the challenge: the inevitable decrease of the quality of early recordings and the sparse, disorganized descriptions. Furthermore, the titles of *Beiguan* music pieces often overlap among the three types or one title evolves into different versions.

To design a complementary method for enhancing the efficiency of *Beiguan* music identification, this research anchors the objective musical indexes. The number of types is reduced to one to simplify the scope. Due to the high similarity in terms of instrumentation and the difficulty of differentiating vocal skills, the two

Table 1. Comparison chart of the original and transferred *Beiguan* music types.

Original type number (ethno-discipline)	Type name pronunciation	Literal meaning of the Chinese character	Main instrument	Transferred type number and abbreviation
1	Pai5-chi2	small chunks of music	wind–percussion ensemble	Wind–Percussion (W–P)
2	Hien5-pho2	a score for strings	string ensemble	Strings (ST)
3	Yiu2-khiek4	a delicate vocal piece	mixed ensemble with vocal	Vocal (VO)
4	Hi2-khiek4	theatrical music	mixed ensemble with vocal	

types involving vocal, *Yiu2-khiek4* and *Hi2-khiek4*, are combined into one type.

Turning qualified musical indexes into quantified social tags to music pieces can be used to train ANN to identify genre, mood, and instrumentation (Lamere, 2008). This procedure avoids the technical difficulties of voice separation and melodic fragmentation caused by the nature of *Beiguan* music. All types of *Beiguan* music are in ensemble form, which means *Beiguan* music is mostly performed by a group of instruments. Accordingly, the frequency spectrum shows a blending feature of wind, percussion, and string instruments. The technique of voice separation or musical instrument identification, as a result, requires future development. All types of *Beiguan* music frequently employ simple and repetitive melodies. The melody of *Beiguan* music seems raw because similar bone structures and limited basic pitches are used. Over the repetitions, players tend to add subtle, improvisational alternations to some pitches. Therefore, labeling fragmented melodies can be less efficient for identifying these types on the current stage.

Nevertheless, the idea of social tagging method suggests a direction, which works for *Beiguan* music. By closely examining the recordings of the three types of *Beiguan* music, the proper quantifying musical indexes focus on two criteria: tempo and instruments. From the aspect of tempo, the three types show slight differences on the average tempo, the level of tempo flexibility, and the frequency of tempo changes. From the aspect of instruments, the three types display discernible instrumental solo phrases, although the main body of music is played by instrumental groups. Contrasting the ensemble part, the length and significance of these solo phrases mark the hint to identification, under the circumstance of the lost information of aging recordings.

This research conducts a thorough survey on current online resources and publications in a hard copy of *Beiguan* music. The selected recordings are collected from government-funded databases and academic projects open for research purposes. These recordings are supported with detailed information, assuring their type and corresponding musical indexes. Each type includes about 16 recordings of authentic origins.

The lengths of the original recordings vary between three and seven minutes. To reduce the possible deviations of the quantified indexes caused by different lengths, two necessary criteria are imposed: (1) the selected recordings of one type must be of similar length and (2) the selected recordings are trimmed into three minutes in length, counting from the beginning.

2.2. Experimental procedure

This research sets up two distinguishing axes, namely, tempo and instruments, according to current *Beiguan* research and the suggestions of social tagging. Both axes are expressed in digits, which can be readable by ANN. Each recording is represented by 11 digits described by 11 quantified indexes. The tempo axis consists of two digits, each representing one of the tempo features of a piece. The tempo features include the maximum of the tempo and times of changing beats per minute (BPM). The instrumental axis consists of nine digits, each representing whether one instrument is used in the recording. The instruments include vocal, bangu, wooden percussion instruments except bangu, Chinese gong, metal percussion instruments except Chinese gong, bowed string instruments, plucked string instruments, suona, wind instrument except suona.

The digits account for two types of response. One type represents negative/positive response by using 0 and 1. Ten digits out of 11 fall into this category. The first digit denotes if the maximum BPM of a song is smaller than 100. The last nine digits are used for the usage of the nine different kinds of instruments. Another type represents the number of times. The only case falls into the tempo axis for the second digit, describing the actual number of tempo changes in the recording. According to the selected recordings, the number of tempo changes ranges from 0 to 6. Take the fourth music recording in the type I in the appendix as an example. The song has a constant BPM that is slower than 100. It is composed for wooden percussion instruments, bowed string instruments, plucked string instruments, and wind instrument, but not for bangu and suona. The song is than labelled as 10001001101.

The idea of ANN is inspired by the architecture of the nervous system (Hagan *et al.*, 2002). The neurons inside the system process and transmit cellular signals via specialized connections called synapses. In the machine learning, activation functions serve as neurons, the core processing units of the network. Activation functions are mathematical equations and provide data normalization. Figure 1 shows several types of activation functions. The hyperbolic tangent sigmoid transfer function, as illustrated in Fig. 1a, produces a value from −1 to +1, whereas the log-sigmoid transfer function, as shown in Fig. 1b, produces a value from 0 to 1. The major difference between the two transfer functions is the exhibition of learning dynamics during the training phase. In Fig. 1c, the input value is clipped by a symmetric hard-limit transfer function. If the initial value is positive or 0, then the output is +1. By contrast, the output is −1 if the initial value is negative. The saturating linear transfer function, as displayed in Fig. 1d, is approximately linear from 0 to 1 and asymptotes quickly outside that range.

An ANN is made of several layers of neurons. The first layer is called the input layer, which receives the input data. The last layer is called the output layer, which predicts the output results. The layers between the input and output layers are called hid-

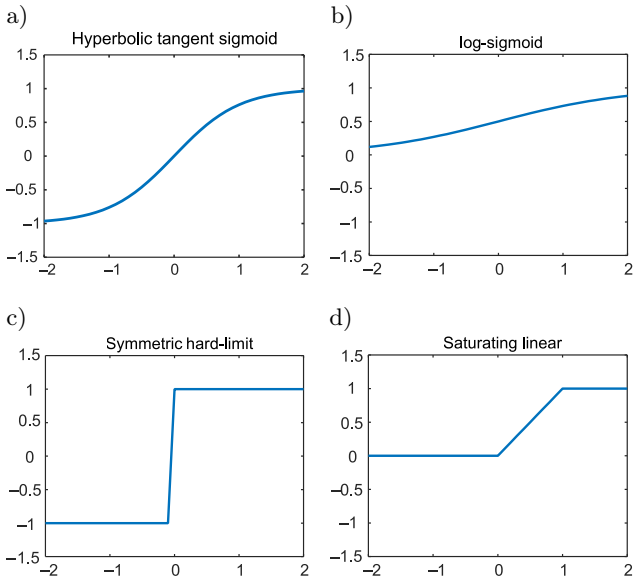

Fig. 1. Four types of neural network activation functions: a) hyperbolic tangent sigmoid, b) log-sigmoid, c) symmetric hard-limit, and d) saturating linear transfer functions.

den layers, which perform most of the required computations. An ANN may have either only one hidden layer or more than one additional layer. The neurons of one layer connect to those of the next layer by channels, which alter the data by weight; thus, the input data are multiplied to the corresponding weights and sent as input data to the neurons in the next layer. The neurons inside the hidden and output layers add up the weighted data. They are also associated with a bias that is added to their input. After determining the architecture of the ANN, training pairs can be fed. A training pair contains training data and target data. Training data are the features of data under test, whereas target data are the actual output results (Yao *et al.*, 2017). During the training process, the ANN automatically adjusts the weights and biases by comparing their predictions with the target data. Until all parameters are assigned, the ANN can predict the output for a new set of similar data.

In our *Beiguan* music recognition, we quantize a music piece into 11 features and feed them into a three-layered (11-3-1) ANN, as illustrated in Fig. 2, where the input layer contains 11 neurons, the hidden layer three neurons, and the output layer one neuron.

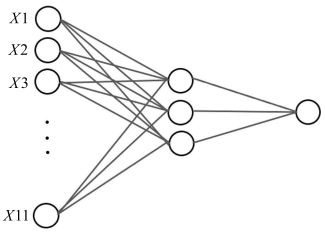

Fig. 2. Three-layered ANN model.

Through the trial and error in the pilot experiment, activation functions are selected as saturating linear transfer functions, as shown in Fig. 1d. In Table 2, given that the output results are from 0 to 1, Type I. ST pieces are marked by a target value of 0.167, Type II. VO pieces 0.5, and Type III. W–P pieces 0.833. The design is based on the tempo and instrumental similarity of the three types. Type II encompasses the largest pool of musical instruments, whereas Types III and I music pieces have smaller bodies of instruments. Types I and III represent contrasting acoustic timbre (string versus wind–percussion), whereas Type II sits in the middle, embodying the mixture of string, wind, percussion, and vocal. Among the three types, Type II is the only type that embodies vocal timbre.

After the training, ANN can assign a predicted value to an unknown music piece according to the input features. The predicted value indicates the corresponding genre. Figure 3 illustrates the recognition scale. If the predicted value is less than 0.333, then the unknown music sample is more likely Type I, a piece featuring a string ensemble. If the predicted value is greater than 0.667, then the unknown music sample is more likely Type III, a music piece for wind–percussion ensemble. The unknown music is believed to be Type II, an ensemble with vocal music, based on the prediction between 0.333 and 0.667.

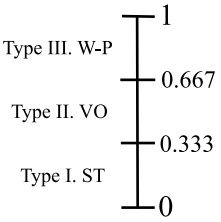

Fig. 3. Recognition scale.

Table 2. Three types of *Beiguan* music and target value.

Target value corresponding to musical features	Three types of *Beiguan* music		
	Type I. ST	Type II. VO	Type III. W–P
Target value	0 to 0.166	0.167 to 0.833	0.833 to 0.999
Notable instrument(s)	Strings	Vocal	Double-reed wind
Number of instruments	Fewer	More	Fewer
Main timbre	Strings	Mixture of strings, wind, and percussion	Wind and percussion

3. Results and discussions

After training ANN by using the 48 sets of digits representing qualified music indexes, we examine whether the system internalizes the rules by executing three rounds of testing. Because the ANN can only find the local optimal solution and the results are slightly different each time, we conducted three rounds. Each round of testing consists of 30 times of identification on the 48 sets of data. The Type I, Type II and Type III contains 15, 17, and 16 music pieces, respectively. The Chinese titles of the selected *Beiguan* music pieces are shown in the appendix. The "leave-one-out" method was applied to the experiment. That is, only one music piece is under test, and the other 47 are the training data. The fractions in Table 3 indicate how many incorrect identifications out of 30 simulations in each round. The overall correctness reaches 97%. The separate correct rate for each type makes 97% (ST), 96% (VO), and 99% (W–P). The primary result in Table 3 indicates that ANN can comprehend the rules behind the sets of digits, recognizing an unknown recording to the corresponding type.

Among the three types of *Beiguan* music, classifying Type III. W–P reaches the highest correct rate, which matches its simplicity and scale. W–P is usually short and simple, featuring only wind and percussion instruments. The highest correct rate can contribute to the uniformity of instrumentation (no vocals or string instruments are involved in this type) and the constant tempo changing feature. Although the 16th song in W–P appears to have a lower correct rate than other W–P recordings, its features are slightly different from other W–P music pieces, shedding light on the topic of qualitative studies regarding its difference suggested by quantified indexes.

Type II. VO accounts for the lowest correct rate among the three types, resulting from complicated instrumentation and its tempo diversity. This type embodies various kinds of theatrical music. Among the VO data, the 11th song in VO has the lowest correct rate on average due to its small instrumentation. Few wind and percussion instruments give it an illusion to

Table 3. Incorrect identifications in the three rounds of testing.

Incorrect identifications – three rounds (x out of 30)				
Type I. ST	01	0/30, 0/30, 0/30	09	3/30, 2/30, 0/30
	02	1/30, 0/30, 0/30	10	0/30, 1/30, 2/30
	03	1/30, 1/30, 1/30	11	0/30, 0/30, 0/30
	04	0/30, 1/30, 0/30	12	0/30, 0/30, 0/30
	05	3/30, 3/30, 1/30	13	0/30, 0/30, 1/30
	06	0/30, 0/30, 0/30	14	2/30, 1/30, 0/30
	07	0/30, 0/30, 0/30	15	1/30, 4/30, 9/30
	08	0/30, 1/30, 0/30		
Type II. VO	01	0/30, 0/30, 0/30	10	3/30, 1/30, 3/30
	02	0/30, 1/30, 0/30	11	5/30, 8/30, 8/30
	03	0/30, 1/30, 0/30	12	3/30, 4/30, 1/30
	04	0/30, 0/30, 1/30	13	0/30, 0/30, 0/30
	05	0/30, 1/30, 1/30	14	0/30, 0/30, 0/30
	06	4/30, 4/30, 3/30	15	0/30, 0/30, 1/30
	07	3/30, 0/30, 1/30	16	0/30, 0/30, 0/30
	08	0/30, 0/30, 0/30	17	1/30, 0/30, 0/30
	09	0/30, 0/30, 0/30		
Type III. W–P	01	0/30, 1/30, 0/30	09	0/30, 0/30, 0/30
	02	1/30, 0/30, 0/30	10	0/30, 0/30, 0/30
	03	0/30, 0/30, 1/30	11	0/30, 1/30, 0/30
	04	1/30, 0/30, 0/30	12	0/30, 0/30, 0/30
	05	1/30, 0/30, 0/30	13	0/30, 0/30, 0/30
	06	1/30, 0/30, 0/30	14	0/30, 0/30, 0/30
	07	0/30, 0/30, 0/30	15	0/30, 0/30, 0/30
	08	0/30, 0/30, 0/30	16	3/30, 2/30, 2/30

Type I. ST. Nevertheless, the 73% accuracy remain satisfying, marking the difference of such data while making a sufficient identification result.

Although ANN successfully identifies 48 data at an average of 97% correctness, it still leaves some confusing results. Like the 15th song in ST, among the three rounds of testing, the correction rate swings between 70% and 97%. It is a rare case compared with the identifications in overall three types. To improve the identification result in future research, such data need further investigations on their quantifying indexes and the ANN mechanism.

4. Conclusion

This research aims to develop an identification system for the types of *Beiguan* music based on artificial intelligence. We focus on the connection between qualified and quantified musical indexes. The 11 quantified indexes are proposed by a music specialist after thoroughly investigating the qualifying research of *Beiguan* music and examining the qualifying features of the recordings. Unlike classical music, *Beiguan* music features repetitions and improvisations on simple melodic and rhythmic patterns. This fact, along with ensemble playing, results in the difficulties of melodic fragmentation and voice separation, a common strategy adopted by MIR researchers.

The experimental results suggest researchers to develop a corresponding strategy when approaching any given type of music. After deep learning matures, integrating these separate units into a complete system is possible. For music amateurs, the function of this system is expected to include instant music identification, music recommendations based on preferences, or music generation based on a given style. For interdisciplinary researchers, the system can raise new questions by shifting between qualifying and quantifying perspectives. For example, a particularly low identification accuracy of a piece may suggest that it should contain some unusual qualifying features. Insightful observations can be brought out during the overall research process.

For very large sets of music, the classification by expert inputs and tagging is not impractical. Therefore, the algorithm for separating the features of a specific instrument is already underway in this research project. Although applying drum-beat separation for tempo is useful for popular music, the solution for the ancient music without percussion should be further investigated. Also, music instrument pitch detections normally find the fundamental tones of an individual instrument. If there are too many polyphony tones, a mix of the fundamental frequency and harmonics leads into technical difficulties. A reliable approach for multi-pitch detection can make computational melody analysis possible.

Appendix

Titles of the selected *Beiguan* music pieces in Chinese characters.

Type I. (ST)	01	百家春	09	一枝香
	02	將軍令	10	雨打芭蕉
	03	大八板	11	串音
	04	水底魚	12	玉連環
	05	醉扶登樓	13	月兒歌
	06	春景	14	萬象包羅
	07	滿堂紅	15	寄生草
	08	梅雀爭春		
Type II. (VO)	01	羅成寫書【彩板】	10	天官賜福
	02	羅城寫書【慢中緊】	11	【七調灣】
	03	蘇武牧羊【平板】	12	【落花洞】
	04	蘇武牧羊【流水】	13	夜奔
	05	架造【平板】	14	卸甲
	06	架造【十二丈】	15	百壽圖
	07	奪棍【平板】	16	雷神洞【二黃】
	08	送妹【平板】	17	三進宮【倒板】
	09	韓信問卜【鴛鴦板】		
Type III. (W-P)	01	一江風（新）	09	普天樂（新）
	02	二犯（新）	10	番竹馬（新）
	03	大甘州（新）	11	一江風（舊）
	04	大瓶爵（新）	12	二犯（舊）
	05	大燈對（新）	13	大甘州（舊）
	06	玉芙蓉（新）	14	大瓶爵（舊）
	07	兔兒（新）	15	大燈對（舊）
	08	風入松+急三槍（新）	16	降黃龍（舊）

Acknowledgment

This work was supported in part by the Ministry of Science and Technology in Taiwan under Grant MOST 109-2221-E-305-011-MY2.

References

1. Briot J.-P., Hadjeres G., Pachet F.-D. (2019), *Deep Learning Techniques for Music Generation*, *Computational Synthesis and Creative Systems*, Springer, arXiv:1709.01620.
2. Hagan M.T., Demuth H.B., Beale M. (2002), *Neural Network Design*, CITIC Publishing House, Beijing.
3. Lamere P. (2008), Social tagging and music information retrieval, *Journal of New Music Research*, **37**(2): 101–114, doi: 10.1080/09298210802479284.
4. Lu C.-K. (2011), *Beiguan Music*, Taichung, Taiwan: Morningstar.

5. Pan J.-T. (2019), The transmission of *Beiguan* in higher education in Taiwan: A case study of the teaching of *Beiguan* in the department of traditional music of Taipei National University of the Arts [in Chinese: 高等教育體制下的北管傳習: 以國立臺北藝術大學傳統音樂學系北管教學實踐為例], *Journal of Chinese Ritual, Theatre and Folklore*, **2019.3**(203): 111–162.

6. Rosner A., Schuller B., Kostek B. (2014), Classification of music genres based on music separation into harmonic and drum components, *Archives of Acoustics*, **39**(4): 629–638, doi: 10.2478/aoa-2014-0068.

7. Tzanetakis G., Kapur A., Scholoss W.A., Wright M. (2007), Computational ethnomusicology, *Journal of Interdisciplinary Music Studies*, **1**(2): 1–24.

8. Wiering F., de Nooijer J., Volk A., Tabachneck-Schijf H.J.M. (2009), Cognition-based segmentation for music information retrieval systems, *Journal of New Music Research*, **38**(2): 139–154, doi: 10.1080/09298210903171145.

9. Yao S.-N., Collins T., Liang C. (2017), Head-related transfer function selection using neural networks, *Archives of Acoustics*, **42**(3): 365–373, doi: 10.1515/aoa-2017-0038.

10. Yeh N. (1988), Nanguan music repertoire: categories, notation, and performance practice, *Asian Music*, **19**(2): 31–70, doi: 10.2307/833866.