IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received March 5, 2022, accepted April 4, 2022, date of publication April 26, 2022, date of current version May 6, 2022.

Digital Object Identifier 10.1109/ACCESS.2022.3169362

An Approach to Discover Similar Musical Patterns

SUDIPTA CHAKRABARTY[1], (Member, IEEE), RUHUL ISLAM[2], EMIL PRICOP[3], (Member, IEEE), AND HIREN KUMAR DEVA SARMA[4], (Member, IEEE)

[1]Department of Information Technology, Sikkim Manipal Institute of Technology, Rangpo, Sikkim 737136, India
[2]Cloud Shine Global LLP, Guwahati, Assam 781028, India
[3]Department of Control Engineering, Computers and Electronics, Petroleum-Gas University of Ploiesti, 100680 Ploiesti, Romania
[4]Department of Computer Science and Engineering, SRM University Andhra Pradesh (SRM AP), Amaravati 522502, India

Corresponding author: Hiren Kumar Deva Sarma (hirenkdsarma@gmail.com)

ABSTRACT An algorithm has been developed to find the similarity between given songs. The song pattern similarity has been determined by knowing the note structures and the fundamental frequencies of each note of the two songs, under consideration. The statistical concept namely Correlation of Coefficient is used in this work. Correlation of Coefficient is determined by applying 16 Note-Measure Method. If Correlation of Coefficient is near to 1, it indicates that the patterns of the two songs under consideration are similar. Otherwise, there exists a certain percentage of similarity only. This basic principle is used in a set of Indian Classical Music (ICM) based songs. The proposed algorithm can determine the similarity between songs, so that alternative songs in place of some well-known songs can be identified, in terms of the embedded raga patterns. A digital music library has been constructed as a part of this work. The library consists of different songs, their raga name, and their corresponding healing capabilities in terms of music therapy. The proposed work may find application in the area of music therapy. Music therapy is an area of research which is explored significantly in recent time. This work can also be exploited for developing intelligent multimedia tool that is applicable in healthcare domain. A multimedia based mobile app has been developed encapsulating the above mentioned idea that can recommend alternative or similar songs to the existing ICM based songs. This mobile app based music recommendation system may be used for different purposes including entertainment and healthcare. As a result of the applications of the proposed algorithm, similar songs in terms of raga patterns can be discovered from within the pool of a set of songs. A music recommendation system built on this algorithm can retrieve an alternative song from within the pool of songs as a replacement to a well-known song, which otherwise may be used for a particular music therapy. Results are reported and analyzed thoroughly. Future scope of the work is outlined.

INDEX TERMS Fundamental frequency measure (FFM), correlation of coefficient, computational musicology, music recommendation system (MIR), music therapy, electronic healthcare.

I. INTRODUCTION

Music has capability to heal some of the illnesses of human body. Thus music is said to have therapy capabilities. Indian Classical Music (ICM) consists of one basic component known as raga. The seven basic notes of music, i.e., Sa, Re, Ga, Ma, Pa, Da and Ni are exploited to create a particular raga [10]. Computational Musicology is an emerging field which draws various basic principles from Computer Science. In the 16 Note-Measure System, the notes Re, Ga, Da, and Ni have three variations and the note Ma has two variations. The 16 different notes are as mentioned below: Sa, Re1, Re2, Re3, Ga1, Ga2, Ga3, Ma1, Ma2, Pa, Da1, Da2, Da3, Ni1, Ni2, and Ni3 [11]. Music therapy is an area of para medicine field in which music is being employed for different therapy applications. Music therapy can be used in curing even psychological and physiological problems like mesothelioma, peritoneal mesothelioma asthma, asbestos cancer, depression etc [11]. The raga of a music is the primary element considered for music therapy. There are various ragas that can be used for different purposes, for example, Ahirbhairav and Todi are used for hypertension, Punnagavarali is used to control anger and violence, Todi is used to relief from cold and headache, Shivaranjani is used for memory related problems, Bhairavi is used to get relief from sinus, cold, phlegm, tooth ache etc [12]. Similarly,

The associate editor coordinating the review of this manuscript and approving it for publication was Zahid Akhtar.

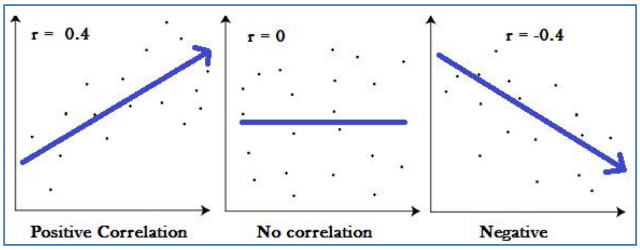

FIGURE 1. Positive, zero, and negative correlations.

Chandrakauns raga is used to treat the heart problems and diabetes, Darbari is used to reduce the tension and to provide relaxation [12].

Therefore, a specific ICM based song of a specific raga is applicable for some health and mind issues [15]. This work introduces an approach by which two similar songs in terms of raga, can be identified. Thus similar musical patterns are possible to identify, computationally. This approach can also be applied to develop an intelligent multimedia mobile application. In turn, such a mobile application may be applied in the electronic healthcare field. This mobile application can recommend alternate music in place of the ICM based songs, having similar healing capabilities. Challenge is to identify similar songs which are suitable for music therapy. ICM is the backbone of this work, as there are a lot of ragas known to be applicable for different therapies. The song pattern similarity can be established by knowing the note structures, and the fundamental frequencies of each note of the songs under consideration. The Correlation of Coefficient is identified by applying 16 Note-Measure Method. If Correlation of Coefficient is close to 1, then it indicates that the patterns of the two songs under consideration are similar. Otherwise, it indicates a certain percentage of similarity only, between the songs. This method has been used in a set of ICM based songs. The ICM based songs are stored in a digital music library along with their raga name, and the corresponding healing capabilities. After applying the algorithm reported in this paper, a set of new songs are discovered as an alternative to the ICM based songs. A multimedia based mobile app has been developed and also reported in this paper that can recommend alternative songs in place of the established ICN based songs, for a particular music therapy. The system that has been reported here has potential to act as an electronic healthcare system for some specific purposes based on music therapy.

Correlation is a statistical concept that helps to analyse and determine the degree of relationship that exists among series of data variables. The degree of relationship among different series of data is expressed by Correlation Coefficient which ranges from $-1 \leq r \leq +1$. The direction of change is determined by a sign. Fig. 1 depicts one example of positive, negative, and zero correlation.

Following are the possible correlations:

[1] If $r = +1$, then the relation of the two series of data variables is said to be positively similar.

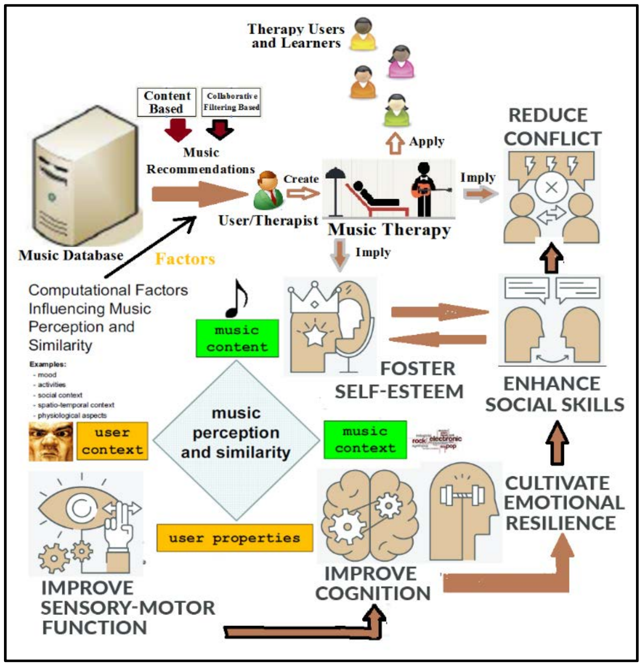

FIGURE 2. Overall relationship between music recommendation system and music therapy.

[2] If $r = -1$, then the relation of the two series of data variables is said to be negatively similar.

[3] If $r = 0$, then there exists no similarities between the two series of data variables.

Correlation of Coefficient deals with the association among series of variables and for that reason it has been assumed that it is the basis of similarity mapping between two song structures. The paper proposes a statistical approach for computing the similarity between two different songs or music structures or music patterns by using Correlation Coefficient of the fundamental frequencies of the two given songs.

Music recommendation system plays an important role in music therapy. Music recommendation system recommends music for the users depending on various factors like, human moods, human behaviours, choices, similarities, fundamental frequencies, time slots, etc. Fig.2. depicts the overall relationship between music recommendation system and music therapy.

Motivation: There are different folk songs available in different parts of the world. The folk songs are less explored in terms of computational musicology. It is already explored and recommended by competent authority that Indian Classical Music has therapy capabilities and can be used for different treatment, e.g., to treat health and mental problems. A very fundamental question that motivates to do this work is "Does the Indian Folk Music (IFM) too have music therapy capabilities like the Indian Classical Music (ICM)?." Although addressing this question is a larger study with wider scope, in this work, we are motivated to develop a method to find out similarity between songs (for example, ICM based and IFM based songs) from computational musicology perspectives. If alternate songs can be recommended from computing perspective, to use as an alternative to ICM based songs, then in the next stage, the music therapy capabilities of the alternate songs may be examined. This fact motivates to develop an approach to identify similar music patterns and recommend alternate songs for music therapy.

The contributions made in this work are as mentioned below.

i) An algorithm is proposed to identify similar song patterns. The statistical measure Correlation Coefficient has been exploited in order to find similar music patterns.
ii) A music database has been created comprising of ICM based and IFM based songs. In this song repository, the raga information of the ICN based songs and the healing capabilities of different ragas are also stored.
iii) A mobile app has been developed that works as a Music Recommendation System. The app implements the proposed algorithm (as mentioned in i)) to identify similar songs and it works over the database developed (as mentioned in ii).
iv) The process of finding similar song patterns has been demonstrated through rigorous experiments and statistical analysis of the obtained experimental results.

The proposed algorithm may be used to identify two similar songs considering the frequency as the basis. Thus this is the first step toward identifying ICM music or other music (for example, IFM) with similar therapeutic effects. In fact, establishing similar therapeutic effect of IFM in comparison to ICM is the next step of this work, in which rigorous experiments involving human has already been planned by this group.

The rest of the paper is organized as follows. Section II reports few related works. The proposed algorithm is detailed in section III followed by the section IV, in which experimental results are analysed. The paper is concluded in section V.

II. RELATED WORK

There are quite a lot of research works that motivate to work further and explore even new dimensions of musicology research. Computational musicology is the most emerging area that depends on different concepts of computer science. Indian Classical Music (ICM) is relatively complex and a vast area which has not been explored significantly in terms of computational musicology.

Music recommendation system has been explored in [27]. The work provides a personalized music recommendation service with the help of polyphonic music objects using MIDI (Musical Instrument Digital Interface) format. The user analyses the profiles for user grouping based on the behaviours and interests of the users. They use pitch density for track selection that contains the melody which can be calculated as:

$$Pitch\ Density = \frac{NP}{AP} \tag{1}$$

where,

NP = Number of distinct pitches in the track

AP = Number of all distinct pitches in MIDI standard

The pitch entropy (PE) can be derived as follows:

$$PE = -\sum_{j=1}^{NP} \left(P_j log P_j\right) \tag{2}$$

where,

Pj is represented as follows:

$$P_j = \frac{N_j}{T} \tag{3}$$

Nj = Total number of notes with the corresponding pitch in the representative track,

T = Total number of notes in the representative track.

The music group containing highly accessed musical objects hold the higher weight than other groups. The weight of music group (GWi) can be calculated as:

$$GW_i = -\sum_{j=1}^{n} TWj \times MOj, i \tag{4}$$

where

TWj = Weight of the transaction Tj

n = Number of latest transactions used for analysis MOj, i = Number of music objects which belong to music group Gi in transaction Tj.

Different numbers (Ri) of musical objects from music groups are computed (also recommended) according to the GWi, as follows [18]:

$$R_i = \lceil N \times \frac{GW_i}{\sum_{k=1}^{m} GW_k} \rceil \tag{5}$$

Although this work is based on music recommendation system, it does not explore Indian Classical Music and associated ragas.

There is a specific relationship between Raga and Rasa. Raga means music origin, and rasa means music emotions. Therefore, music and emotions are directly related to each other and that have been established. A content-based culture-specific music recommendation system model has been proposed in [13]. The paper [14] describes a research project that is aimed at developing a music analysis system which presents an analysis of clinical music therapy. Music is a very effective mode of mental treatment and human mental management can be controlled by music therapy, based on ICM [5].

The paper [16] is a reference of website that illustrates different raga names and their respective healing powers. The work reported in [17] introduces music recommendation technique based on content and context information mining. The work reported in [18] introduces a context-aware mobile music recommendation system.

The work reported in [19] is a modeling technique and useful tool that formalizes the music composition rules; the technique increases music analysis speed with the help of Music Petri nets that introduces Schoenberg's rules. The work presented in [20] introduces an approach that determines the similarity mapping between two songs; this is achieved by the notes and the fundamental frequencies of each note of the two songs. The Pearson's Correlation of Coefficient is exploited in this work. The work presented in [21] is a method to generate song list for listening; the songs may be downloaded according to age factor of the online users. It is a web-based application that recommends different songs depending on the listeners' choice that too based on their age group. Songs are downloaded from the music library and unknown songs are classified depending on the review of the users.

The work presented in [22] introduces a model of musical creativity rather than algorithmic music variations with the help of genetic algorithms. The implementation of this model is based on Genome software. A statistical approach has been exploited to find similar song patterns with the help of coefficient of variance [23]. A time based raga recommendation system has been developed by using Neural Networks in [24]. A Music Recommendation System that classifies different songs appropriate for different time of a day has been reported in [25]. An intelligent mechanism to identify the density of a given music rhythm and complexity of that music rhythm automatically has been proposed in [26]. Different music research areas and their applications are illustrated in [27]. The Chi-square table link is given in [28].

Based on this survey it is found that there is no work available in the context of ICM that can recommend alternate songs keeping applications like music therapy in mind. As mentioned under the motivation sub-section of the introduction section of this paper, there is a research gap in order to find equivalent songs that can be used as an alternative to an ICM in the context of music therapy. Such an alternative may be a folk song also, that can have similar healing capability with respect to music therapy. However, the work presented in [10] is in the similar direction as the work reported in this paper, but was at a very nascent stage.

Some important characteristics of ICM are enlisted in Table 1.

TABLE 1. Characteristics of Indian classical music.

ICM Features	Descriptions
Thaat (Raga Origin)	These are known as Raga origin which consists of a set of ragas. Ragas are organized in thhats. Some of the thhats are - Kalyan, Bhairav, Kafi, Asavari, Bilabal, Khamaj, Bhairavi, Purbi and Torhi etc.
Raga	Ragas are the backbone of Indian Classical Music. It is the combinations of different note structures. Ragas are used for different music compositions that provide different melodies to music.
Notes	Note can be a beat or combination of beats.
Aroha (Ascending Notes)	The ascending order note frequency sequence from the tonic of the scale is called Aroho. Example: Ni Sa, ga Ma Pa, Ni Sa (Next Octave).
Aboroha (Descending Notes)	Descending order note frequency sequence from the tonic of the scale is called Aboroho. Example: Sa, Ni dha Pa, Ma ga, re Sa (Next Octave).
Notation	Combinations or series of different notes that indicate various aspects regarding how a piece of music is to be performed.
Pitch	Pitch is the number of times a musical sound wave can repeat in one second. It can be measured by Hz.
Tempo	Tempo is the speed of music rendition and it is denoted by bits per minute.
Melody	Melody is the combination of two most important musical elements: pitch and rhythm.
Tonic	Tonic is one of the most important attributes of music patterns which is reserved for tonal context of music. Normally, tonic means the first degree scale of note from which all other notes are referenced hierarchically. For example ga (Minor) and Ga (Major) both are known as tonic GA.
Shruti (Microtones)	Shrutis ordinarily refers to the frequency of notes which means it is a group of frequencies with different amplitude levels. Therefore, the note frequencies which have the maximum amplitude level are known as Shruti. In Indian Classical Music, there are three types of Shruti-System existing. They are: 12 Shruti-System, 16 Shruti-System, 22 Shruti-System.
Tala (Rhythm)	Rhythm is the style or pattern of sound in musical piece that combines with the recurrence of notes and rests.
Genre	Genre is the style of musical phrases like traditional music, classical music, folk music, devotional music, rock music, pop music, etc.
Aalap (Rendition)	Aalap is the melodic distribution of musical notes of a particular raga in which the combinations of all possible valid note combinations are performed without any fixed rhythm.
Timbre	Music Timbre is the quality of music sound or quality of music tone or the quality of music notes. Several instruments can play the same musical pitches or same notes in same volume but can produce different timbres.

Though some of the above characteristics of ICM are applicable for measuring the similarity between two songs, pitch is one of the most important features to find the similarity between the music patterns. Therefore, computing pitch or fundamental frequencies of any song is the primary task to find similarity of two songs using pitches of the songs. Pitch values of the songs can be extracted by any standard music software like Wavesurfer. Wavesurfer has been adopted in this work.

Music Information Retrieval (MIR) involves series of activities like, music recommendation, song detection, music genre recognition, pitch tracking, music score generation, beat tracking, music transcription, music mood similarity mapping, music melodic similarity, musical instrument recognition, tempo estimation, query by humming etc.

Content based Music Information Retrieval System is the combinations of different research fields like computational musicology, music cognition, music perception, and these research fields are applied for intelligent music recommendation system for advanced searching, processing, and retrieval of music. The overall architecture of Content based Music Retrieval System is depicted in Fig 3.

In the first phase of Fig 3, the required data are gathered and organized. The phase consists of the three sub-phases - feature extraction, normalization, and storage. Feature extraction includes pitch processing, timbre generation, computation of loudness from several audio files. In data normalization phase the extracted data are normalized using some standard form, and finally, date are stored in database

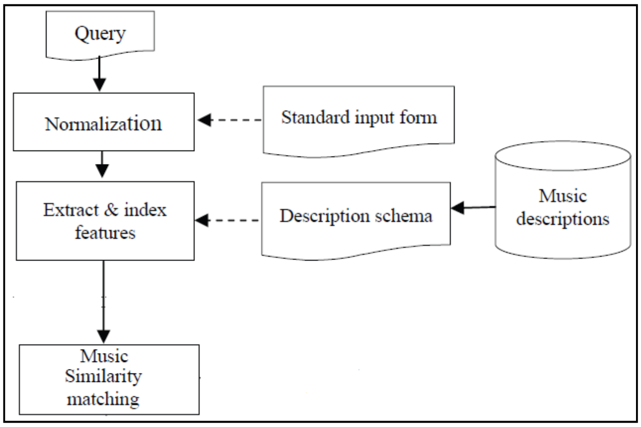

FIGURE 3. The overall architecture of content based music retrieval system.

using indexing. In the next phase, music similarity mapping can be achieved by using different similarity measuring algorithm [1].

As per [2], the music similarity mapping in MIR has two basic research areas, first, exploring the overall functionalities and application areas of MIR, and second, music similarity mapping through different procedures and comparative performance analysis among these procedures.

Some relevant music similarity mapping approaches using the different features of ICM are enlisted in table 2.

III. PROPOSED METHOD

In this section, an algorithm has been proposed that can be used to identify a similar song to a benchmark song. For validation of the algorithm, a song library has been created containing different ICM based songs. Different songs, their associated raga, and corresponding healing capabilities of various ragas are also stored in the library. After applying the algorithm on the library/database, a new song database has been created containing the songs having the same healing power. Thus groups of similar songs are getting created automatically. It is expected that songs of a particular group can be used alternatively as they have similarity in terms of their embedded ragas.

In order to find the similarities of the frequency patterns of two given songs, a statistical method based on Correlation Coefficient has been proposed which is the core of the proposed algorithm. The primary objective of the Correlation Coefficient is to examine whether the two series of fundamental frequencies of two given song structures, are similar. Moreover, Correlation Coefficient may also be used to determine whether the fundamental pitches of the two songs are significantly similar or not.

Finally, an app (for mobile) has been developed embedding the proposed algorithm, and the song database as mentioned above. The app is able to find the similarity between two songs running the proposed algorithm. Depending on the fundamental frequency patterns, similar songs are

TABLE 2. Music similarity mapping approaches using different features of ICM.

Work	ICM elements or other elements	Evaluation metric	Results & discussion
Signal processing for music analysis [3].	Pitch, timbre, melody, harmony, rhythm	Different digital signal processing (DSP) techniques	Some DSP techniques addressing musical features like melody, harmony, rhythm, timbre, etc are used.
Music recommendation using collaborative filtering algorithm [4].	User's history, user's hobbies, music popularity	K-means algorithm of collaborative filtering	It creates personalized music recommendation system after user's context information are classified and modeled.
Measuring disruption in song similarity networks [5].	Musical disruption and genre trajectory	Mel-frequency cepstral coefficients (MFCCs) as feature for audio similarity estimation	This work focused to the music disruption using similarity through metadata-networks.
Automatic mood classification of Indian popular music [6].	Genre, mood, style, pitch, rhythm, harmony, timbre	Random forests using bootstrap aggregation,	This work finds the music emotions automatically.
Mood based music categorization system for Bollywood music [7].	Timbre, intensity, rhythm	K-means algorithm	Automatically identifies the mood of the Bollywood movie songs.
Audio similarity-based retrieval [8].	Fingerprinting, remixes / sampling, cover songs, genre, artist	Gaussian mixture models (GMM) of MFCC features	The work has been applied to the wide spectrum of collective audio for similarity retrieval.
Symbolic melody similarity [9].	Notes, pitch contour,	String-based methods for monophonic melodies	The work searches the database for entries with matching regular expressions.

discovered. It is already known that some songs based on ICM have healing power that can be used in music therapy for treating different health and mind issues. This app is implemented in such a way that it can function as a search engine and also a music recommender that recommends alternate songs instead of the standard ICM that may have similar healing capability. Thus the app functions as a music recommendation system. Moreover, the app contains a large collection of Indian Folk Music (IFM). Thus as an alternative to the ICM, an IFM from within the database may be recommended. Such an app may be used as an E-Healthcare application. The structure of the app is outlined below.

App Name: MMES (Multimedia Mobile E-Healthcare System)

The app consists of eight different components:

(1) **Playlist**: It is a list of video or audio files that can be played on a media player.
(2) **Artists**: It is a list of artists that can be played on a media player
(3) **Albums**: It is a collection of audio or video recordings treated as a collection of songs.
(4) **Songs**: It is a collection of note structures performed by singers.
(5) **TV & Movies**: Some media from where music files can be downloaded.
(6) **Downloaded Music**: It is the digital transfer of music through the Internet into a device capable of storing locally.
(7) **Song Similarity Mapping**: It is the primary focus of this app; using the proposed algorithm, the similarity between two or more songs is determined.
(8) **Music Therapy in E-Healthcare:** It is another focus of this app; it may be used as a tool for music therapy. This part functions as a multimedia based mobile E-Healthcare application.

Proposed Algorithm for Song Similarity Mapping: In this sub-section, the proposed algorithm has been detailed that can be used to find song similarity. It is necessary to know the note structures and the fundamental frequencies of each note of the two songs in order to find the similarity between the two songs through the algorithm designed.

In order to create the pitch file and determine the fundamental frequency of the songs, the wave surfer software has been used. The following procedure describes how to use the wave surfer software in order to create the pitch file (pre-processing); the proposed algorithm to find song similarity has also been presented in this procedure.

Proposed Procedure

```
Pre-Processing:
 (1) Pick a song of a particular Raga
that has some healing power and
another normal song from the available
song library/repository.
(2) Click on the wave surfer button to
open the software. Run one song
through the Wave Surfer which is used
to generate the pitch values of that
song. Firstly ".mp3" song file is used
to build the pitch file of the song
with the extension of.f0. This file
consists of all the pitches that are
used in the song.
(3) The basic steps to create the.f0
format file from a given song are:
  a. Click on the File of Wave Surfer.
  b. Open and choose a song and then
     click on Transform and then choose
     Convert button with sample rate
     22050, sample encoding Lin 16, and
     fix the channel as Mono.
  c. Right click on the black line.
  d. Then click on Create Pane and
     choose Pitch Contour.
  e. Now Right click on the black dots
     and click on Properties and then
     Pitch Contour and set Pitch Method
     is AMDF (Average Magnitude
     Difference Formula) and finally
     click on OK button. The other
     basic properties of Pitch Contour
     are -
       i. Max Pitch Value: 400 Hz
      ii. Min Pitch Value: 60 Hz
     iii. Analysis Window Length:
          0.0075
      iv. Frame Interval: 0.01
       v. Tuning (C1): 65.4064
      vi. Scalar Color: Gray
     vii. Record Scroll Speed: 250
          Pixel/second
  f. After that click on the black dots
     and save the data file.
 (4) The .f0 file consists of huge
number of frequencies of monotonic
song. This file format is converted
into ".csv" format.
```

Proposed Algorithm

Input: Two Songs

Output: Song Similarity Scores

Steps:

Step1: Calculate the number of occurrences of all the fundamental frequencies of each song.

Step2: Fix sixteen (16) frequencies which have highest occurrences respectively, from the list of frequencies of the .fo file of each of the songs, as it applies 16 Note -Measure Method.

Step3: Compute total pitch value of individual note of Song 1 using the following expression:

$$S_1F_i = S_1f_i \times S_1o_i \tag{6}$$

where, i = $1, 2, 3 \ldots, n$

S_1F_i = Total Pitch value of individual note of Song 1,

S_1f_i = Frequency of individual note of Song1,

S_1o_i = Occurrence of individual note of Song 1.

Step4: Compute total pitch value of individual note of Song 2 using the following expression:

$$S_2F_i = S_2f_i \times S_2o_i \tag{7}$$

where, i $= 1, 2, 3, \ldots, n$
S_2F_i = Total Pitch value of individual note of Song 2,
S_2f_i = Frequency of individual note of Song 2,
S_2o_i = Occurrence of individual note of Song 2.
Step5: Now find the value of $\overline{S1F_i}$ and $\overline{S2F_i}$ as follows:

$$\overline{S1F_i} = Mean\ \ of\ \ S_1F_i = \frac{\sum_i^n S_1f_i \times S_1o_i}{n} \tag{8}$$

$$\overline{S2F_i} = Mean\ \ of\ \ S_2F_i = \frac{\sum_i^n S_2f_i \times S_2o_i}{n} \tag{9}$$

Now consider the sum of square (SoS) values of a set of n fundamental frequencies of (S_1F_i, S_2F_i) about $\overline{S1F_i}$ and $\overline{S2F_i}$ respectively as:

$$SoS_{S_1F_iS_1F_i} = \sum S_1F_i^2 - n\overline{S1F_i}^2$$

$$SoS_{S_1F_iS_1F_i} = \sum S_1F_i^2 - 2n\overline{S1F_i}^2 + n\overline{S1F_i}^2$$

$$SoS_{S_1F_iS_1F_i} = \sum S_1F_i^2 - 2\overline{S1F_i}\sum S_1F_i + \sum \overline{S1F_i}^2$$

$$SoS_{S_1F_iS_1F_i} = \sum (S_1F_i - \overline{S1F_i})^2 \tag{10}$$

Again

$$SoS_{S_1F_iS_1F_i} = \sum S_2F_i^2 - n\overline{S2F_i}^2$$

$$SoS_{S_1F_iS_1F_i} = \sum S_2F_i^2 - 2n\overline{S2F_i}^2 + n\overline{S2F_i}^2$$

$$SoS_{S_1F_iS_1F_i} = \sum S_2F_i^2 - 2\overline{S2F_i}\sum S_2F_i + \sum \overline{S2F_i}^2$$

$$SoS_{S_2F_iS_2F_i} = \sum \left(S_2F_i - \overline{S2F_i}\right)^2 \tag{11}$$

Now

$$SoS_{S_1F_iS_1F_i} = \sum S_1F_iS_2F_i - n\overline{S1F_i}\ \ \overline{S2F_i}$$

$$SoS_{S_1F_iS_1F_i} = \sum S_1F_iS_2F_i - n\overline{S1F_i}\ \ \overline{S2F_i} - n\overline{S1F_i}\ \ \overline{S2F_i} + n\overline{S1F_i}\ \ \overline{S2F_i}$$

$$SoS_{S_1F_iS_1F_i} = \sum(S_1F_iS_2F_i - \overline{S1F_i}S_2F_i - S_1F_i\overline{S2F_i} + \overline{S1F_i}\ \ \overline{S2F_i}$$

$$SoS_{S_1F_iS_2F_i} = \sum \left(S_1F_i - \overline{S1F_i}\right)\left(S_2F_i - \overline{S2F_i}\right) \tag{12}$$

Now the song similarity can be measured by Pearson's Correlation formula using the following expression:

$$Song\ \ Similarity = \frac{SoS_{S_1F_iS_2F_i}}{\sqrt{SoS_{S_1F_iS_1F_i}SoS_{S_2F_iS_2F_i}}} \tag{13}$$

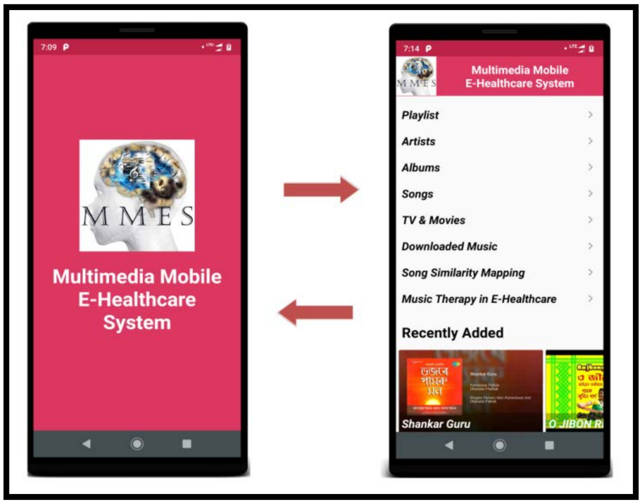

FIGURE 4. Multimedia mobile E-Healthcare App.

$$Song\ \ Similarity = \frac{\sum_i^n (S_1F_i - \overline{S1F_i})(S_2F_i - \overline{S2F_i})}{\sqrt{\sum_i^n (S_1F_i - \overline{S1F_i})^2 \sum_i^n (S_2F_i - \overline{S2F_i})^2}} \tag{14}$$

Using the above mentioned algorithm, song similarity may be computed in terms of percentage.

In the following section, results of different experiments implementing this algorithm have been presented. The mobile app that has been developed is based on this algorithm. The mobile app is able to recommend alternate songs to ICM based songs from a pool of IFM based songs, according to this algorithm.

IV. RESULTS AND ANALYSIS

As mentioned above, an app for mobile has been developed that implements the algorithm described in the previous section. A snapshot of the user interface of the "Multimedia Mobile E-Healthcare System" is presented in Fig. 4.

In this section, different results derived based on the proposed algorithm are presented. Different ICM based songs taken from Hindi movies, and a few Indian folk songs are considered for experiments. The data sets are available and kept as .f0 format files. To be more specific, total five songs are considered in the experiments. One ICN based song has been considered as the basis, and then the similarity patterns are identified considering other four songs. Four test cases are presented in this work. The base song that has been considered is titled as "Laaga Chunri Mein Daag"; this was sang by Manna Dey. The raga of this song is Raga Bhairavi. Raga Bhairavi is used to reduce sinus problem, cold, and toothache. Experiments were carried out to find out the similarities of other five songs with the base song according to their similarity values. The Waveform, Spectrogram and Pitch Contour of this song are depicted in Fig 5, and Mean plus Standard Deviation of Song 1 (Laaga Chunri Mein Daag) are depicted in Fig. 6.

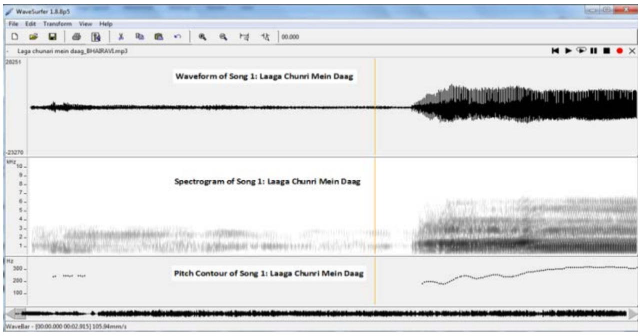

FIGURE 5. Waveform, spectrogram, and pitch contour of Song 1: Laaga Chunri Mein Daag.

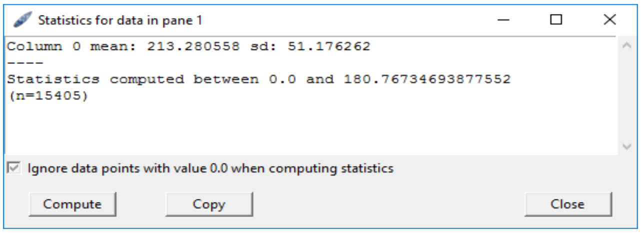

FIGURE 6. Mean and standard deviation of Song 1: Laaga Chunri Mein Daag.

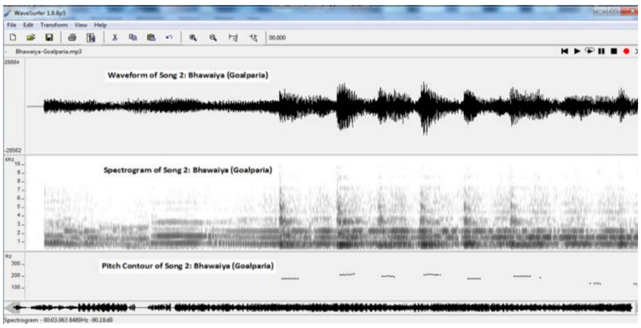

FIGURE 7. Waveform, spectrogram, and pitch contour of Song 2: Bhawaiya.

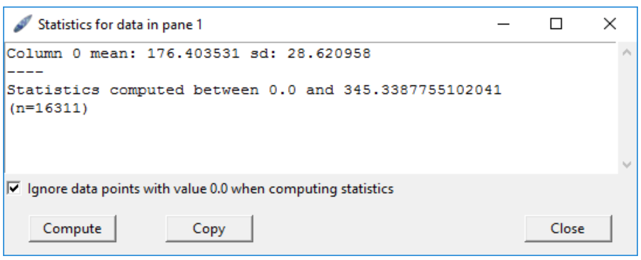

FIGURE 8. Mean and standard deviation of Song 2: Bhawaiya.

Song 1: Laaga Chunri Mein Daag
Movie Name: Dil Hi to Hai
Song Type: Indian Classical Music
Singer: Manna Dey
Raga Name: Bhairavi
Solve Disease: Sinus Problem, Cold, Toothache
Song 2: Bhawaiya
Song Type: Indian Folk Music
Singer: Krishnamoni Chutiya

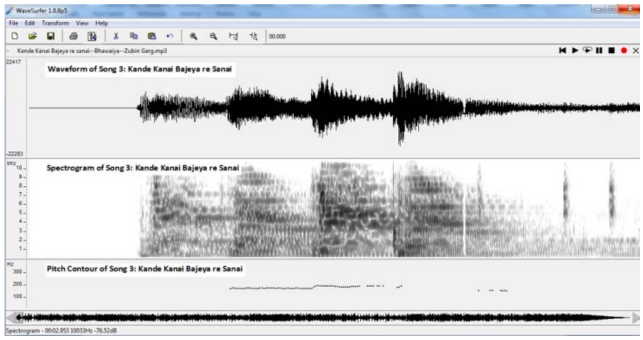

FIGURE 9. Waveform, spectrogram, and pitch contour of Song 3: Kande Kanai Bajeya re Sanai.

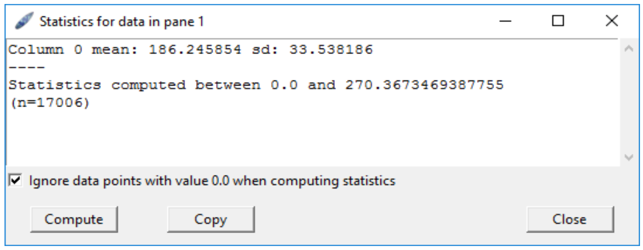

FIGURE 10. Mean and standard deviation of "Kande Kanai Bajeya re Sanai."

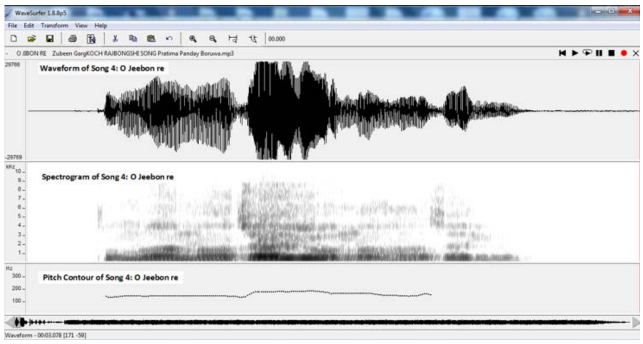

FIGURE 11. Waveform, spectrogram, and pitch contour of Song 4: Oh Jeebon re.

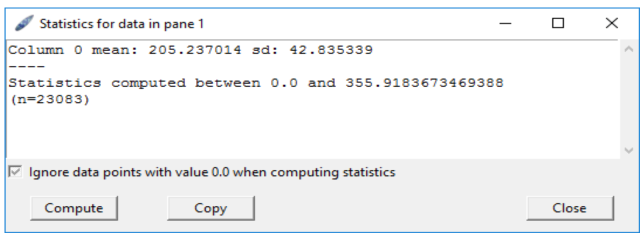

FIGURE 12. Mean and standard deviation of Song 4: Oh Jeebon re.

The Waveform, Spectrogram, and Pitch Contour of the Song 2 are depicted in Fig 7. Mean plus Standard Deviation of Song 2 (Bhawaiya) are presented in Fig. 8.

Thus the first test case is, Test Case 1: Song 1 is compared with Song 2.

Song 3: Kande Kanai Bajeya re Sanai
Song Type: Indian Folk Music
Singer: Jubin Garg

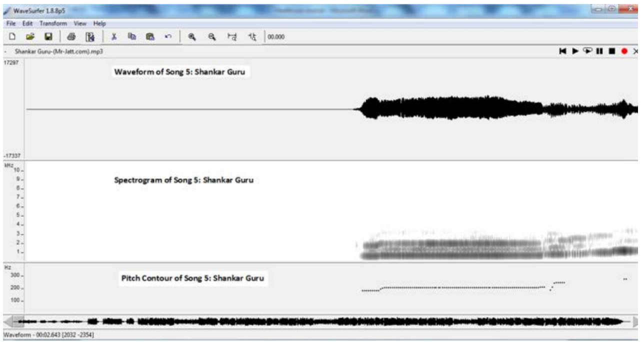

FIGURE 13. Waveform, spectrogram, and pitch contour of Song 5: Shankar Guru.

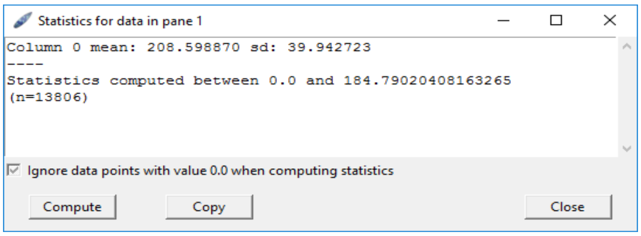

FIGURE 14. Mean and standard deviation of "Shankar Guru."

TABLE 3. Total pitch values of Song 1 and Song 2.

S_1f_i	S_1o_i	S_1F_i	S_2f_i	S_2o_i	S_2F_i
110	546	60060	160	625	100000
123	529	65067	179	527	94333
113	525	59325	180	517	93060
111	519	57609	159	485	77115
119	495	58905	177	464	82128
109	461	50249	162	440	71280
121	449	54329	176	387	68112
116	445	51620	182	385	70070
117	438	51246	158	371	58618
114	428	48792	175	341	59675
98	426	41748	157	327	51339
136	424	57664	165	325	53625
108	405	43740	183	323	59109
126	399	50274	164	318	52152
107	388	41516	173	305	52765
106	339	35934	214	295	63130

The Waveform, Spectrogram, and Pitch Contour of Song 3 are depicted in Fig 9 and Mean plus Standard Deviation of Song 3 (Kande Kanai Bajeya re Sanai) are presented in Fig. 10.

Thus the second test case is, Test Case 2: Song 1 is compared with Song 3.

TABLE 4. Computation of song similarity.

S_1F_i	S_2F_i	$\overline{S_1F_i}$	$\overline{S_2F_i}$	$D = S_1F_i - \overline{S_1F_i}$	$D1 = S_2F_i - \overline{S_2F_i}$	$\sum DD1$	$\sum D^2$	$\sum D1^2$	Song Similarity
60060	100000			8305.125	30843.063	256155489.4	68975101.27	951294504.4	
65067	94333			13312.125	25176.063	335146891	177212672	633834123	
59325	93060			7570.125	23903.063	180949171	57306792.52	571356396.9	
57609	77115			5854.125	7958.0625	46587492.63	34270779.52	63330758.75	
58905	82128			7150.125	12971.063	92744718.26	51124287.52	168248462.4	
50249	71280			-1505.875	2123.0625	-3197066.74	2267659.516	4507394.379	
54329	68112			2574.125	-1044.9375	-2689799.74	6626119.516	1091894.379	
51620	70070	51754.875	69156.9375	-134.875	913.0625	-123149.305	18191.26563	833683.1289	0.7240924
51246	58618			-508.875	-10538.938	5363001.82	258953.7656	111069203.6	
48792	59675			-2962.875	-9481.9375	28093795.57	8778628.266	89907138.75	
41748	51339			-10006.875	-17817.938	178301873.3	100137547.3	317478896.8	
57664	53625			5909.125	-15531.938	-91780160.2	34917758.27	241241082.5	
43740	59109			-8014.875	-10047.938	80532963.07	64238221.27	100961048	
50274	52152			-1480.875	-17004.938	25182186.82	2192990.766	289167899.4	
41516	52765			-10238.875	-16391.938	167834999.1	104834561.3	268695615	
35934	63130			-15820.875	-6026.9375	95351424.82	250300085.8	36323975.63	
						1394453831	963460349.8	3849342077	

TABLE 5. Contingency table between Song 1 and Song 2.

OF(S1)	OF(S2)	OF(S1+S2)	EF(S1)	EF(S2)	EF(S1+S2)
110	160	270	107.6946498	162.3053502	270
123	179	302	120.4584602	181.5415398	302
113	180	293	116.8686385	176.1313615	293
111	159	270	107.6946498	162.3053502	270
119	177	296	118.0652458	177.9347542	296
109	162	271	108.0935189	162.9064811	271
121	176	297	118.4641148	178.5358852	297
116	182	298	118.8629839	179.1370161	298
117	158	275	109.6889952	165.3110048	275
114	175	289	115.2731622	173.7268378	289
98	157	255	101.7116137	153.2883863	255
136	165	301	120.0595911	180.9404089	301
108	183	291	116.0709004	174.9290996	291
126	164	290	115.6720313	174.3279687	290
107	173	280	111.6833406	168.3166594	280
106	214	320	127.6381035	192.3618965	320
Σ=1834	Σ=2764	Σ=4598	Σ=1834	Σ=2764	Σ=4598

Song 4: Oh Jeebon re
Song Type: Indian Folk Music
Singer: Jubin Garg

The Waveform, Spectrogram, and Pitch Contour of Song 4 are depicted in Fig. 11, and Mean plus Standard Deviation of Song 4 (Oh Jeebon re) are presented in Fig. 12.

Thus the third test case is, Test Case 3: Song 1 is compared with Song 4.

Song 5: Sankar Guru
Song Type: Indian Folk Music
Singer: Rameswar Pathak

TABLE 6. Computation of chi-square, and coefficient of contingency.

Pairs	Observed Pitch	Expected Pitch	Square of difference between Observed and Expected Pitch	Chi-Square	Coefficient of Contingency of Song1 and Song2
(S1, F1)	110	107.6946	0.049349151	14.2596795	0.049621326
(S1, F2)	123	120.4585	0.053623669		
(S1, F3)	113	116.8686	0.12806142		
(S1, F4)	111	107.6946	0.101447379		
(S1, F5)	119	118.0652	0.0074007		
(S1, F6)	109	108.0935	0.007601825		
(S1, F7)	121	118.4641	0.054284065		
(S1, F8)	116	118.863	0.068959036		
(S1, F9)	117	109.689	0.487294018		
(S1, F10)	114	115.2732	0.014061747		
(S1, F11)	98	101.7116	0.13544251		
(S1, F12)	136	120.0596	2.116420967		
(S1, F13)	108	116.0709	0.561203825		
(S1, F14)	126	115.672	0.922149774		
(S1, F15)	107	111.6833	0.196391683		
(S1, F16)	106	127.6381	3.668242556		
(S2, F1)	160	162.3054	0.032744697		
(S2, F2)	179	181.5415	0.035580973		
(S2, F3)	180	176.1314	0.084972737		
(S2, F4)	159	162.3054	0.067313492		
(S2, F5)	177	177.9348	0.004910594		
(S2, F6)	162	162.9065	0.005044047		
(S2, F7)	176	178.5359	0.036019166		
(S2, F8)	182	179.137	0.045756466		
(S2, F9)	158	165.311	0.323334743		
(S2, F10)	175	173.7268	0.009330406		
(S2, F11)	157	153.2884	0.08987032		
(S2, F12)	165	180.9404	1.404311162		
(S2, F13)	183	174.9291	0.372376199		
(S2, F14)	164	174.328	0.611875067		
(S2, F15)	173	168.3167	0.130311992		
(S2, F16)	214	192.3619	2.43399307		

The Waveform, Spectrogram, and Pitch Contour of Song 5 are depicted in Fig 13 and Mean plus Standard Deviation for the same song (Sankar Guru) are presented in Fig. 14.

Thus the fourth test case is, Test Case 4: Song 1 is compared with Song 5.

A. FINDINGS FROM TEST CASE 1

Table 3 presents the 16 fundamental pitch values and their corresponding occurrences in Song 1 and Song 2.

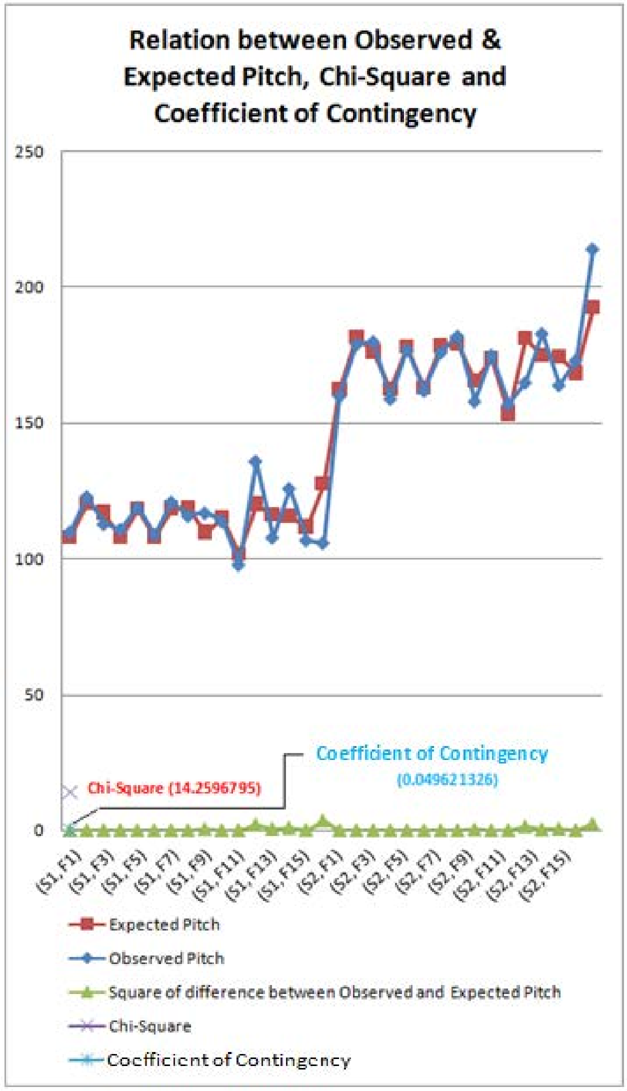

FIGURE 15. Comparison between Song1 and Song 2 with respect to observed frequency and expected frequency.

In Table 3, S_1f_i = Pitch frequency, S_1o_i = Pitch occurrence, S_1F_i = total Pitch frequency of Song 1; and S_2f_i = Pitch frequency, S_2o_i = Pitch occurrence, S_2F_i = total Pitch frequency of Song 2.

Table 4 depicts the song similarity between Song 1 and Song 2 and its value is 0.7240924 $\cong$ 72.40924%.

B. VALIDATION OF TEST CASE 1

Table 5 presents the expected frequencies depending on observed frequencies of Song 1 and Song 2.

In Table 5, OF(S1) = Observed Pitch Frequency of Song 1, OF(S2) = Observed Pitch Frequency of Song 2, EF(S1) = Expected Pitch Frequency of Song 1, and EF(S2) = Expected Pitch Frequency of Song 2.

TABLE 7. Total pitch values of Song 1 and Song 3.

S_1f_i	S_1o_i	S_1F_i	S_3f_i	S_3o_i	S_3F_i
110	546	60060	175	731	127925
123	529	65067	173	654	113142
113	525	59325	176	603	106128
111	519	57609	196	536	105056
119	495	58905	177	493	87261
109	461	50249	198	441	87318
121	449	54329	172	432	74304
116	445	51620	195	404	78780
117	438	51246	232	396	91872
114	428	48792	220	371	81620
98	426	41748	179	370	66230
136	424	57664	170	366	62220
108	405	43740	147	350	51450
126	399	50274	200	331	66200
107	388	41516	169	312	52728
106	339	35934	234	310	72540

TABLE 8. Computation of song similarity.

S_1F_i	S_3F_i	$\overline{S_1F_i}$	$\overline{S_3F_i}$	$D = S_1F_i - \overline{S_1F_i}$	$D1 = S_3F_i - \overline{S_3F_i}$	$\sum DD1$	$\sum D^2$	$\sum D1^2$	Song Similarity
60060	127925	51754.875	82798.375	8305.125	45126.625	374782261.5	68975101.27	2036412284	0.7144741
65067	113142			13312.125	30343.625	403938129	177212672	920735578.1	
59325	106128			7570.125	23329.625	176608177.5	57306792.52	544271402.6	
57609	105056			5854.125	22257.625	130298919	34270779.52	495401870.6	
58905	87261			7150.125	4462.625	31908326.58	51124287.52	19915021.89	
50249	87318			-1505.875	4519.625	-6805990.3	2267659.516	20427010.14	
54329	74304			2574.125	-8494.375	-21865583	6626119.516	72154406.64	
51620	78780			-134.875	-4018.375	541978.3281	18191.26563	16147337.64	
51246	91872			-508.875	9073.625	-4617340.92	258953.7656	82330670.64	
48792	81620			-2962.875	-1178.375	3491377.828	8778628.266	1388567.641	
41748	66230			-10006.875	-16568.375	165797657.6	100137547.3	274511050.1	
57664	62220			5909.125	-20578.375	-121600190	34917758.27	423469517.6	
43740	51450			-8014.875	-31348.375	251253307.1	64238221.27	982720615.1	
50274	66200			-1480.875	-16598.375	24580118.58	2192990.766	275506052.6	
41516	52728			-10238.875	-30070.375	307886810.8	104834561.3	904227452.6	
35934	72540			-15820.875	-10258.375	162296468.6	250300085.8	105234257.6	
						1878494428	963460349.8	7174853096	

Expected frequencies may be computed depending on the observed frequencies as given in (15).

$$(EF(S_i), f_j) = \frac{OF(S_i) \times [OF(S_i) + OF(S_j)]}{N} \tag{15}$$

In order to determine the degree of association between Song 1 and Song 2, Chi-Square measure and Coefficient of Contingency are computed by using the equations (16) and (17), respectively.

$$\chi^2 = \sum_{i=0}^{n} \frac{((O_i - E_i)^2}{E_i} \tag{16}$$

where,
χ^2 = Chi-Square
O = Observed Frequency

TABLE 9. Contingency table of Song 1 and Song 3.

OF(S1)	OF(S2)	OF(S1+S2)	EF(S1)	EF(S2)	EF(S1+S2)
110	175	285	107.8378378	177.1621622	285
123	173	296	112	184	296
113	176	289	109.3513514	179.6486486	289
111	196	307	116.1621622	190.8378378	307
119	177	296	112	184	296
109	198	307	116.1621622	190.8378378	307
121	172	293	110.8648649	182.1351351	293
116	195	311	117.6756757	193.3243243	311
117	232	349	132.0540541	216.9459459	349
114	220	334	126.3783784	207.6216216	334
98	179	277	104.8108108	172.1891892	277
136	170	306	115.7837838	190.2162162	306
108	147	255	96.48648649	158.5135135	255
126	200	326	123.3513514	202.6486486	326
107	169	276	104.4324324	171.5675676	276
106	234	340	128.6486486	211.3513514	340
Σ=1834	Σ=3013	Σ=4847	Σ=1834	Σ=3013	Σ=4847

E = Expected Frequency

$$C = \sqrt{\frac{\chi^2}{N + \chi^2}} \tag{17}$$

where,
C = Coefficient of Contingency
N = Total Population

$$Degree\ of\ Freedom(df) = (r - 1) \times (c - 1) \tag{18}$$

where,
r = Number of rows
c = Number of columns

The 16 Shruti-Measure systems applied for all the computations in order to measure song similarity; in each test case, it has been compared between one pair of songs.

Therefore, for each comparison, the value of r = 16 and c = 2. Therefore, the Degree of Freedom for each song comparison = (16 − 1) × (2 − 1) = 15.

Table 6 presents the computation of Chi-Square measure, and Coefficient of Contingency between Song1 and Song2.

In Test Case 1, Degree of Freedom (df) = 15 and χ^2 between Song 1 and Song 2 = 14.2596795. From the chi-square table, for df = 15, chi-square value at 0.05 level is 24.996 and at 0.025 level is 27.488. Therefore, calculated value of chi-square is less than the both tabulated value and the value of coefficient of contingency is near to zero. Therefore, there is no significant difference between the two series. Thus, it is mostly significant and rejects the null hypothesis and the conclusion is that Song 1 and Song 2 are similar at a certain percentage.

TABLE 10. Computation of chi-square, and coefficient of contingency.

Pairs	Observed Pitch	Expected Pitch	Square of difference between Observed and Expected Pitch	Chi-Square	Coefficient of Contingency
(S1, F1)	110	107.8378	0.043351624	17.6666808	0.058702952
(S1, F2)	123	112	1.080357143		
(S1, F3)	113	109.3514	0.121741857		
(S1, F4)	111	116.1622	0.229402742		
(S1, F5)	119	112	0.4375		
(S1, F6)	109	116.1622	0.441594461		
(S1, F7)	121	110.8649	0.926542089		
(S1, F8)	116	117.6757	0.023861253		
(S1, F9)	117	132.0541	1.716149848		
(S1, F10)	114	126.3784	1.212424576		
(S1, F11)	98	104.8108	0.442579763		
(S1, F12)	136	115.7838	3.529815524		
(S1, F13)	108	96.48649	1.373881444		
(S1, F14)	126	123.3514	0.056872822		
(S1, F15)	107	104.4324	0.063126016		
(S1, F16)	106	128.6486	3.987304095		
(S3, F1)	175	177.1622	0.026387945		
(S3, F2)	173	184	0.657608696		
(S3, F3)	176	179.6486	0.074103739		
(S3, F4)	196	190.8378	0.139636452		
(S3, F5)	177	184	0.266304348		
(S3, F6)	198	190.8378	0.268796628		
(S3 F7)	172	182.1351	0.563982141		
(S3, F8)	195	193.3243	0.014524241		
(S3, F9)	232	216.9459	1.044612951		
(S3, F10)	220	207.6216	0.737997568		
(S3, F11)	179	172.1892	0.269396377		
(S3, F12)	170	180.9404	0.661502578		
(S3, F13)	147	174.9291	4.459147199		
(S3, F14)	200	174.328	3.78053617		
(S3, F15)	169	168.3167	0.002774261		
(S3, F16)	234	192.3619	9.012864266		

Fig. 15 presents the comparison between Song 1 and Song 2 with respect to Observed Frequency and Expected Frequency.

C. FINDINGS FROM TEST CASE 2

Table 7 represents 16 fundamental pitch values and their corresponding occurrences in Song 1 and Song 3.

In Table 7, S_1f_i = Pitch frequency, S_1o_i = Pitch occurrence, S_1F_i = total Pitch Frequency of Song 1; and S_3f_i = Pitch frequency, S_3o_i = Pitch occurrence, S_3F_i = total Pitch frequency of Song 3.

TABLE 11. Total pitch values of Song 1 and Song 4.

S_1f_i	S_1o_i	S_1F_i	S_4f_i	S_4o_i	S_4F_i
110	546	60060	220	946	208120
123	529	65067	222	880	195360
113	525	59325	218	855	186390
111	519	57609	216	679	146664
119	495	58905	225	608	136800
109	461	50249	214	575	123050
121	449	54329	196	526	103096
116	445	51620	195	521	101595
117	438	51246	198	515	101970
114	428	48792	212	451	95612
98	426	41748	227	431	97837
136	424	57664	200	426	85200
108	405	43740	193	418	80674
126	399	50274	210	408	85680
107	388	41516	191	396	75636
106	339	35934	190	371	70490

Table 8 presents the song similarity between Song1 and Song3 and its value is 0.7144741 ≅ 71.44741%.

D. VALIDATION OF TEST CASE 2

Table 9 presents the expected frequencies depending on observed frequencies of Song 1 and Song 3.

Table 10 presents the computation of Chi-Square measure, and Coefficient of Contingency between Song 1 and Song 3.

In Test Case 2, Degree of Freedom (df) = 15 and χ^2 between Song 1 and Song 3 = 17.6666808. From the chi-square table, for df = 15, chi-square value at 0.05 level is 24.996 and at 0.025 level is 27.488. Therefore, calculated value of chi-square is less than the both tabulated values, and the value of coefficient of contingency is near to zero. Therefore, there is no significant difference between the two series. Thus it is mostly significant and rejects the null hypothesis; thus the conclusion is that Song 1 and Song 3 are similar at a certain percentage.

Fig. 16 presents the comparison between Song 1 and Song 3 with respect to Observed Frequency and Expected Frequency.

E. FINDINGS FROM TEST CASE 3

Table 11 represents 16 fundamental pitch values and their corresponding occurrences in Song1 and Song4.

In Table 11, S_1f_i = Pitch frequency, S_1o_i = Pitch occurrence, S_1F_i = total Pitch frequency of Song 1; and S_4f_i = Pitch frequency, S_4o_i = Pitch occurrence, S_4F_i = total Pitch frequency of Song 4.

Table 12 presents the song similarity between Song1 and Song3 and its value is 0.7860254 ≅ 78.60254%.

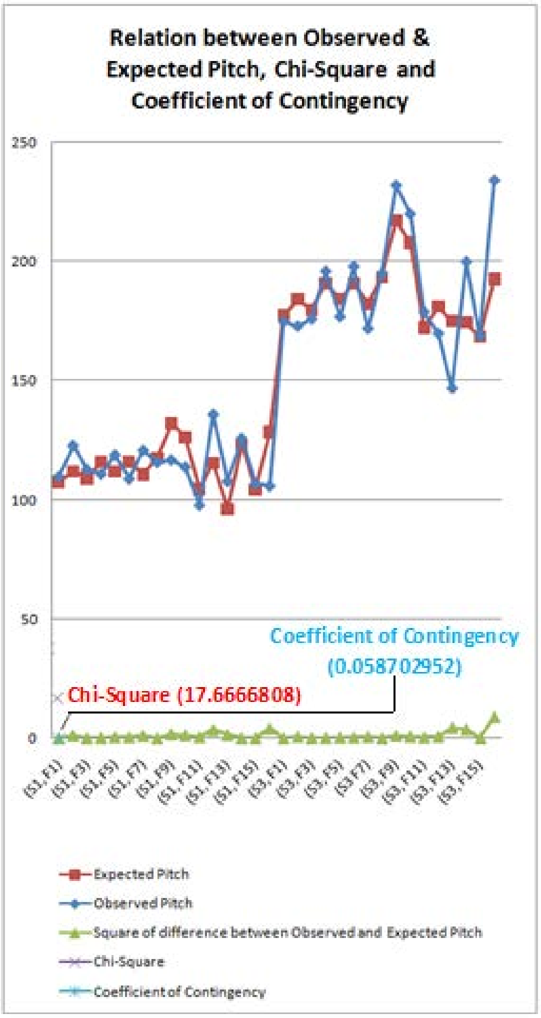

FIGURE 16. Comparison between Song1 and Song 3 with respect to observed frequency and expected frequency.

TABLE 12. Computation of song similarity.

S_1F_i	S_4F_i	$\overline{S_1F_i}$	$\overline{S_4F_i}$	$D = S_1F_i - \overline{S_1F_i}$	$D1 = S_4F_i - \overline{S_4F_i}$	∑DD1	$\sum D^2$	$\sum D1^2$	Song Similarity
60060	208120	51754.875	118385.875	8305.125	89734.125	745253124.9	68975101.27	8052213190	0.7860254
65067	195360			13312.125	76974.125	1024689174	177212672	5925015920	
59325	186390			7570.125	68004.125	514799726.8	57306792.52	4624561017	
57609	146664			5854.125	28278.125	165543678.5	34270779.52	799652353.5	
58905	136800			7150.125	18414.125	131663295.5	51124287.52	339079999.5	
50249	123050			-1505.875	4664.125	-7023589.23	2267659.516	21754062.02	
54329	103096			2574.125	-15289.875	-39358049.5	6626119.516	233780277.5	
51620	101595			-134.875	-16790.875	2264669.266	18191.26563	281933483.3	
51246	101970			-508.875	-16415.875	8353628.391	258953.7656	269480952	
48792	95612			-2962.875	-22773.875	67476144.89	8778628.266	518649382.5	
41748	97837			-10006.875	-20548.875	205630023.5	100137547.3	422256263.8	
57664	85200			5909.125	-33185.875	-196099484	34917758.27	1101302300	
43740	80674			-8014.875	-37711.875	302255964.1	64238221.27	1422185516	
50274	85680			-1480.875	-32705.875	48433312.64	2192990.766	1069674260	
41516	75636			-10238.875	-42749.875	437710626.4	104834561.3	1827551813	
35934	70490			-15820.875	-47895.875	757754651.4	250300085.8	2294014842	
						4169346898	963460349.8	29203105630	

F. VALIDATION OF TEST CASE 3

Table 13 presents the expected frequencies depending on the observed frequencies of Song 1 and Song 4.

TABLE 13. Contingency table of Song 1 and Song 4.

S1(OF)	S4(OF)	OF(S1+S4)	S1(EF)	S4(EF)	EF(S1+S4)
110	220	330	117.2679713	212.7320287	330
123	222	345	122.5983337	222.4016663	345
113	218	331	117.6233288	213.3766712	331
111	216	327	116.2018989	210.7981011	327
119	225	344	122.2429762	221.7570238	344
109	214	323	114.7804689	208.2195311	323
121	196	317	112.648324	204.351676	317
116	195	311	110.516179	200.483821	311
117	198	315	111.937609	203.062391	315
114	212	326	115.8465414	210.1534586	326
98	227	325	115.4911839	209.5088161	325
136	200	336	119.4001163	216.5998837	336
108	193	301	106.9626041	194.0373959	301
126	210	336	119.4001163	216.5998837	336
107	191	298	105.8965317	192.1034683	298
106	190	296	105.1858167	190.8141833	296
Σ=1834	Σ=3327	Σ=5161	Σ=1834	Σ=3327	Σ=5161

TABLE 14. Computation of chi-square, and coefficient of contingency.

Pairs	Observed Pitch	Expected Pitch	Square of difference between Observed and Expected Pitch	Chi-Square	Coefficient of Contingency
(S1, F1)	110	117.268	0.450450419	12.0109005	0.049718023
(S1, F2)	123	122.5983	0.001315971		
(S1, F3)	113	117.6233	0.181725593		
(S1, F4)	111	116.2019	0.232868416		
(S1, F5)	119	122.243	0.086032711		
(S1, F6)	109	114.7805	0.291110683		
(S1, F7)	121	112.6483	0.619188014		
(S1, F8)	116	110.5162	0.272107605		
(S1, F9)	117	111.9376	0.228947204		
(S1, F10)	114	115.8465	0.029433034		
(S1, F11)	98	115.4912	2.64904648		
(S1, F12)	136	119.4001	2.307838111		
(S1, F13)	108	106.9626	0.010061369		
(S1, F14)	126	119.4001	0.364810908		
(S1, F15)	107	105.8965	0.011498415		
(S1, F16)	106	105.1858	0.006302128		
(S4, F1)	220	212.732	0.248309609		
(S4, F2)	222	222.4017	0.000725425		
(S4, F3)	218	213.3767	0.100175755		
(S4, F4)	216	210.7981	0.128368102		
(S4, F5)	225	221.757	0.047425306		
(S4, F6)	214	208.2195	0.160473998		
(S4, F7)	196	204.3517	0.341325764		
(S4, F8)	195	200.4838	0.149998601		
(S4, F9)	198	203.0624	0.126206544		
(S4, F10)	212	210.1535	0.016224882		
(S4, F11)	227	209.5088	1.460279906		
(S4, F12)	200	216.5999	1.27218969		
(S4, F13)	193	194.0374	0.005546303		
(S4, F14)	210	216.5999	0.201101054		
(S4, F15)	191	192.1035	0.006338471		
(S4, F16)	190	190.8142	0.003474031		

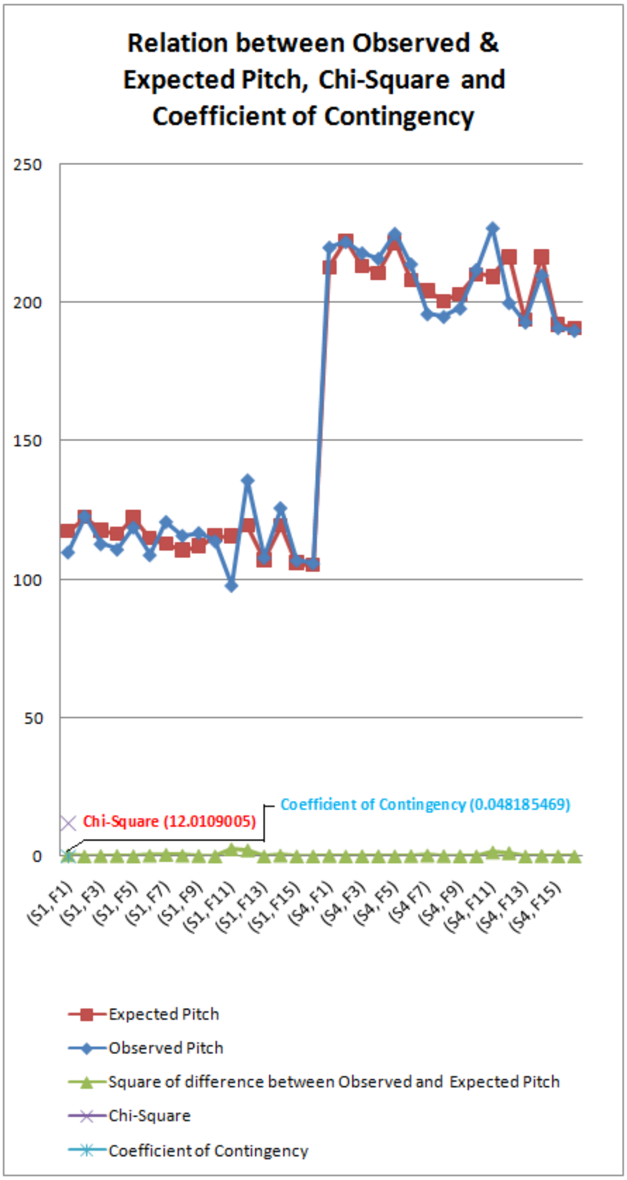

FIGURE 17. Comparison between Song1 and Song 4 with respect to observed frequency and expected frequency.

Table 14 presents the computation of Chi-Square measure, and Coefficient of Contingency between Song 1 and Song 4.

In Test Case 3, Degree of Freedom (df) = 15 and χ^2 between Song 1 and Song 4 = 12.0109005. From the chi-square table, for df = 15, chi-square value at 0.05 level is 24.996 and at 0.025 level is 27.488. Therefore, calculated value of chi-square is less than the both tabulated values and the value of coefficient of contingency is near to zero. Therefore, there is no significant difference between the two series. Thus it is mostly significant and rejects the null hypothesis; the conclusion is that Song 1 and Song 4 are similar at a certain percentage.

Fig. 17 presents the comparison between Song 1 and Song 4 with respect to Observed Frequency and Expected Frequency.

TABLE 15. Total pitch values of Song 1 and Song 5.

$S_1 f_i$	$S_1 o_i$	$S_1 F_i$	$S_5 f_i$	$S_5 o_i$	$S_5 F_i$
110	546	60060	206	946	194876
123	529	65067	208	880	183040
113	525	59325	204	855	174420
111	519	57609	202	679	137158
119	495	58905	210	608	127680
109	461	50249	229	575	131675
121	449	54329	200	526	105200
116	445	51620	234	521	121914
117	438	51246	227	515	116905
114	428	48792	198	451	89298
98	426	41748	185	431	79735
136	424	57664	212	426	90312
108	405	43740	183	418	76494
126	399	50274	186	408	75888
107	388	41516	196	396	77616
106	339	35934	195	371	72345

TABLE 16. Computation of song similarity.

$S_1 F_i$	$S_5 F_i$	$\overline{S_1 F_i}$	$\overline{S_5 F_i}$	$D = S_1 F_i - \overline{S_1 F_i}$	$D1 = S_5 F_i - \overline{S_5 F_i}$	$\Sigma DD1$	ΣD^2	$\Sigma D1^2$	Song Similarity
60060	194876	51754.875	115909.75	8305.125	78966.25	655824577	68975101.27	6235668639	0.8040744
65067	183040			13312.125	67130.25	893646279.3	177212672	4506470465	
59325	174420			7570.125	58510.25	442929906.3	57306792.52	3423449355	
57609	137158			5854.125	21248.25	124389911.5	34270779.52	451488128.1	
58905	127680			7150.125	11770.25	84158758.78	51124287.52	138538785.1	
50249	131675			-1505.875	15765.25	-23740495.8	2267659.516	248543107.6	
54329	105200			2574.125	-10709.75	-27568235.2	6626119.516	114698745.1	
51620	121914			-134.875	6004.25	-809823.219	18191.26563	36051018.06	
51246	116905			-508.875	995.25	-506457.844	258953.7656	990522.5625	
48792	89298			-2962.875	-26611.75	78847288.78	8778628.266	708185238.1	
41748	79735			-10006.875	-36174.75	361996201.4	100137547.3	1308612538	
57664	90312			5909.125	-25597.75	-151260304	34917758.27	655244805.1	
43740	76494			-8014.875	-39415.75	315912309.3	64238221.27	1553601348	
50274	75888			-1480.875	-40021.75	59267209.03	2192990.766	1601740473	
41516	77616			-10238.875	-38293.75	392084919.5	104834561.3	1466411289	
35934	72345			-15820.875	-43564.75	689232464.2	250300085.8	1897887443	
						3894404509	963460349.8	24347581899	

G. FINDINGS FROM TEST CASE 4

Table 15 represents 16 fundamental pitch values and their corresponding occurrences in Song 1 and Song 5.

In Table 15, $S_1 f_i$ = Pitch frequency, $S_1 o_i$ = Pitch occurrence, $S_1 F_i$ = Total Pitch frequency of Song 1; and $S_5 f_i$ = Pitch frequency, $S_5 o_i$ = Pitch occurrence, $S_5 F_i$ = total Pitch frequency of Song 5.

Table 16 represents the song similarity between Song 1 and Song 5 and its value is 0.8040744 ≅ 80.40744%.

H. VALIDATION OF TEST CASE 4

Table 17 presents the expected frequencies depending on observed frequencies of Song 1 and Song 5.

TABLE 17. Contingency table of Song 1 and Song 5.

S1(OF)	S3(OF)	OF(S1+S3)	S1(EF)	S3(EF)	EF(S1+S3)
110	206	316	113.4358974	202.5641026	316
123	208	331	118.8205128	212.1794872	331
113	204	317	113.7948718	203.2051282	317
111	202	313	112.3589744	200.6410256	313
119	210	329	118.1025641	210.8974359	329
109	229	338	121.3333333	216.6666667	338
121	200	321	115.2307692	205.7692308	321
116	234	350	125.6410256	224.3589744	350
117	227	344	123.4871795	220.5128205	344
114	198	312	112	200	312
98	185	283	101.5897436	181.4102564	283
136	212	348	124.9230769	223.0769231	348
108	183	291	104.4615385	186.5384615	291
126	186	312	112	200	312
107	196	303	108.7692308	194.2307692	303
106	195	301	108.0512821	192.9487179	301
Σ=1834	Σ=3275	Σ=5109	Σ=1834	Σ=3275	Σ=5109

Table 18 presents the computation of Chi-Square measure, and Coefficient of Contingency between Song 1 and Song 5.

In Test Case 4, Degree of Freedom (df) = 15 and χ^2 between Song 1 and Song 5 = 9.33710823. From the chi-square table, for df = 15, chi-square value at 0.05 level is 24.996 and at 0.025 level is 27.488. Therefore, calculated value of chi-square is less than the both tabulated values and the value of coefficient of contingency is near to zero. Therefore, there is no significant difference between the two series. Thus it is mostly significant, and rejects the null hypothesis; the conclusion is that Song 1 and Song 5 are similar at a certain percentage.

Fig. 18 presents the comparison between Song 1 and Song 5 with respect to Observed Frequency and Expected Frequency.

TABLE 18. Computation of chi-square, and coefficient of contingency.

Pairs	Observed Pitch	Expected Pitch	Square of difference between Observed and Expected Pitch	Chi-Square	Coefficient of Contingency
(S1, F1)	110	113.4359	0.104071032	9.3371 0823	0.042711198
(S1, F2)	123	118.8205	0.147012606		
(S1, F3)	113	113.7949	0.005552282		
(S1, F4)	111	112.359	0.016436706		
(S1, F5)	119	118.1026	0.006819422		
(S1, F6)	109	121.3333	1.253662997		
(S1, F7)	121	115.2308	0.288846671		
(S1, F8)	116	125.641	0.739801145		
(S1, F9)	117	123.4872	0.340792445		
(S1, F10)	114	112	0.035714286		
(S1, F11)	98	101.5897	0.126846064		
(S1, F12)	136	124.9231	0.982190228		
(S1, F13)	108	104.4615	0.119859519		
(S1, F14)	126	112	1.75		
(S1, F15)	107	108.7692	0.028778154		
(S1, F16)	106	108.0513	0.038942233		
(S5, F1)	206	202.5641	0.058279778		
(S5, F2)	208	212.1795	0.082327059		
(S5, F3)	204	203.2051	0.003109278		
(S5, F4)	202	200.641	0.009204555		
(S5, F5)	210	210.8974	0.003818876		
(S5, F6)	229	216.6667	0.702051278		
(S5, F7)	200	205.7692	0.161754135		
(S5, F8)	234	224.359	0.414288641		
(S5, F9)	227	220.5128	0.190843769		
(S5, F10)	198	200	0.02		
(S5, F11)	185	181.4103	0.071033796		
(S5, F12)	212	223.0769	0.550026527		
(S5, F13)	183	186.5385	0.067121331		
(S5, F14)	186	200	0.98		
(S5, F15)	196	194.2308	0.016115766		
(S5, F16)	195	192.9487	0.021807651		

I. COMPARATIVE PERFORMANCE EVALUATION

In this subsection, a comparative performance analysis is presented. Apart from considering the findings from the above mentioned four test cases using the proposed method (i.e., using correlation co-efficient), outcomes regarding the similarity level determined between two songs have been calculated by using different sound analysis methods such as mean and standard deviation.

Then all the computed values are presented in Table 19.

Table 19 presents the song similarity values between (Song 1 & Song 1), (Song 1 & Song 2), (Song 1 & Song 3), (Song 1, & Song 4), and (Song 1 & Song 5) that have been computed using different measures such as mean, standard deviation, and the proposed algorithm.

Fig. 19 presents the song similarity between (Song1, & Song1), (Song1 & Song2), (Song 1 & Song3), (Song1, & Song4), and (Song1, & Song5) using bar diagram.

As a summary, it is found through rigorous experiments that all the four songs of IFM are similar to the ICM based song titled as "Laaga Chunri Mein Daag." The Song 4 of IFM (that is "Oh Jeebon re") is highly similar to Song 1 (that is "Laaga Chunri Mein Daag"). Thus, all the four IFM based songs are applicable as the alternative to the ICM based song "Laaga Chunri Mein Daag." However, out of these four

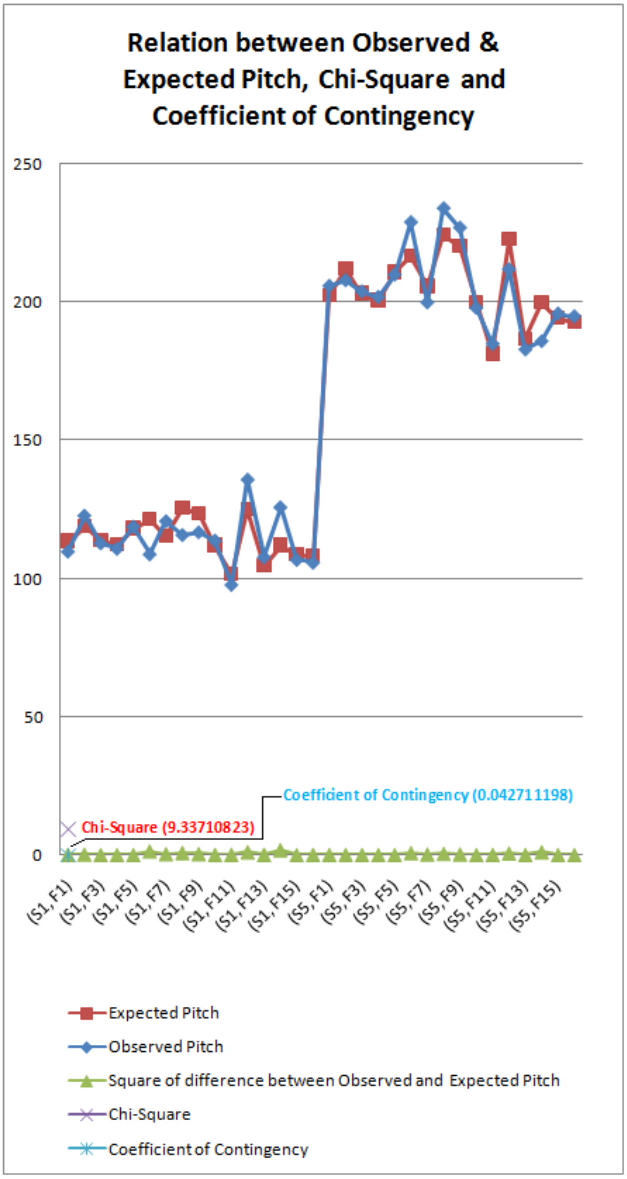

FIGURE 18. Comparison between Song 1 and Song 5 with respect to observed frequency and expected frequency.

TABLE 19. Computation of song similarity.

Compare	Mean Similarity % (A)	Standard Deviation Similarity % (B)	Song Similarity % using Correlation Coefficient (C)
Song (1,1)	100	100	100
Song (1,2)	55.9262	82.7096	72.40924
Song (1,3)	65.5347	87.3243	71.44741
Song (1,4)	83.7016	96.2287	78.60254
Song (1,5)	78.0493	97.8049	73.84429

IFM based songs the Song 4 (that is ''Oh Jeebon re'') of IFM database, may be considered as the best alternative.

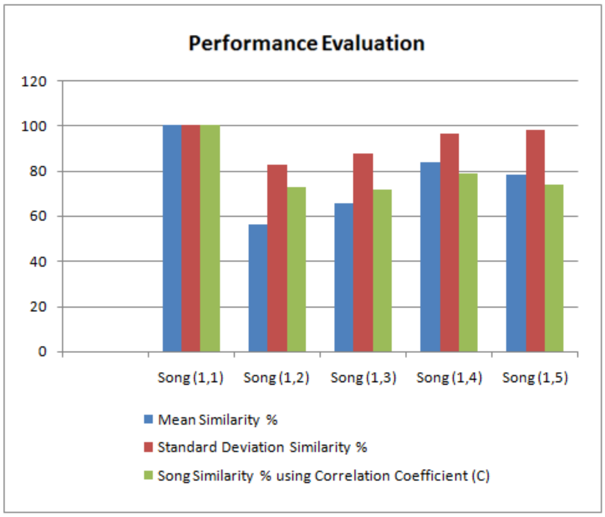

FIGURE 19. Song pattern similarity between (Song 1, Song 1), (Song 1, Song 2), (Song 1, Song 3), (Song 1, Song 4), and (Song 1, Song 5).

V. CONCLUSION AND FUTURE SCOPE

In this paper, an algorithm has been proposed that can identify similar music patterns based on the statistical measure like Correlation Coefficient. A mobile app has also been developed that implements the proposed algorithm to identify the alternate songs for Indian Classical Music (ICM) based songs, from a pool of Indian Folk Music (IFM). Rigorous experiments have been carried out and results are presented in this paper to identify the alternate songs, algorithmically.

Correlation Coefficient is one of the most suitable parameters to calculate the similarities between two different song samples. If computed value of Correlation Coefficient is near to +1, it indicates that the two song structures are similar to each other, and otherwise, it indicates presence of a certain percentage of similarity.

Two other similarity measures used for sound analysis, namely, Mean Similarity and Standard Deviation Similarity have also been explored for determining similarity levels between two input songs.

The goal of this work is to develop a methodology to identify similar songs in terms of their corresponding raga contents. Such a methodology may be applicable in the broad areas of music information retrieval (MIR). An application of such a method may be found in recommending an alternate but similar song to a standard song having well-known therapy capability or healing power. Based on the similarity value of two songs determined by the proposed method, it may be decided to replace one song by the other for music therapy like applications.

In future, rigorous experiments shall be carried out to measure the actual impact of the alternate songs identified by the proposed method in terms of their therapy capabilities, so that alternate music therapy can also be applied to the prospective users. These alternate songs are planned to be picked up from IFM like Goalparia Lokgeet, Kamrupia Lokgeet and Boul Geet.

ANNEXURE A
LIST OF VARIABLES WITH CORRESPONDING SIGNIFICANCE

Variable Names	Significance
PD	Pitch Density
NP	Number of distinct Pitches in the track
AP	Number of All distinct Pitches in MIDI standard
PE	Pitch Entropy
Nj	Total number of notes with the corresponding pitch in the representative track
T	Total number of notes in the representative track
GWi	Weight of music group
TWj	Weight of the transaction Tj
MOj,I	Number of music objects which belongs to music group Gi in transaction Tj
S_1F_i	Total Pitch value of individual note of Song 1
S_1f_i	Frequency of individual note of Song1
S_1o_i	Occurrence of individual note of Song 1
S_2F_i	Total Pitch value of individual note of Song 2
S_2f_i	Frequency of individual note of Song 2
S_2o_i	Occurrence of individual note of Song 2
$\overline{S_1F_i}$	Mean of S_1F_i
$\overline{S_2F_i}$	Mean of S_2F_i
SoS	Sum of Square
OF(S1)	Observed Pitch Frequency of Song 1
OF(S2)	Observed Pitch Frequency of Song 2
EF(S1)	Expected Pitch Frequency of Song 1
EF(S2)	Expected Pitch Frequency of Song 2
$(EF(S_i), f_j)$	Expected Frequencies computed with respect to Observed Frequencies
χ^2	Chi-Square
O	Observed Frequency
F	Expected Frequency
C	Coefficient of Contingency
N	Total Population
df	Degree of Freedom
r	Number of rows
c	Total population
S_3f_i	Pitch frequency of Song 3
S_3o_i	Pitch occurrence of Song 3
S_4f_i	Pitch frequency of Song 4
S_4o_i	Pitch occurrence of Song 4
S_5f_i	Pitch frequency of Song 5
S_5o_i	Pitch occurrence of Song 5

ANNEXURE B
DATA SET DESCRIPTION

The data set (song) has been created using the following features of ICM.

1. Thaat (Raga Origin): These are known as Raga origin which consists of a set of ragas. Ragas are organized in terms of the thaats. Some of the thhats are - Kalyan, Bhairav, Kafi, Asavari, Bilabal, Khamaj, Bhairavi, Purbi and Torhi etc.
2. Raga: Ragas are the backbone of ICM. It is the combinations of different note structures for different music compositions that are providing different melodies to music.
3. Notes: Notes can be a beat or combinations of beats.
4. Notation: Combination or series of different notes that indicate various aspects of how a piece of music is to be performed.
5. Pitch: Pitch is the number of times a musical sound wave can repeat in one second. It can be measured in Hz.
6. Shruti (Microtones): Shrutis ordinarily refers to the frequency of notes which means it is a group of frequencies with different amplitude levels. Therefore, the note frequencies which have the maximum amplitude level are known as Shruti. In ICM, there are three types of Shruti-Systems. They are: 12 Shruti-System, 16 Shruti-System, and 22 Shruti-System.

Thus the data set used in this work is totally based on different characteristics of ICM.

REFERENCES

[1] M. A. Casey, R. Veltkamp, M. Goto, M. Leman, C. Rhodes, and M. Slaney, "Content-based music information retrieval: Current directions and future challenges," *Proc. IEEE*, vol. 96, no. 4, pp. 668–696, Apr. 2008.

[2] K. Gurjar and Y.-S. Moon, "A comparative analysis of music similarity measures in music information retrieval systems," *J. Inf. Process. Syst.*, vol. 14, no. 1, pp. 32–55, 2018.
[3] M. Müller, P. W. Daniel Ellis, A. Klapuri, and G. Richard, "Signal processing for music analysis," *IEEE J. Sel. Topics Signal Process.*, vol. 5, no. 6, pp. 1–23, Oct. 2011.
[4] H. Ning and Q. Li, "Personalized music recommendation simulation based on improved collaborative filtering algorithm," *Complexity*, vol. 2020, pp. 1–11, Dec. 2020.
[5] F. Falcão, N. Andrade, F. Figueiredo, D. Silva, and F. Morais, "Measuring song disruption in song similarity networks," in *Proc. Music Inf. Retr. Conf.*, 2020, pp. 1–8.
[6] V. Verma, "Automatic mood classification of Indian popular music," *Int. J. Res. Applier Sci. Eng. Technol.*, vol. 5, no. 6, pp. 2133–2144, 2017.
[7] A. Ujlambkar, O. Upadhye, A. Deshpande, and G. Suryawanshi, "Mood based music categorization system for bollywood music," *Int. J. Adv. Comput. Res.*, vol. 4, no. 1, pp. 223–230, 2014.
[8] M. Casey and M. Slaney, "The importance of sequences in musical similarity," in *Proc. IEEE Int. Conf. Acoust. Speed Signal Process.*, Toulouse, France, May 2006, pp. 1–4.
[9] A. Kornstädt, "Themefinder: A web-based melodic search tool," in *Melodic Similarity: Concepts, Procedures, and Applications, Computing in Musicology*, vol. 11, W. Hewlett and E. Selfridge-Field, Eds. Cambridge, MA, USA: MIT Press, 1998.
[10] P. Sriram, "A carnatic music primer," Carnatic Music Assoc. North Amer., Ridgewood Ave, Paramus, NJ, USA, Tech. Rep. 375, 1990.
[11] J. Vasudha, G. Iyshwarya, A. T. Selvi, S. Iniya, and G. Jeyakumar, "Application of computer-aided music composition in music therapy," *Int. J. Innov., Manage. Technol.*, vol. 2, no. 1, pp. 55–57, Feb. 2011.
[12] G. K. Koduri and B. Indurkhya, "A behavioral study of emotions in south Indian classical music and its implications in music recommendation systems," in *Proc. ACM Workshop Social, Adapt. Personalized Multimedia Interact. Access (SAPMIA'10)*, 2010, pp. 55–60.
[13] J. Erkkila, O. Lartillot, G. Luck, K. Rikkila, and P. Toiviainen, "Intelligent music systems in music therapy," *Music Therapy Today*, vol. 5, pp. 1–21, Nov. 2004.
[14] S. Bashetti, N. Kundoor, K. V. Desai, K. N. Radha, and A. V. Bhongir, "Indian music therapy: Could it be helpful in the management of mental," *Int. J. Med. Res. Health Sci.*, vol. 3, no. 2, pp. 354–357, 2014.
[15] *Raga Therapy*. Accessed: Jul. 17, 2021. [Online]. Available: http://www.pilu.in/raga-therapy.html
[16] J.-H. Su, H.-H. Yeh, P. S. Yu, and V. S. Tseng, "Music recommendation using content and context information mining," *IEEE Intell. Syst.*, vol. 25, no. 1, pp. 16–26, Jan. 2010.
[17] X. Wang, D. Rosenblum, and Y. Wang, "Context-aware mobile music recommendation for daily activities," in *Proc. 20th ACM Int. Conf. Multimedia (MM)*, 2012, pp. 99–108.
[18] B. Adriano, M. A. Davide, H. Goffredo, and L. L. Andrea, "Formalizing Schoenberg's fundamentals of musical composition through Petri nets," in *Proc. 15th Sound Music Comput. Conf. (SMC)*, Limassol, Cyprus, Jul. 2018, pp. 254–258.
[19] S. Chakrabarty, M. R. Islam, and H. K. Debsharma, "An approach towards the modeling of pattern similarity in music using statistical measures," in *Proc. 5th Int. Conf. Parallel, Distrib. Grid Comput. (PDGC)*, 2018, pp. 436–441, doi: 10.1109/PDGC.2018.8745827.
[20] S. Chakrabarty, B. Sangeeta, M. R. Islam, and K. D. S. Hiren, "Context aware song recommendation system," *Proc. 3rd Nat. Conf. Commun., Cloud, Big Data (CCB)*, 2018, pp. 157–165.
[21] A. Vsevolod and A. Alexey, "Genetic algorithms for music variation on genom platform," in *Proc. 9th Int. Conf. Theory Appl. Soft Comput., Words Perception (ICSCCW)*, Budapest, Hungary, Aug. 2017, pp. 24–25.
[22] S. Chakrabarty, M. R. Islam, and D. De, "Modelling of song pattern similarity using coefficient of variance," *Int. J. Comput. Sci. Inf. Secur.*, pp. 388–394, vol. 15, no. 1, pp. 388–394, 2017.
[23] R. Samarjit, C. Sudipta, and D. Debashis, "Time-based raga recommendation and information retrieval of musical patterns in Indian classical music using neural networks," *IAES Int. J. Artif. Intell.*, vol. 6, no. 1, pp. 33–48, 2017.
[24] C. Sudipta, R. Samarjit, D. Debashis, S. Bhattacharyya, H. Bhaumik, S. De, and G. Klepac, *Handbook of Research on Intelligent Analysis of Multimedia information (Hardcover)* (Time-Slot Based Intelligent Music Recommender in Indian Music). Hershey, PA, USA: IGI Global, 2016, ch. 12.
[25] S. Chakrabarty, G. Karmakar, M. R. Islam, and D. De, "Reckoning of music rhythm density and complexity through mathematical measures," in *Advanced Computational and Communication Paradigms* (Lecture Notes in Electrical Engineering), vol. 475, S. Bhattacharyya, T. Gandhi, K. Sharma, and P. Dutta, Eds. Singapore: Springer, 2017, pp. 387–394, doi: 10.1007/978-981-10-8240-5_43.
[26] S. Chakrabarty, S. Roy, and D. De, "A foremost survey on state-of-the-art computational music research," in *Proc. Int. Sci. Congr. Assoc.*, Indore, India, 2015, pp. 16–25.
[27] H.-C. Chen and L. P. A. Chen, "A music recommendation system based on music and user grouping," *J. Intell. Inf. Syst.*, vol. 24, pp. 2–3, pp. 113–132, 2005.
[28] *Table: Chi-Square Probabilities*. Accessed: Aug. 11, 2021. [Online]. Available: https://people.richland.edu/james/lecture/m170/tbl-chi.html

SUDIPTA CHAKRABARTY (Member, IEEE) received the M.Tech. degree in information technology from Bengal Engineering and Science University, Shibpur (presently known as IIEST). He is currently pursuing the Ph.D. degree with the Department of Information Technology, Sikkim Manipal Institute of Technology (SMIT), a constituent unit of Sikkim Manipal University (SMU). He is also working as an Assistant Professor in Techno India, Salt Lake at the Department of Master of Computer Application, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), formerly known as the West Bengal University of Technology (WBUT). He has published three research articles in international journals, more than 20 research papers in international conferences, one book chapter, and four reference books. His research interests include pattern recognition using soft computing, optimization techniques, computational musicology, and statistical modeling.

RUHUL ISLAM received the B.E. degree in CSE from VTU, Belgaum, the M.Tech. degree in IT from SMIT, and the Ph.D. degree in CSE from SNU, India. He is currently with Cloud Shine Global LLP, as an IT Consultant (Band A), and he is working on a project for which Oracle India Pvt. Ltd., is the client. His research areas include cloud computing, wireless networks, 4G security, mobile ad hoc networking, and pattern recognition.

EMIL PRICOP (Member, IEEE) is currently an Associate Professor with the Department of Automatic Control, Computers and Electronics, Petroleum-Gas University of Ploiesti, Romania, where he is also the Head, since February 2020. His research interests include cyber security, focusing on industrial control system security, personal identification methods (biometrics and RFID), and Industry 4.0 technologies. In addition, he is currently researching machine learning applications in cyber security. Also, he is the Chairperson and an Initiator of the International Workshop on Systems Safety & Security.

HIREN KUMAR DEVA SARMA (Member, IEEE) received the B.E. degree in mechanical engineering from Assam Engineering College, in 1998, the M.Tech. degree in information technology from Tezpur University, in 2000, and the Ph.D. degree from the Department of Computer Science and Engineering, Jadavpur University, in 2013. He is currently a Professor (Guest) with the Department of Computer Science and Engineering, SRM University Andhra Pradesh (SRM AP). He has published more than 80 research papers in different international journals and referred international and national conferences of repute. He has coauthored three books (reference) and also co-edited one book volume and five conference proceedings. His current research interests include wireless communication, cognitive radio networks, distributed computing, and computational musicology. He was a recipient of the Young Scientist Award from the International Union of Radio Science (URSI) in the XVIII General Assembly 2005, held at New Delhi, India.