iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: II Month of publication: February 2025

DOI: https://doi.org/10.22214/ijraset.2025.67155

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue II Feb 2025- Available at www.ijraset.com

Review of AI in Indian Classical Music

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Abstract: The Artificial Intelligence (AI) wave has revolutionised all industries including the music industry. AI is now being leveraged in the music world in ways that could not have been imagined earlier. Music generation, music retrieval, music production are just some of the areas in which AI has started making its mark. There have been significant efforts in literature to review and bring out the impact of AI in Western music. Indian classical music forms are extremely distinct from Western music in terms of ornamentation, emotional depth, and structure. This makes it difficult for the established AI methods in Western music from being leveraged in Indian classical music. Though there have been some efforts made to use AI tools in Indian classical music, there has not been a comprehensive survey of the same. In this paper, we attempt to provide a systematic review of use of AI specifically in the Indian classical music forms of Hindustani and Carnatic music. We cover the three fields of music generation, music retrieval, music production and look into key technologies, datasets and established applications. Additionally, we bring out current challenges, research gaps, and future directions to advance AI-driven innovations in this domain.
Keywords: Indian classical music, Hindustani, Carnatic, Music Generation, Music Retrieval.

I. INTRODUCTION

In recent years we have seen a rapidly increasing interest in the use of Artificial Intelligence (AI) technologies in the field of music. AI technology has been experimented in various ways in the music industry, be it for music generation [36]-[37], composition, production [31] or vocalization [45]. Mechanisms of providing music based on user preferences in the form of music recommendation systems are all driven by AI technologies [41]. Additionally, there has also been a growth of commercial products which offer these facilities at competitive prices. Most of these tools and technologies have been directed towards the Western music industry which has a very high consumer base.

India is the cradle of two traditional classical music families namely Hindustani and Carnatic music. Hindustani music finds resonance in North India while Carnatic music is practiced predominantly in South India. The two genres of music have a rich history and a vast collection of music. The use of AI on Indian music has been on a limited scale [25]. Indian classical music forms are extremely distinct from Western Music in terms of ornamentation, emotional depth, and structure. This makes it difficult for the established AI methods in Western music from being leveraged in Indian classical music.

In this paper we will provide a systematic review of the advancements of AI specifically in Indian Classical Music (ICM). We cover the three fields of music generation, music retrieval, music production and look into key technologies, datasets and established applications. Over the years, several review papers have been published, most of them are directed towards Western music [31], [2], [26], [28]. Some survey papers have looked into Indian classical music but with a focus towards raga generation [14], raga identification [46] etc. We found that there was a requirement for a comprehensive survey of recent works in the field of AI towards Indian classical music, spanning across the activities of music generation, production, and retrieval. We attempt to address this requirement in this review paper.

The main contributions of this review are (1) A detailed summary framework that systematically categorizes and compares different technological approaches, including helping readers better understand the full spectrum of technologies in the field; (2) offering an extensive survey of current literature, covering topics such as datasets, and open source APIs, providing a broad reference for related research; (3) conducting a detailed analysis of the practical impact of AI in music generation, retrieval and production, specifically targeted towards Indian classical music.

In this paper, we cover a review of 37 papers. The music topics covered and the year wise distribution of the papers surveyed under the topics are shown in **Error! Reference source not found.** and **Error! Reference source not found.** respectively. Figure 2 does not include the references for music production as we have found very limited number of papers towards the same. In the following section, we give a brief introduction to Indian classical music families of Hindustani and Carnatic. This is followed by Sections on music generation, music retrieval and music production. We briefly cover the datasets and the music APIs which are available as

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue II Feb 2025- Available at www.ijraset.com

open-source for Indian classical music in the Sections VI & VII. We summarise the existing challenges in Section VIII and propose further research directions in the final section.

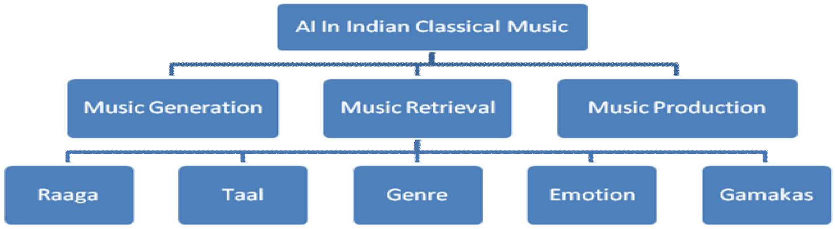

Fig. 1 Visualisation of the musical topics covered in this paper

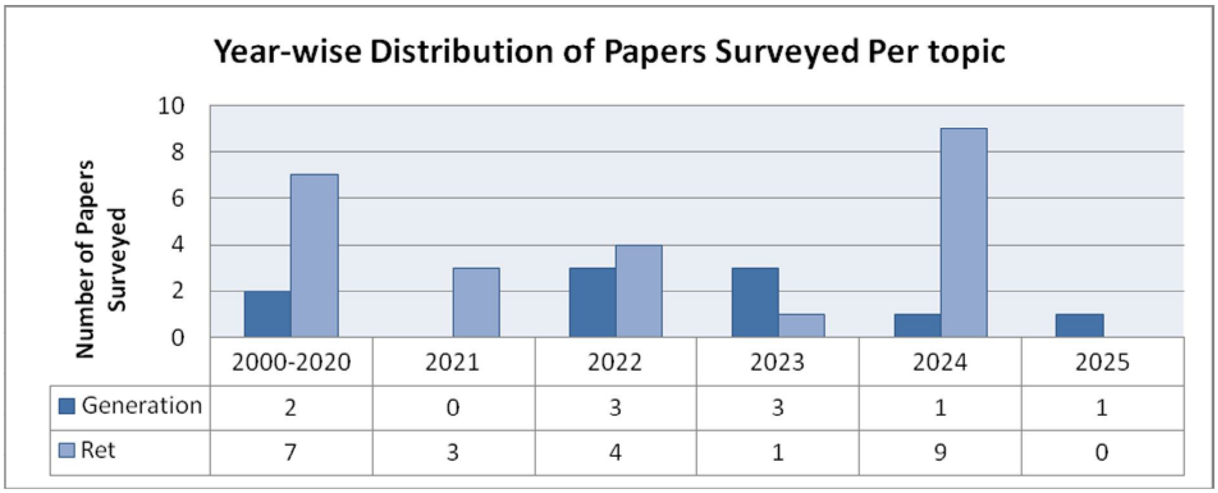

Fig. 2 Graph showing year wise distribution of papers surveyed per topic. (Music Generation and Music Retrieval)

II. BRIEF INTRODUCTION TO INDIAN CLASSICAL MUSIC FORMS

Rooted in spirituality, classical music in India is a profound art form that reflects the country's heritage. Indian music is said to be rooted in the Vedas, specifically Samaveda. Initially only three Swaras were evolved and used for the musical recitation and chanting of the Samaveda. This was then further evolved to the current spectrum of twelve swaras. The current forms of Indian classical music have imbibed influences from Persian music [19]. Two major forms of Indian classical music emerged during 14^{th} to 18^{th} century namely the Hindustani music and the Carnatic music. There is a third subgenre of Indian classical music namely, the Odissi music. In this paper, we will be restricting our work to Hindustani and Carnatic music forms only.

Hindustani music is found predominantly in the northern parts of India. Various styles of singing in Hindustani music are Dhrupad, Khayal, Thumri, Tarana and Tappa. Carnatic music, is commonly associated with South India [50]

While they differ in their roots, structure and style, they also share similarities [48]

1) Both are based on Raagas and Thaalas
2) Both make use of exactly 22 Shrutis (microtones) for nuances and subtle expressions.
3) Both have twelve notes in a saptak(scale). In either form, the raaga serves as the core or foundation. [10]

A Raaga is defined as a melodic structure with fixed notes and a set of rules that characterize a particular mood which is conveyed through performance. While the raaga is the melodic framework of Indian music, Thaala is the rhythmic component. Raagas are based on Swaras. There are 7 Swaras- Sa, Ri, Ga, Ma, Pa, Da and Ni. There are 8 major thaalas namely, Aadi, Rupakam, Dhruva, Triputa, Jhampa, Matya, each having different beat durations. Together, Raagas and Thaalas beautifully complement each other in creating a memorable musical experience.

III. MUSIC GENERATION

Music, at its core, is an expression of human feelings and emotions. With its blend of creativity and technical structure, it is hard to comprehend AI to produce something that appeases the soul and not merely imitate pre-existing music. Further, Indian music, with its complexities and subtle nuances through raagas and shrutis, makes it harder for AI systems to perfectly capture its essence. Two aspects of Indian music need to be met by the AI systems- the raaga and the thaala- the melodic and rhythmic framework.

Western music has become a fertile ground with various approaches being explored for Automatic Music Generation (AMG). From the first computer-composed piece 'Illiac Suite' in 1956 (https://distributedmuseum.illinois.edu/exhibit/illiac-suite/) to the use of generative systems to incorporate artificial intelligence in finish an incomplete symphony of Beethoven [64], the spectrum of technologies which have been attempted are diverse and range from probabilistic methods to classical optimization based approaches.

In Indian classical music, we have surveyed 10 papers towards music generation, spanning the past 10 years. **Error! Reference source not found.** brings out the top-level breakup of the approaches attempted in the field.

TABLE I
SUMMARY OF APPROACHES FOR INDIAN CLASSICAL MUSIC

Approach	Papers
Finite State Machine	[65], [15], [23].
Generative Adversarial Network	[1], [62]
Neural Network	[8]
Transformer	[17]
Recurrent Neural Network	[28], [18], [11]

A. *FSM Based Approaches*

A Finite State Machine (FSM) is defined as a system containing a set of states and sets of transitions between pairs of states. Due to a condition/action, the transition is affected which causes the respective state to be performed.

In one of the early approaches using Finite State Machines [65], the authors define a state for each rising and decaying movement for a unique raaga. It was able to generate simple raagas.

In their paper [12], the authors developed a bigram finite state machine for Carnatic music generation. The model generated note patterns that conformed to the raaga grammar.

Another approach for alapana generation in Carnatic music was made in [20]. In this paper, the authors attempted to create alapana sequences that follow a given input raaga. They used several evaluation metrics like Frechet Audio Distance, Percentage of Correct Pitches etc to compare the performance of models generated using FSM and GAN.

FSM based approaches were found to have limited scale of generation. The approaches attempted were able to demonstrate capability to generate small number of simple raagas. These were the early approaches and have now been superseded by the use of Neural Network based approaches.

B. *Neural Network Based Approaches*

In a unique attempt to incorporate the generation of music using emotions defined by the user, the authors in their work [7], experimented with the creation of a neural network capable of generating raagas and musical notations based on emotions. The authors used emotion indices for a defined song lyrics using ChatGPT-4. The emotion index was then used to generate corresponding Swaralipi (written notes to represent aural music). This was one of the few approaches which used emotions to generate music. It required comprehensive data preparation to associate emotion to raaga and then train the network to learn the same.

C. *Generative Adversarial Network (GAN) Based Approaches*

In their work [1], the authors have proposed a method of using Wasserstein GAN (WGAN) for generating Indian music. MIDI based piano music was given as an input to the WGAN trained on a dataset of Indian classical music recordings. They were able to demonstrate results which were similar to human generated music. An attempt to generate Indian classical music by leveraging the structured nature of Indian Carnatic music was made in the work [49]. The authors first prepared a dataset of melody and lyrics, which were paired together to extract features. GANs were then used on classical lyrics to compose music.

D. Transformer Based Approaches

Automatic Music Generation in Indian classical music is a comparatively underrepresented field. In their paper [17], the authors present the application of AI using deep learning to produce Indian raaga based melodies. They proposed a Raga Multi-Track Music Model(R-MMM) which was based on Multi-Track Music Machine (MMM) transformer architecture. The system takes inputs from raaga based datasets, processes the relationship between the notes and generates raaga-based music based on the given prompts and inputs within the raaga rules. They conclude that R-MMM is better suited for Raga- based music generation due to its ability to harmonize polyphonic music.

E. Recurrent Neural Network (RNN) based approaches:

In their work [28], the authors employ LSTM to automatically generate chords and note sequences from a collection of Indian songs stored as .wav files.

A novel attempt was discussed in the work [18]. The authors attempted improvised sequence generation in Hindustani music using three approaches, namely, Finite State Machine, bi-gram language model and an LSTM-RNN model. They were able to empirically conclude that the LSTM model was best suited for the generation of the sequences.

In their work [11], the authors present a unique approach which analyses and identifies emotions through webcam access and automatically translates it into a melodious piece of music associated with that particular emotion or rasa. Emotional to Music Mapping takes into consideration the Nava rasas which help in the identification of the emotions and respectively generating its appropriate melodies. The system used LSTMs and RNNs to create melodies and harmonies corresponding to their emotions.

F. Other Approaches

In the paper [61], the authors propose two methods for automatic generation of notes (swaras). The first is based on First Order Markov Models and the other based on Hidden Markov Models. The system works in two phases. In the first phase, called the Learning Phase, training examples are used by the system to learn the probability model of the chosen raaga and no hand-coded rules are required. In the second phase, called the Synthesis Phase, using the previously constructed transition table, swaras are generated for the desired raaga. Overall summarisation of the relative strengths and weaknesses of the approaches listed above is captured in Table II.

TABLE III

COMPARATIVE SUMMARISATION OF STRENGTHS AND WEAKNESSES OF APPROACHES

Approaches	Advantages	Disadvantages
FSMs	• Can produce simple and basic raagas	• Have only a limited scale of generation. • Cannot improvise
GANs	• Produces slightly more realistic raagas • Produces wide variety of raagas until the desired one is generated.	• Struggles with improvisation
RNNs	• Can capture patterns in long sequences of raagas	• Can store only temporary patterns
LSTMs	• Can capture long term dependencies and patterns	• Computationally heavy • Struggles with improvisation
Transformers	• Best at learning long raagas • Can harmonise polyphonic music	• Requires large number of datasets for training

IV. MUSIC RETRIEVAL

Music Information Retrieval is defined as “extraction and inference of meaningful features from music, indexing of music using these features, and the development of different search and retrieval schemes.” [49]. Music Retrieval is important for automatic tagging of music, retrieval of music snippets based on user query, music recommendation systems etc.

Music retrieval methods have concentrated variously on identification of thaala, raaga, rasa, gamaka. A variety of approaches have been attempted for the same with varying successes. In this section, we will look at approaches for identification, classification, prediction of Indian classical music based on different criteria. A tabular summary of the section is brought out in Table III.

TABLE III

TABULAR SUMMARY OF MUSIC RETRIEVAL

Tala Prediction	[14], [19], [16], [51], [41], [22], [4]
Raga identification	[24], [39], [21], [3], [55], [6], [42], [53]
Gamaka Identification	[44], [29]
Emotion	[45], [38], [5], [13], [60]
Genre	[62], [50], [34]

A. Tala Prediction

Among some of the early approaches, authors attempted a tree-based classifier for tabla strokes [14]. They used Decision Tree, ID3 and Random Forest as classifiers for classifying based on 31 extracted features and their means and variances. The Random Forest based approach performed better than the other two approaches.

Classical ML approaches like Support Vector Machine, Naive Bayes, Decision Tree, Random Forest and k-Nearest Neighbor classifiers were explored in the paper [19]. The authors extracted features from Hindustani music using MATLAB MIRToolbox. Decision Tree obtained an accuracy of 51.61% and Naïve Bayes obtained an accuracy of 64.16% with cross-validation.

In a distinct work [16], the authors attempted to identify a singer based on the timbre of the voice for Hindustani music, using Tanpura as the only instrument in the background. They summarized that roll off, brightness, roughness and irregularity are the four strong audio descriptors designated under the Timbre category of MIR Toolbox that plays vital role in the identification of a singer from North Indian classical music giving accuracy of identification of 96. 66%.

Among the recent works using Neural networks, in their work [51] the authors have proposed an approach for table thaala identification in Hindustani classical music. The system proposed predicts the thaala (Rhythm), using descriptors of timber such as zero cross rate, roll-off, roughness, brightness, and irregularity) . These are combined with mel-frequency cepstral coefficient to extract the audio features. Overall, 366 audio excerpts containing sound samples of 9 basic tabla strokes are used to train the system. Machine learning algorithms, multi-support vector machine, and feed-forward backpropagation neural network were used to identify the tabla strokes, and frequency of occurrence of each basic stroke was calculated. With the tabla as the percussion, they have attained an accuracy of 93.33% in thaala prediction, using the number and type of basic tabla strokes identified.

Another work in tabla thaala prediction was proposed by the authors in their paper [41]. They attempted a combination of both Feedforward Neural Networks (FNN) and Convolutional Neural Networks (CNN). This model was trained to recognize diverse features unique to tabla thaalas like Addhatrital, Ektal etc.

One of the notable works exploring the use of Deep Neural Networks (DNN) for thaala prediction was presented in the paper [22]. The authors attempted the classification of four major thaalas namely Aadi, Rupaka, MishraChapu and KhandaChapu in Carnatic music by using DNNs. They demonstrated a DNN incorporating six hidden layers with a classification accuracy of 97.50% to classify the thaalas.

In another recent work [4] the authors attempted an approach for raga recognition based on Multiple Acoustic Features (MAF) consisting of various statistical, spectral, and time domain features. Changes in intonation, timbre, prosody and pitch of the musical speech were captured in the MAF. A Deep CNN (DCNN) was used to improve the representation of the raaga sound and to provide higher order abstract level features, achieving an accuracy of 89.38% for eight raaga classifications.

B. Raaga Recognition

In Hindustani classical music tradition, raagas are classified based on Raga-Ragani and Thaat method while in Carnatic Music, raagas are classified based on Janaka and Janya method (Carnatic Music Junior Grade Text Book). We will now look into the various approaches for raaga identification for both the forms of Indian classical music.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue II Feb 2025- Available at www.ijraset.com

In their work [24], the authors have used K Nearest Neighbor (KNN) and Support Vector Machine (SVM) classifiers are used on the raaga dataset of Yaman and Bhairavi of Hindustani music to achieve classification and identification of the raaga.

In their paper [39], the authors propose a model based on Random Forest (RF) for classification of 72 Melakarta raagas. They compared it with a Support Vector Classifier (SVC) and were able to demonstrate an accuracy of 99.72% with the RF model.

In their work for automated raaga recognition [21], the authors used a combination of machine learning and deep learning techniques. For machine learning (ML) classifiers were chosen for their diverse strengths such as Logistic Regression, Support Vector Machine with a Radial Basis Function (SVM(RBF)), and XGBoost. In DL, Deep Neural Networks (DNNs) and LSTMs were employed. This was applied to two distinct raagas, Yaman and Bhairavi and achieved an impressive 97% accuracy on 10 subsets of raagas and 88.1% on the full CompMusic dataset, setting a new benchmark in raaga recognition.

There have been varied attempts of using the Convolutional Neural Network (CNN), Deep Neural Networks for Raga Prediction [3], [55], [6], [42].

A novel attempt was made to use model explainability models namely, SoundLIME and GradCAM++ for raaga identification in the paper [53]. The authors, curated a dataset for Hindustani classical music and trained a CNN-LSTM model. The model predictions were then used by the model explainability techniques to identify whether classifiers predictions align with the human understanding of the raagas.

C. Gamaka

The term gamaka itself means "ornamented note" in Sanskrit. Gamakas involve the variation of pitch of a note, using oscillations or glides between notes. Gamaka is any graceful turn, curve or cornering touch given to a single note or a group of notes, which adds emphasis to each raaga's individuality. The unique character of each raaga is given by its gamakas, making their role essential rather than decorative in Indian music.[64]

In their work [44], the authors state that in order to create a standalone raaga generator or synthesiser, it is necessary for the gamakas to be predicted based on music notations. They further try to predict gamakas in a data driven manner. The method involved transcribing a reference performance of a sparsely detailed composition into a representation that accurately captured gamaka details. Using the composition's internal consistency and the artist's stylistic choices, elaboration tables, continuity constraints, and rules for adapting gamakas to various melodic contexts were developed. Two distinct representations were utilized, and the resulting systems were evaluated by expert musicians for their acceptability, the range of variations generated, and their scope of applicability in music generation.

Similarly, an early attempt at identification of Gamakas was published in [29]. The authors used Hidden Markov Models to characterize the pitch contour. A dataset of 160 songs from different raagas were used to build and test the model.

D. Emotion Identification

Music Emotion Recognition has been attempted using various approaches for Indian classical music. In their [45], the authors have generated 40 features from MFCC for each music snippet for classification. They explored multiple classification algorithms like ANN, KNN, Naïve Bayes, Random Forest, SVM.

[38] presents a new dataset called JUMusEmoDB comprising 1600 audio clips corresponding to happy, sad, calm and anxiety emotions. Different conventional 'raaga' renditions, played on sitar and sarod, two Indian stringed instruments, were used for the audio clip generation. They proposed an ODE-Net architecture for CNN for emotion classification and instrument classification. Towards this, a nonlinear technique, Multifractal Detrended Fluctuation Analysis (MFDFA) was also applied on the musical clips to classify them on the basis of complexity values extracted from the method. Another extension of the work, [5], attempted the classification of timbres (Sitar and Sarod), emotions (happy and sad) and audience category (musician and non-musician), from Alaap renditions as input signals. Using parameters like multifractal width (MW) and asymmetry, they were able to demonstrate significant classification results. Another attempt of instrument and emotion classification using Transformer was made in the work [13]. The authors used the transformer wav2vec2.0 architecture to learn representations from audio samples of Indian classical music and classify them based on the instruments present in the examples and their emotional content. Labelled training data of three instruments, namely, the flute, sitar, and sarod, pre-classified into four emotions, anxiety, sadness, happiness, and calm, were used to train the Transformer Network.

In another work [60], the authors address the Music Emotion Recognition (MER) problem by proposing a system using Spiking Neural Network (SNN) classifier. They advocated pre-processing to convert larger audio files into smaller audio frames. Music

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue II Feb 2025- Available at www.ijraset.com

related temporal, spectral and energy features were then extracted. They were able to empirically demonstrate accuracy of 94.5% for their selected dataset.

E. Genre Identification

Another important category based on which classification of Indian classical music has been attempted, is to make an identification of a music piece as belonging to Hindustani or Carnatic music.

One of the early efforts in this direction [62], explored the use of melodic structure to distinguish between the two forms of music. They crafted features along the dimensions such as structure of a performance, aesthetics, voice production and instrumentation.

In one of the works along this line, [50], the authors attempted two approaches for implementing the classifiers. In the first approach, MFCCs were used as features for models DNN (1 Layer, 2 Layers, 3 Layers), CNN (1 Layer, 2 Layers, 3 Layers), RNN-LSTM, SVM (Sigmoid, Polynomial & Gaussian Kernel). In the second approach, a 3-channel input was created by merging features like MFCC, Spectrogram and Scalogram for models like VGG-16, CNN (1 Layer, 2 Layers, 3 Layers), ResNet-50. They were able to demonstrate that 3 Layered CNN and RNN-LSTM model performed best among all the approaches.

Another approach [34] attempted to classify morning and evening raagas using an architecture named the "1d-SRiyam" network. Time-specific characteristics that captured the emotive expressions and melodic nuances inherent in each raag was used for the classification. The authors demonstrated that 1d-SRiyam network outperformed the conventional CNN-LSTM model.

V. MUSIC PRODUCTION

Music production is the process by which music is created, recorded and manipulated. It involves processes such as mixing, mastering and blending the various instruments to create one cohesive track.

AI in Indian classical music production is a field with limited research. Existing papers focus primarily on generation and retrieval of Indian classical music. There are studies such as [25] which involve Hilber Huang transform using the Empirical Mode Decomposition technique (EDM) for pitch detection and correction, which may be later useful in music production.

NaadSadhana is an AI tool exclusive to Indian classical music used for recording, mixing and sharing tracks. It offers automatic mixing as well as over 26 instruments, 250+ Raagas. (https://www.naadsadhana.com/)

SwarShaala is another app which provides real-time pitch detection feature for practice and additionally to add audio effects such as reverb, compression, equalization, delay. (https://www.swarclassical.com/SwarShala/)

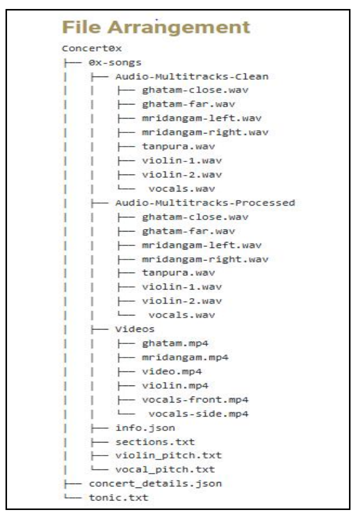

Fig. 3 Screenshot of the file structure of Sanidha dataset

VI. TOOLS AND OPEN-SOURCE PRODUCTS

There are a large number of tools and open-source products which are now available online which leverage AI to make the music journey easier for the user. These tools vary from music recommender systems to music tutors, music composer etc. In this section we will briefly cover popular tools and open-source products available for Indian classical music.

1) Swaragram [54]: The library is implemented in Python programming language and published under the GNU-GPLv3 license on github at https://github.com/yeshwantsingh/swaragram

2) Google Magenta: This is a research project exploring the role of Machine Learning in the process of creating art and music. It has mechanisms for generating note sequences which can be leveraged for generating and working with Indian Classical music.

VII. CHALLENGES OF AI IN INDIAN CLASSICAL MUSIC

Let us now look into some of the key challenges posed to AI in ICM.

1) *Lack of Improvisation:* One of the major challenges faced by AI in Indian classical music is the failure of capturing the nuances in every raaga. Both Carnatic and Hindustani music, are known for its gamakas, which is not found in Western music. Musicians improvise heavily, adding shrutis (microtones) and gamakas (ornamentation). This is hard for AI to replicate, as it is trained on rigid, structured data and it further produces predictable outputs.
2) *Variability across Musicians:* Indian classical music is deeply rooted in its culture and traditions, yet it evolves significantly, person to person, with their own interpretations and styles. The same raaga can be performed in different ways, with different rasas (emotions), and improvisational techniques. AI trained with limited datasets, may generalise the raga across all variations.
3) *Lack of Emotional Depth:* Music, a form of human expression, is deeply intertwined with emotions. Emotional depth and expressions are found to be heavily lacking in AI generated music. Indian classical music weave stories with its emotions, which AI fails to replicate, making it sound mechanical.

VIII. SUMMARY AND CONCLUSION

In this review paper, we have attempted to survey important research in the domain of Indian classical music. We have brought out the advances made in literature in the fields of music generation, music retrieval and music production.

We have also brought out the tools and open-source dataset for Carnatic and Hindustani music families. Additionally, we have also highlighted the challenges faced by AI in ICM. We have endeavoured to make it a comprehensive survey which provides any beginner in the field, an overall knowledge of the developments in the field.

There is a lot of work which needs to be done in terms of music production for Indian classical music. Through this review, we have also been able to brought out that there are rich resources in terms of datasets and APIs however, there is a pressing need for larger volume of data with richer characteristics covering further gharanas (sub-genres) in ICM. Further, most of the work in terms of instrumentation are captured in terms of Tabla, Sarod etc. ICM boasts of a plethora of rich instruments of flutes, veenas, sitar, shenai etc. Digitalisation of historically recorded audio tracks and making them available as publicly annotated datasets will strengthen AI research in the domain.

Lastly, most of the work in ICM was found in literature alone. Very few supporting codes could be found on publicly hosted sites such as Github. Public sharing of codes and generated models needs to be encouraged to further advance research in this domain.

We anticipate that future researches would be directed towards evolving AI from standalone/piecemeal system to a comprehensive end-to-end music aide for an immersive music experience.

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