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Categorization of Alpha Wave Music by SOM Reduction

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Abstract: People usually listen music to refresh, relax and help sleep. While humans are in various states of minds, there are different frequencies of brain waves detected. Some music can resonate with human brain waves to achieve the better effect on someone's state of mind. Among brain waves, the alpha wave predominantly appears when people are in wakeful relaxation with closed eyes. There has been several medical reports demonstrated that some specific music, called alpha wave music, can resonate with the alpha wave and strengthen it. Therefore, when people take the rest and listen to the alpha wave music at the same time, it can be very helpful to achieve better relaxing. However, the alpha wave music album is not popular on the market because it only can be classified manually by expertise. Until now, there is still very little research on the automatic identification of alpha wave music. This study analyses the music characterizations and tries to categorize the alpha wave music by Self Organizing Map (SOM) reduction.

Keywords: Music classification; alpha wave music; artificial neural network.

1. Introduction

Now is a time of fully-competition. Many people have too many pressures which can lead to unintended consequences. Such as anxiety, panic, melancholy, manic depression and other mental illness which may come to the door and even affect the physical health. There are also a numerous regrettable cases in the society caused by excessive pressure. Therefore, it is very important to relieve stress appropriately. People usually listen music to relieve stress and to relax. Some even treat patients with mental or physical illness by music. That is because some music can resonate with human brain waves to achieve the better effect on relaxation [1].

British ambient band Marconi Union has drummed up the world's most relaxing song – Weightless, which was named one of the 50 best inventions of the Year in Time magazine, 2011 [2]. This song was proved to result in a 65 percent reduction in participants' overall anxiety, and a 35 percent reduction in their usual physiological resting rates. The song was composed to be a relaxation inducing sound and was made in collaboration with sound and music therapists. Its carefully arranged harmonies, rhythms, and bass lines help slow a listener's heart rate, reduce blood pressure and lower levels of the stress hormone cortisol. Indeed, "Weightless" is so successful at inducing somnolence that scientists caution drivers not to listen to it while behind the wheel [2, 3].

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While humans are in various states of minds, there are different frequencies of brain waves detected. Among these diverse frequencies, there are four major types of brain waves existed discovered, including Beta (β) wave, Alpha (α) wave, theta (θ) wave, and delta (δ) wave [4, 5]. Measured by EEG (Electroencephalography) [6], the frequency between 8Hz and 13Hz of alpha wave was detected when people close their eyes for a short rest [7]. There has been several medical reports demonstrated that some specific music, called alpha wave music, can resonate with the alpha wave and strengthen it [1, 5]. Therefore, when people take the rest and listen to the alpha wave music at the same time to enhance the brain wave, it can be very helpful to achieve better relaxing. Until now, the alpha wave music album is rare on the market because it only can be classified manually by expertise. Due to time-consuming and laborious in classification, it cannot be widespread.

The contents of music provided diverse musical features such as: melody, rhythm and chords, etc., which may represent a music genre. Therefore, content-based music retrieval and classification are important research fields for music databases [8, 9, 10, 11]. In this research, we will investigate the features of the alpha wave music for analyzing and tries to categorize the alpha wave music by Self Organizing Map (SOM) approach [12, 13, 14].

2. Related Works

2.1 Categories of Brain Waves

In 1925, Dr. Hans Beck found that there were four major types of human brain waves generated from the human brain, including beta (β) wave, alpha (α) wave, theta (θ) wave, and delta (δ) wave [5]. Usually, one of these brain waves will be relatively stronger presence when people are in a variety of different situations. If the music people listened is synchronized with the frequency of brain wave, it can be enhanced by resonance [1, 5].

2.1.1 Beta Brain Wave

The beta wave (>12.5Hz) is more intensely presented, when the person is awake in concentration, thinking, and stress [2, 5]. The frequency of beta brain wave measured by EEG (Electroencephalography) is shown in Figure 1.

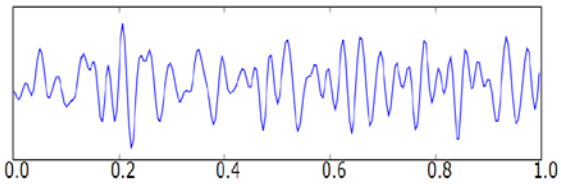

Figure 1. Frequency of beta brain waves detected by EEG [15].

The beta wave music is with similar frequency to beta brain wave. Listening beta waves music can be helpful for longer studying or driving and will help you to maintain a good level of concentration and focus, while also increasing brainwave activity associated with memory and learning. There some beta wave music albums can be found on the market, such as:

(1) Remembrance
(2) Barque Garden for Concentration
(3) Einsten's Dream
(4) Seasons at Roberts Mountain
(5) Water Music

2.1.2 Alpha Brain Wave

The alpha wave (7.5-12.5Hz) predominantly appears when people are in wakeful relaxation with closed eyes [2, 5]. The Figure 2 represents alpha brain wave frequency detected by EEG. The frequency is little smoother than beta brain wave.

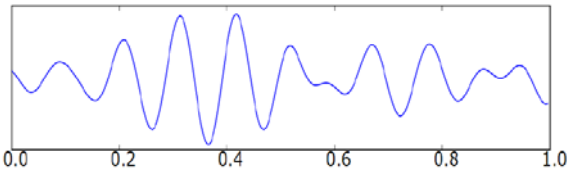

Figure 2. Frequency of alpha brain waves detected by EEG [16].

It has been found that the alpha waves are wave relaxation. Listening alpha wave music is ideal for anti stress relief. We can find some alpha wave music albums on current market, such as:

(1) Masterworks
(2) The Journey Home
(3) Into The Deep
(4) Gaia
(5) Cloudscapes.

2.1.3 Theta Brain Wave

The theta wave (4-7Hz) are the brain states of rapid eye movement sleep, hypnosis, lucid dreaming, and the barely conscious state just before sleeping or just after waking [2, 5]. The frequency of theta brain wave measured by EEG (Electroencephalography) is shown in Figure 3.

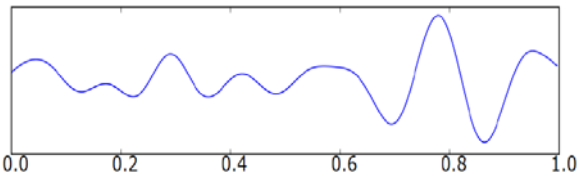

Figure 3. Frequency of theta brain waves detected by EEG [17].

Theta waves are commonly associated with deep relaxation, meditation, intuition and higher consciousness. Listening theta wave music can access the theta state. There are available theta wave music albums as follows:

(1) Out of the Physical Body
(2) Endless Journey
(3) Steal This Album!
(4) Deep Theta: Brainwave Entrainment Music
(5) Theta Wave State

2.1.4 Delta Brain Wave

The delta wave (0.5-4Hz) appears when people are in deep sleep [2, 5]. The Figure 4 represents delta brain wave frequency detected by EEG.

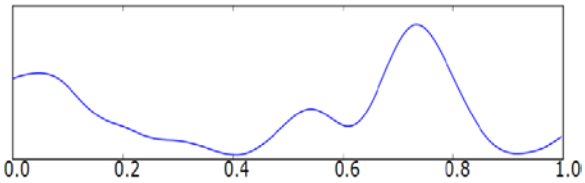

Figure 4. Frequency of delta brain waves detected by EEG [18].

Playing delta wave music when sleeping can help the person reach a deeper sleep. Some delta wave music can be found on the market or download from the internet.

(1) Sounds of Universe
(2) Across the Galaxies
(3) Inner Space
(4) Sleep Music Delta Waves
(5) Beautiful Relaxing Sleep Music

2.2 Alpha Wave Music Classification

2.2.1 Content-based Classification

Lo et al investigated the content-based features of the alpha wave music and develop the distance function for music classification [11]. The music features can be the occurrence frequencies of notes, rhythms, and etc. The *n* highest occurrences of a feature for a music genre can be the coordinates of the centre as in an *n* dimensional space. The distance function $d(y_1, y_2, \ldots, y_n)$ for the music to the centre can be derived as equation (1). The y_i denotes the features of examined music and x_i denotes the centre of a music genre. Thus, the examined music can be identified by the shortest distance.

$$d(y_1, y_2, ..., y_n) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \tag{1}$$

Nevertheless, this study emphasized on analyzing the common features of already identified alpha wave music. It can not substantiate the accuracy for further application on classifying of alpha wave music [19].

2.2.2 Similar Music Genre Discovering

Discovering similar genre for alpha wave music was proposed by Lo et al [19]. This study investigated the content-based features of music and used them to analyze the similarity between alpha wave music and existing music genres. They explored the contents of classical, pop, jazz, folk, blues, and alpha wave music by distance equations and learning machine approaches. In the machine learning algorithm [20, 21], this study used Support Vector Machine (SVM) through LIBSVM [22] and MATLAB [23] to achieve. They concluded that the notes of alpha wave music are the most similar to classical music as well as the pitch changes of alpha wave music are the most similar to blues music.

2.3 Artificial Neural Network

Artificial Neural Network (ANN) is a kind of machine learning [24, 25]. It is an algorithm developed by a neural network imitating creatures. The neural network is like a framework for many various machine learning algorithms to work together and process complex data inputs. It is suitable for sample identification, prediction or classification, clustering, and the like. Generally, it can divide into two steps of learning and recalling. The collected data set is trained for generating a neurological model, and the actual data is used to verify or produce the result. There have been many different types of neural networks published. They can roughly divide into several categories according to the learning methods.

(1) Supervised Learning [26]: Learning and training is through a set of known training data sets and expected answers, such as Perceptron, BPN, PNN, LVQ, and CPN.
(2) Unsupervised Learning [27]: There is no standard answer in the training data set, so that the network can automatically find the potential regularity between the training materials based on the input parameters according to the relevance, such as SOM and ART.
(3) Associate Learning Network [28]: The network uses the weight matrix to memorize all training patterns. The output recalled based on the learned patterns, such as Hopfield, BAM, and Hopfield-Tank.
(4) Optimization Application Network [25]: The network is designed to perform the optimizing solution or global solution, such as ANN and HTN.

We investigate the Self Organizing Map (SOM) [12, 13, 27] reduction approach which belongs to unsupervised learning of ANN for categorizing alpha wave music in this research. In the SOM reduction, data is trained using unsupervised learning to produce a low-dimensional, discrete representation of the input space of the training samples, and is therefore a method to do dimensionality reduction [23].

3. Research Method

3.1 Music Features

Music, known as the art of sound, makes long history in every culture. In the present life, it is also an indispensable existence. A musical composition consists of three basic elements - melody, rhythm and harmony. Chords are a part of harmony as well. Moreover, the pitch change is also an important characteristic to compose music.

3.1.1 Melody

A melody consists of continuous notes which according to the level, length and strength changes, are arranged in some sequences and compositions. The melody is usually the spindle of musical and the most easily identifiable features. Each note has a different audio frequency. We would like to investigate the notes of alpha wave music to ascertain whether there are specific notes existing most likely to have the harmonic resonance with the brain frequency.

3.1.2 Rhythm

Rhythm is the pattern of musical movement through time. It is formed by a series of notes differing in duration and stress. The rhythm needs to be based on a steady tempo. Different tempos will bring different atmospheres. Generally, slower-paced rhythm is most likely to be able to soothe the emotions and quicker-paced rhythm can boost the human's spirit. The rhythm of alpha wave music will be one of important features in our study.

3.1.3 Chord

A chord in music is any harmonic set of two or more notes that is heard as if sounding simultaneously. People listening to different chords have distinct feelings such as sorrowful for major chords, suddenly enlightened for diminished seventh chords, and unexpectedly flying overhead for major second chords. Chords are more complex and have many variations than other musical features.

3.1.4 Pitch Change

Pitch change is the variation of two adjacent notes. Since the pitch change is not effected by music key up and down, it is one of favourable features for query by example in music retrieval. Usually, the pitch change of hot music is more significant that may inspirit people. On the contrary, the pitch change of lyrical music is smoother that may allow people to relax. The alpha wave music seems to have the same effect as lyrical music does.

Among these music features, the chord is complicate in variety. Therefore, only melody, rhythm and pitch change will be investigated in our studies. We will use them to discriminate alpha wave music from other music genres.

3.2 Categorization Method

The categorization method used in this research is Self Organizing Map (SOM) reduction [12, 13, 14]. The SOM is a effective tool for the visualization of high-dimensional data [12, 14]. It converts complex and nonlinear statistical relationships between high-dimensional data items into simple geometric relationships on a low-dimensional display (typically two-dimensional) called a map. The SOM compresses information while preserving the most important topological and metric relationships of the primary data items on the display [13].

SOM operates in two modes: training and mapping. The training mode builds the map using input samples, while the mapping mode generates the output as classified a new input vector. A dimensionality reduction in SOM is shown in Figure 5, in which high dimensional space $x_1, \ldots, x_i$ is converted into two-dimensional vector Y_{jk} as outputs.

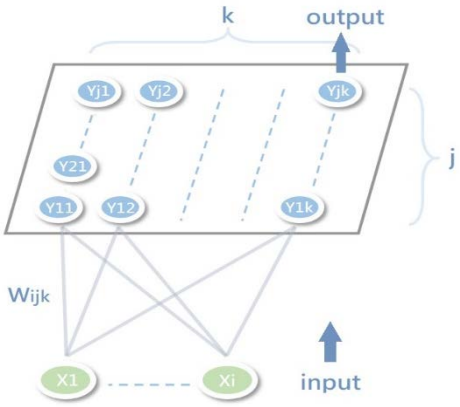

Figure 5. Dimensionality reduction in SOM.

The SOM applies competitive process (also called vector quantization) in which using a neighborhood function to preserve the topological properties of the input space. The SOM algorithm is as following:

(1) It starts from initializing the weight vectors. Each node's weights are initialized.
(2) A vector is chosen at random from the set of training data.
(3) Every node is examined to calculate which one's weights are most like the input vector. The winning node is commonly known as the Best Matching Unit (BMU).
(4) Then the neighbourhood of the BMU is calculated. The amount of neighbors decreases over time.
(5) The winning weight is rewarded with becoming more like the sample vector. The neighbors also become more like the sample vector. The closer a node is to the BMU, the more its weights get altered and the farther away the neighbor is from the BMU, the less it learns.

4. Experimental Design

The experimental music database used in this study is collected by Lo et al [11, 19] including six music genres - blues, classical, folk, jazz, pop and alpha wave music. Among them, there are 150 pieces music for each genre except alpha wave music which has only 87 pieces due to difficult collection. The melodies, rhythms, and pitch changes of music features are also extracted from collected music and analyzed their occurrence frequencies for experimental studies.

In this experiment, we will build a SOM network for each music feature and will discriminate music genres through these SOM networks. Every music feature is split into two portions in which one is for training and the other one is for testing the accuracy of its categorization. Such that each feature is explored whether there is any special representation of alpha wave music.

4.1 Melody Categorization

The 21 highest occurrence notes (such as Do, Re, Me) in melodies are used for inputs, such as X1.. X21, as shown in the melody SOM reduction diagram of Figure 6. In the output layer, Y11, Y12, ..., and Y23 denote the classified 6 music genres – probably alpha wave music, blues, classical, folk, jazz and pop. According to topology of SOM, the top shape of output layer is set to 2x3 and categorized into six groups, named Group A~E.

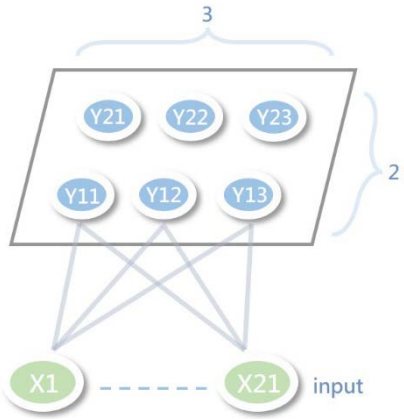

Figure 6. Melody SOM reduction diagram.

4.2 Rhythm Categorization

The 1/8, 1/4, 1/2, 3/4, 1, 1 1/2, 2, 3, and 4 are the most common beats in music. For example, the 3/4 time signature means three quarter-note beats per bar and the beat pattern is strong-weak-weak. These 10 beats will be used for rhythm categorization as the inputs (X1, …,X10) for Rhythm SOM reduction diagram as shown in Figure 7. Again, the Y11, Y12, ..., and Y23 denote the output of six classified music group, named Group A~E.

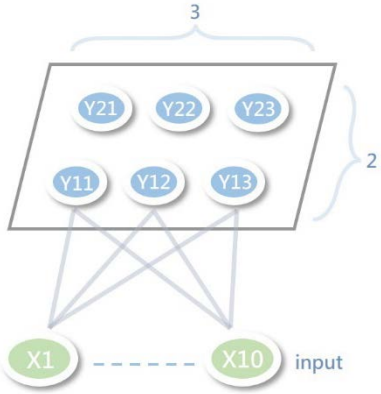

Figure 7. Rhythm SOM reduction diagram.

4.3 Pitch Change Categorization

For instance, a melody segment of the Little Bee is “So Mi Mi Fa Re Re Do Re Me Fa” such that the pitch changes will be “-2 0 +1 -2 0 -1 1 1 1”. The 24 highest occurrence pitch changes are used as inputs for categorization as shown in Figure 8. The output is also categorized into six groups A~E.

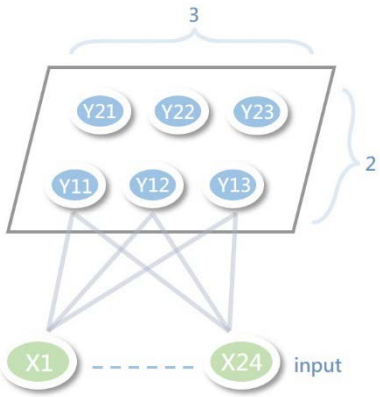

Figure 8. Pitch Change SOM reduction diagram.

4.4 Experimental Environment

For experimental study, the software used is MATLAB (MATrix LABoratory) which is a commercial math software produced by the Math Works Company in United States [23]. It provides high-level computing languages and interactive environments for algorithmic development for data visualization, data analysis, and numerical computation. There are many additional tools that can be applied in various areas. The MATLAB version used for our study was R2016a, so does the neural network tools.

5. Experimental Results

In our experiments, half the amount of each music genre was used for training through the Self Organizing Mapping and the other half amount of each music genre was used for categorization forecasting.

5.1 Categorization by Melodies

The melody is an important feature of music. We first used melodies for categorization. The half amount melodies of each music genres were trained in SOM conversion. Thereafter, the half portion of each music genre is used for categorization forecasting. The experimental result of melody categorization for alpha wave music is shown in Figure 9. We find that there is 78% of alpha wave music categorized into Group E. The recall can be 78%. It is obvious that there is 22% of alpha wave music allocated at different groups. We also analyzed all music assigned to Group E as shown in Figure 10. The Group E consists of 49% alpha wave music only. It also owns 22% of classical, 12% of pop, 7% of blue, 5% of folk, and 5% of jazz. If Group E is the correct categorization for alpha wave, the precision may be only 49%. It can be in two reasons. The first one is, due to difficult and less data collection, for the alpha wave music used too little samples to forecast. The other reason is that the remaining 51% music in Group E may be the not yet determined candidates of alpha wave music with the similar characteristics.

5.2 Categorization by Rhythms

In this study, the rhythms of each music genres are explored for categorizing alpha wave music. After data training and forecasting, there is 51% of alpha wave music categorized into Group E as shown in Figure 11. Rhythm may not be as good as melody for categorizing alpha wave music. The ratios of every music genres in Group E are shown in Figure 12. The alpha wave music has the highest part in Group E, however, it is only 35%. It seems that rhythm is not a proper feature for discriminating alpha wave music.

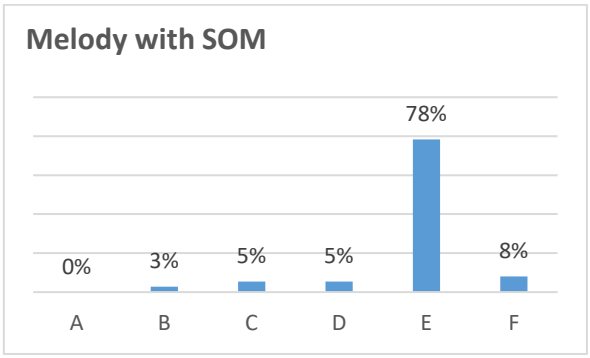

Figure 9. Melody categorization of alpha wave music.

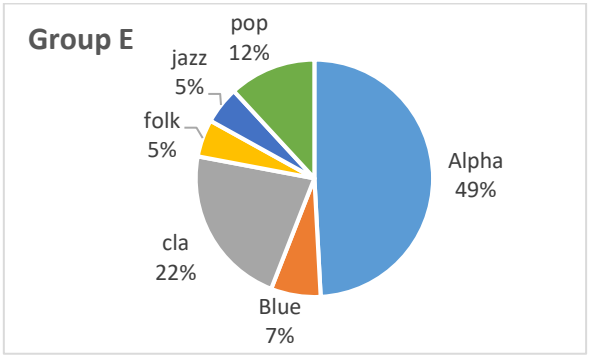

Figure 10. Analysis of melodies in Group E.

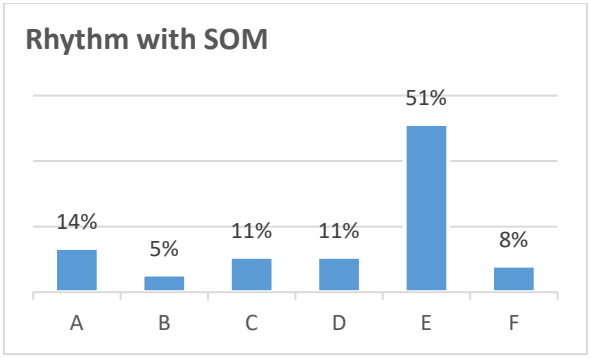

Figure 11. Rhythm categorization of alpha wave music.

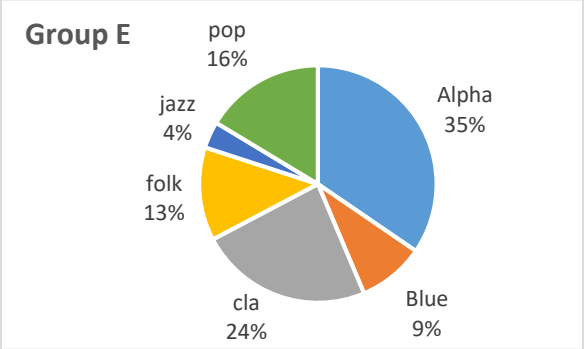

Figure 12. Analysis of rhythm in Group E.

5.3 Categorization by Pitch Changes

The pitch changes of music features were investigated in this experiment for categorization alpha wave music. The experimental result is shown in Figure 13. The alpha wave music is 89% assigned to Group A, 11% assigned to Group B, and nowhere else. Furthermore, we also examined all music assigned into Group A and found that it consisted of 69% of alpha wave music as shown in Figure 14. The remaining 31% of music in Group A is all blues. The pitch changes are most likely a common feature for blue and alpha wave music that can be found the similar report in [19]. In this investigation, both recall and precision of pitch changes outperform our experimental study in melody and rhythm for categorizing alpha wave music.

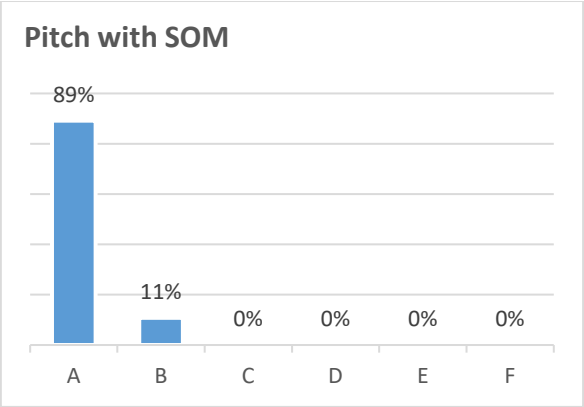

Figure 13. Pitch changes categorization of alpha wave music.

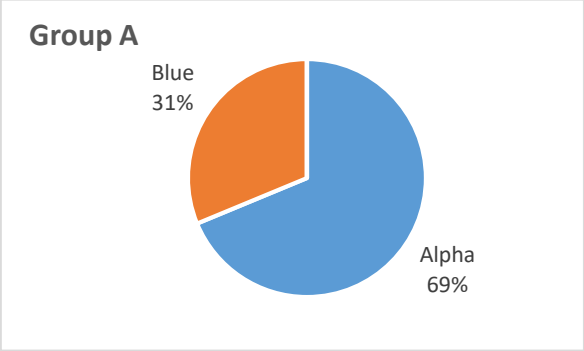

Figure 14. Analysis of pitch changes in Group A.

6. Conclusion

In this paper, there were three music features (melodies, rhythms, and pitch changes) used as inputs in Self Organizing Map conversion for discriminating alpha wave music. Among them, pitch changes can most distinguish alpha wave music with near 89% recall and 69% precision which surpasses melody and rhythm. Therefore, pitch change is the key feature for alpha wave music categorization.

Moreover, we also found that the Group A not only consists of 69% of alpha wave music, but also consists of 31% of blues in pitch changes study. This reflects a similar research conclusion in [19] that alpha wave music and blue are relatively close in pitch changes analysis.

Nowadays, the alpha wave music is relatively rare and more difficult to collect in the market. We still will try to find more samples of alpha wave music for further research. For future work, we will introduce multi-feature classification methods to make alpha music categorization more practical and feasible.

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