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SOFT COMPUTING FOR MUSIC ANALYTICS

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Abstract— **Soft computing is recently developed branch of computing focusing on tolerance in the computation to model everyday problems with natural uncertainty built in. Music analytics is a multidisciplinary field with wide applications in computational music. This paper covers main components of soft computing as fuzzy logic, neural networks and evolutionary computing and their applications in the domain of music analytics. Many applications such as music recommendation, similarity, classification, composition etc. have inherent uncertainty and soft computing plays major role in modeling it. Sample application to model music similarity using fuzzy logic is presented.**

Keywords— **Soft Computing, Music analytics, Pattern Recognition, Computational Music**

I. INTRODUCTION

Soft computing deals with acceptance for imprecision, uncertainty and partial truth to ultimately simulate human brain functioning as closely as possible. Soft Computing involves various fields such as neural networks, fuzzy logic, Evolutionary computing as shown in Fig.1. Hybrid solutions with combination of various techniques are also proposed to simulate and solve specific problems. Soft computing attempts to simulate human perceptions and our decision making process.

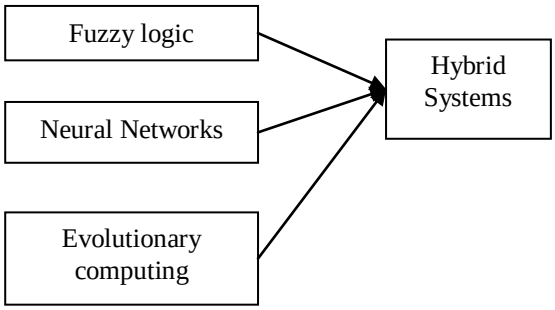

Fig.1 Soft Computing

Music analytics is a field of musicology which includes wide range of applications from generation of music, analysis, perception study etc. Automatic music processing using computer algorithms is prevailing since last many years. Benchmark used for performance evaluation of such systems is generally human decision making process. Soft computing techniques are more suitable for music processing as they attempt to model human thinking and analyzing process.

Soft computing techniques applied to musical processing include modeling of music composition, our perception and user modeling, recognizing different musical aspects, understood and respond with emotional feelings generated or tapping or dancing etc. Music similarity is generally subjective and has inherent fuzziness. Fuzzy soft computing approach is more suitable for modeling similarity.

II. BACKGROUND

Although Soft computing terminology was existed since 1980's, it became formal branch of computing since 1990s due to major contribution by Prof. Zadeh in fuzzy logic (1996). Hard computing deals with precision and accurate solutions whereas soft computing deals with acceptance for impression, uncertainty and partial truth to ultimately simulate human brain functioning as closely as possible. Soft computing attempts to simulate human perceptions and our decision making process.

Humans have very good perceptional abilities in terms of interpreting the data, information or any situation and take appropriate decisions. Scientist are working on "How our brain works?" to understand and simulate the systems in robots to have human like behavior. Pinker (1999) describes the process as computation view of mind as a cognitive process happening and kind of adaptations that the human brain possesses.

A simple example of soft computing can be the way one apply the brakes while driving the vehicle when one sight some obstacle on the road. We estimate our speed, distance from object, direction etc. and take decision to apply heavy or soft brakes and/or change direction in order to avoid any collision. We take such decisions without actually calculating distance or checking our actual speed or checking how much pressure we should apply on brakes. Certain approximations are done and decision is taken in fraction of second. Here our objective is to avoid collision and exact pressure one applies or exact distance from object i.e. precision is of less importance.

Many such situations exist in our day today life where precision is of less importance but end result matters most.

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Soft computing attempts to model such situations and different soft computing techniques are applied to have machine behave like humans. Our brain mechanism and decision making process is very complex and we do have elements such as emotions, anticipation or intuition etc. Modeling such parameters is very difficult as they themselves are very difficult to define precisely.

III. MUSIC ANALYTICS

Music analytics is a field of Computer musicology to analyze different musical parameters by machine. Music analytics is a multidisciplinary field which incorporates various aspects such as music acoustics, digital signal processing, psychology, soft computing or artificial intelligence, cognitive science etc.
One listen to different music and classify genre, detect singer or instrument, recognize rhythm, find the scale or raga in case of classical music, observe different emotions and so on. We do have inherent capabilities to identify different patterns and recognize such parameters. In order to simulate them in machine, we need to know how our sensory mechanism works for the stimuli of music and our processing method of this information. Music analytics involves development of applications using music processing, feature engineering, pattern recognition as shown in fig. 2.

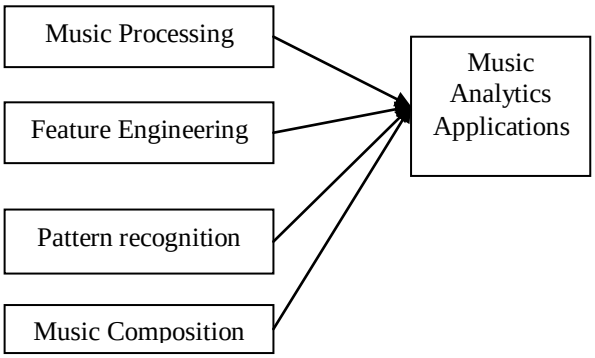

Fig. 2 Music analytics

Music perception can be different for novice or trained listeners. Seasoned or trained listeners are likely to notice the music in more details and possibly can appreciate it more than novice listeners. Familiarity towards specific music, cultural background, individual brought up, musical training, musical liking etc. have an impact on persons and have a large impact on music perception by individuals. Despite of presence of individual perceptions, common perceptions do prevail in musical analysis. Subjectivity of individuals is more on aesthetic parts such as liking of music or awareness or expertise in music.
Different signal processing techniques are applied to music signal for finding parameters such as timbre identification (instrument or singer detection), bit finder (rhythm identification), and pitch tracking with frequency (scale recognition) and so on. Feature values of music are extracted using signal processing of music signal. These feature values are used as an input to algorithms in music analytics for further analysis.
Music analytics for music industry can have varied applications. Ramesh, V.M. (2008) explored music analysis for notation identification from the audio data. Music recommendation by analyzing user preferences is one of the most promising applications. Celma (2010) modeled the user's perceived quality of recommendation with main theme as similarity and proposed that the recommendation system should propose novel and relevant music. Van den Oord et. al. (2013) focused on cold start problem in recommendation when user profile is unknown and proposed the use of deep convolutional neural network learning for sensible music recommendations. Another serious issue for music industry is piracy. Music as a service is proposed as a possible alternative by Dorr et. al. (2013) and proposed a business model Maas. A detailed survey on music sales and music streaming done by Hiller (2016) showed that YouTube dominated the music distribution more than streaming services by spotify, itunes radio, Google play music etc. It seems to indicate that top selling albums are getting benefit from the promotion through free online availability. Recent report by Clark (2016) estimates as much as 95% music is downloaded from innovative illegally downloading websites and suggests the need as effective measures to prevent it. Hyrkas et. al. (2016) proposed a music analytics platform as musicDB to predict future trends.
The objective of this paper is to explore possible use of soft computing techniques in music analytics. Various applications in music analytics are being explained with the use of soft computing techniques used effectively to solve specific problems.

IV. SOFT COMPUTING FOR MUSIC ANALYTICS

Soft computing techniques are more suitable for music processing as music processing itself is not precise for humans. Remember specific tune such as storing a specific musical pattern is our brain's neural mechanism. The tune may not be stored precisely. One can retrieve the tune and/or can find the similarity in case of similarly sounding tunes. Such similarity analysis is itself fuzzy in nature and fuzziness or imprecision is an important aspect in soft computing.
Soft computing has wide applications for musicians such as analysis/synthesis of sound, making responsive instrument for accompaniment for singers, restoring old recordings, transcribing sound to musical notations, analysis of musical performance, online training etc. Other applications can be data compression, music retrieval based on musical contents or parameters, classification of music based on parameters such as genre or singers or rhythms or scales etc.
ANN (Artificial neural network) system is an attempt to model our brain neuron architecture. One can use supervised,

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unsupervised, semi-supervised or reinforcement learning techniques to train the neural network and simulate our brain. In case of retrieval of music on web where the search space is very large GA's (Genetic Algorithms) can be useful for acceptable solutions in real time.

Different hybrid soft computing techniques can be useful for applications, when there is a need of utilizing advantages of multiple soft computing techniques. Neuro-fuzzy hybrid system or genetic neuro hybrid techniques are few examples of such hybrid techniques in which combination of different soft computing techniques is used to take advantages of both in order to solve specific problem. In this paper, we have attempted to analyze different soft computing techniques and their possible use related to music analytics.

A. Fuzzy logic for music analytics -

Despite of the fact that fuzzy logic has gained tremendous success in wide applications, its potential is probably not fully utilized for music processing applications. Fuzzy logic deals with membership function with support in the range [0, 1]. It is different from Boolean logic which has only 2 states as 1 and 0 or true and false. In fuzzy logic, support value can be between 0 and 1 including both. It becomes easier to model natural problems with uncertainty or partial truth using fuzzy logic. As an example, if we consider music similarity between two musical pieces, the possible outcomes can be not similar, somewhat similar, exactly similar or highly correlated etc. This pattern can be modeled using fuzzy logic with possible support with membership values. Fuzzy logic implications in music domain can be many and many researchers have explored different research directions in music processing using fuzzy logic.

Music emotion classification using fuzzy logic proposed by Yi-Hsuan Yang et.al. (2006) based on Thayer's model for mood presented with valence and arousal showed that fuzzy nearest mean classification approach performs better than conventional approach and incorporate the subjective nature of emotion perception. Preliminary results for music genre classification using fuzzy rule based system were presented by Francisco Fernandez (2011) for two genres as jaaz and classical music. A real time emotion based music accompaniment system using fuzzy logic controller proposed by Ping-huan kuo et. al. (2015). Fuzzy cognitive maps used by Maftei et.al. (2016)for identifying critical success factors in online music streaming. Musical tuning using fuzzy logic for different musical scales such as equal temperament, Pythagorean etc. proposed by Teresa Leon and Vicente Liern (2010). Velankar et. al. (2018) proposed use of fuzzy logic in query by humming for music retrieval by approximating pitch in user queries. These different directions of using fuzzy logic for music processing exhibits the use of fuzzy logic in music analytics and one can expect wide use of fuzzy logic in the development of systems in the future.

B. Neural networks for music analytics –

Neural networks are a directed graph of artificial neurons as nodes and edges representing weights. Different activation functions are used to activate neurons and produce outputs. A simple neural network can be shown as in Fig. 3. Here a and b are the inputs, w_1 and w_2 are the weights associated with edges, z is the output, X_1 and X_2 represent input layer, Y_1 represents output layer. Input to Y_1 is X_1. $W_1 + X_2 . W_2$ and z i.e. output is determined by the activation function used at Y_1. This representation is basic representation and there may be multiple input and output nodes. Intermediate or hidden layers are also added in the neural network to model the non-linearity for classification. Various variants are possible in neural networks with simple feed forword neural network without feedback or neural network with feedback i.e. recurrent network etc.

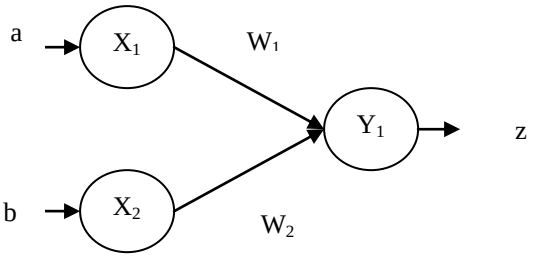

Fig. 3 Simple neural network

Neural networks are first trained using some learning mechanism such as supervised, unsupervised or reinforcement learning strategies for different input patterns. They are further tested for unseen samples to test the accuracies. Neural networks are used for various applications in music analytics. Sigtia et. al. (2016) presented a supervised neural network model for polyphonic music transcription. Convolutional recurrent neural network was proposed by Choi et.al. (2016)for music tagging and automatic classification. A pre-trained convolutional neural network was designed and tested by Dieleman et. al. (2011)for artist recognition, musical key identification and genre recognition. Feature Engineering and feature generation for different music analytics tasks are covered in detail by Velankar, M., & Kulkarni, P. (2018). Feature learning using deep belief network by Hamel et.al. (2010) showed promising results and motivation to apply deep learning for different music information retrieval tasks. Use of neural networks for music composition by prediction was proposed by Mozer (1994) with exploration of psychoacoustics and multi-scale processing. Similar work using LSTM recurrent neural networks for music composition was performed by D. Eck (2002). Makris et.al. (2017) proposed a system with the combination of LSTM and feed forward neural network for conditional rhythm composition. Hit song prediction using convolutional neural networks was

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proposed by Yang et. al. (2017). Many such varied applications in music analytics are proposed by researchers using neural networks.

C. Evolutionary Computing for music analytics –

Evolutionary computing is a branch of soft computing inspired by natural phenomenon. Different algorithms based on nature are proposed to utilize the power of soft computing like genetic algorithms, ant colony optimization, particle swarm optimization etc.

A behavior-inspired evolutionary algorithm, harmony search was suggested by Geem et. al. (2007) for music composition. A multi-criteria Ant colony optimization algorithm was proposed by Mocholi et. al. (2012). Bang (2013) proposed an approach using genetic programming for emotion classification. Combination of genetic programming and genetic algorithm proposed by Tokui et. al. (2000) for music composition. A novel approach proposed using genetic programming and uses a tree-based domain model for music compositions by Hofmann (2015). PSO automatically optimizes the performance quality of music recommender systems using a swarm intelligence perspective as it contains the best search efficiency as per the experimentation done by Katarya (2018). A system for recognizing emotional content in music based on particle swarm optimization (PSO)-based fuzzy hyper-rectangular composite neural networks by Chin et. al. (2017). This is an example of hybrid approach using different elements of soft computing. Similar such research directions proposed by researchers to use different evolutionary computing tools in the domain of music analytics.

V. MODELING MUSIC SIMILARITY

Music similarity is a hard computational problem considering different musical facets such as timbre, tune, rhythm, genre, mood etc. Velankar et. al. (2015) proposed a system to model melodic similarity using human perception and music synthesis approach. Human perception can be modeled using fuzzy logic in soft computing to model similarity. Similarity can be presented in the linguistic manner as not similar, somewhat similar, very similar, exactly same etc. This linguistic terminology is best suitable for fuzzy logic. Fig. 4 shows the modeling of music similarity using fuzzy logic. Here X axis represents the similarity parameter as x and Y axis represents the support for it as a membership function of x i.e. $\mu(x)$. Not similar is mapped to $\mu(x) = 0$ and exactly similar is mapped to $\mu(x) = 1$. Fuzzification of the similarity is done for the linguistic terms such as somewhat similar or very much similar to represent it within the range from 0 to 1 value of the membership function excluding the limits. Higher values of this function $\mu(x)$ represents more similarity and lower values represents less similarity. This fuzzy modeling of similarity is useful to represent similarity in numerical form for further computation and processing. Liao and Xu (2015) proposed hesitant fuzzy linguistic term sets to raise the flexibility of extracting the linguistic information.

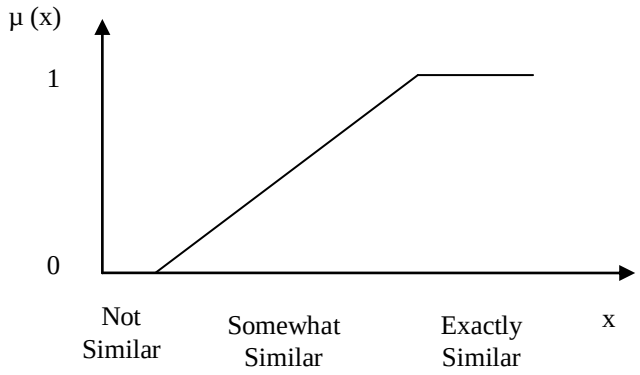

Fig. 4 Fuzzification of music similarity

Use of fuzzy sets in cognitive and decision making process for pattern perception is explained in detail by Zadeh et. al (1994, 2015) Any music analytics application with perception or human cognition can be modeled effectively using fuzzy logic.

VI. CONCLUSION

Soft computing has variety of applications in music analytics. Vagueness or imprecision is the need in to be modeled in some of the applications where fuzzy logic plays a major role. Inherent musical pattern recognition is another challenging task in music analytics and this can be achieved successfully by training neural networks. Tasks like automatic music composition are well suited for genetic algorithms where different tunes can be generated. However evaluating the good music is a challenge considering the fact that it is highly subjective.

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