Analysis and Classification of Ornaments in North Indian (Hindustani) Classical Music

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. . . to Maa, Baba & Didi

Abstract

North Indian Classical Music also known as “Hindustani Classical Music” is one of the oldest music cultures still being performed actively. Although the technologies related to Music analysis have taken a giant leap over the past few years, not much has been researched related to the expressiveness of Hindustani Classical Music.

In the current work, we have tried to analyze & classify the four major types of ornaments present in the Hindustani music viz. *Kan*, *Meend*, *Andolan* and *Gamak* based on the micro variations of the pitch information of Hindustani Music. The choice of research based on the pitch data was made because of the fact that Hindustani music is primarily monophonic and melody based, as such the “Time Series” analyses techniques could be applied to the pitch data for analysis of Hindustani Music.

AutoCorrelation Function and Dynamic Time Warping has been used to classify the four different ornaments. *Kan-Meend* vs. *Andolan-Gamak* has been classified with a success rate of 88.7% while *Kan* vs. *Meend* with 85.4% and *Andolan* vs. *Gamak* with 86.8%

Apart from the methodology for analyzing & classifying the ornaments described in the current text, while undertaking the current work, a new method to correct “Octave Errors” in Hindustani Music was also developed.

Acknowledgements

First of all I would like to present my sincere gratitude to Dr. Xavier Serra who right from the beginning showed his faith on me by giving me a chance to be involved with the *Music Technology Group* not only just as a Masters student but also by putting the responsibility of managing the MTG-Web on my shoulders.

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Spotify, Corsega 538, Girones 27, Dalt 24 need to be thanked as well because of the ambience they provided while drafting this text.

Lastly my deepest gratitude to Dr. Hendrik Purwins, my supervisor, mentor, guide, advisor, counsellor the list goes on and on. This masters' thesis would not have been possible if I had had a different supervisor. Hendrik showed his interest to remember the *Hindi* lingo of the Hindustani Music, saved me from the dead-ends of research by his not-so-rememberable suggestions and when needed provided me the necessary moral support that I needed throughout. Thanks Hendrik.

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Chapter 1

Introduction

Ornaments in music are the small, usually undocumented improvisations that enhance the expressiveness of a musical piece. The ornament can be a grace note, a glide between two notes, multiple oscillations of a single note, oscillation between notes, etc. The nomenclature of the ornaments differ between musical genres, culture and era. In western music, during the period of Baroque music, ornaments flourished a lot and were used heavily in musical performances[16]. Of the many ornaments used in Western Music, *Glissando* & *Vibrato* are two popular ones.
The usage of a particular ornament can be a distinguishing feature between similar musical cultures like *Irish, Scottish* & *Cape Breton Music*. In Hindustani Music, ornaments play a pivotal role and differentiates the melodic modes which have a similar melodic structure.

1.1 Indian Classical Music

Indian Classical Music is one of the oldest form of classical music in the world. Its roots can be traced back to old Hindu sacred book *Samaveda* written around 1000 BC [18]. The *Samaveda* is a collection of religious hymns [11] sung as *Samagana*. The *Samagana* was the building stone on which Indian Classical Music was conceived [17].

Indian Classical Music is both elaborate and expressive. Like Western classical music, it divides the octave into 12 semitones of which the 7 basic notes are Sa, Re, Ga, Ma, Pa, Dha, Ni, Sa, in order, replacing Do, Re, Mi, Fa, Sol, La, Ti, Do. However, it uses the just intonation tuning, unlike most modern Western classical music, which uses the equal-temperament tuning system [1].

The two main genres of the Indian Classical Music are:

- **Hindustani Classical Music:** Often regarded as "North Indian Classical Music" or just "Hindustani Music" is the branch of Indian Classical Music which evolved in North India.
- **Carnatic Music:** is the part of Indian Classical Music which evolved in South India.

Although both Hindustani Music & Carnatic Music evolved from the same *Samagana*, in modern day both of them are quite distinct and different from each other.

1.2 Tonality in Hindustani Classical Music

Hindustani classical music is primarily monophonic. The compositions are based on a melody line over a cycle of rhythm known as *Taal*. The melody is governed by a melodic mode or scale termed as *Raga*.

Like Western music, Hindustani music also has a solfège of 12 notes known as *Sargam*. The 7 notes used in Hindustani Music are listed in Table 1.1:

Of the 7 notes listed in Table 1.1 only ***Madhyam*** can be played as a **sharp** (♯) note, whereas Table 1.2 lists the notes which can be used both as **natural** (♮) and **flat** (♭) as well.

Although in modern practice Indian Classical Music has 12 notes, it has been documented that originally the octave was divided into 22 intervals called *Shrutis*, which were the smallest possible musical intervals [15]. In addition to the current 12 intervals of the octave, performers occasionally use micro tones between the standard

Full Name	Symbol	Compared to
Shadaj	***Sa***	Do
Rishabh	***Re***	Re
Gandhar	***Ga***	Mi
Madhyam	***Ma***	Fa
Pancham	***Pa***	So
Dhaiwat	***Dha***	La
Nishad	***Ni***	Si

Table 1.1: Notes in Hindustani Music

Full Name	Symbol	Compared to
Rishabh	***Re***	Re
Gandhar	***Ga***	Mi
Dhaiwat	***Dha***	La
Nishad	***Ni***	Si

Table 1.2: Notes in Hindustani Music which has a flat version

intervals. The usage of these undocumented micro tones strictly depend on the *Raga* being rendered by the artist.

Unlike Western music which is based on Major & Minor scales and is heavily characterized by harmony and counterpoint, the cornerstone of Hindustani music lies on **Melody** & **Timing**. Hindustani music is monophonic in nature and the key of the performance is arbitrarily chosen by the performer depending on the range of the voice or the range of the instrument. There is no harmony or chord progression of any kind in Hindustani music.

An usual Hindustani music performance consists of a solo performer (vocalist or instrumentalist), a percussion instrument like *Table*, *Pakhawaj*, etc and *Tanpura*, a drone instrument to help the performer stick to the key of the performance. Apart from the drone and the percussion instrument, sometimes an additional string instrument like *Sarangi* is used as a fill-in instrument to mimic the vocal performance.

Thaat	Scale
Asavari	C D E♭ F G A♭ B♭
Bilawal	C D E F G A B
Bhairav	C D♭ E F G A♭ B
Bhairavi	C D♭ E♭ F G A♭ B♭
Kafi	C D E♭ F G A B♭
Kalyan	C D E F♯ G A B
Khamaj	C D E F G A B♭
Poorvi	C D♭ E F♯ G A♭ B
Todi	C D♭ E♭ F♯ G A♭ B♭

Table 1.3: Thaats and their scales

1.3 A brief introduction to *Ragas*

In its simplest description a *Raga* is a collection of notes. But, since *Ragas* are the building blocks of Hindustani classical music, they are a lot more than just a collection of notes. *Ragas* are the melodic modes on which a Hindustani musical performance is based.

Unlike the Western music, which can be categorized into Major & Minor scales, Hindustani music cannot be categorized into such scales. Instead each performance can be categorized into one of the hundreds of *Ragas*. Thus, loosely defining, a *Raga* can be compared to a scale.
As classified in [2],all the *Ragas* can be grouped together into 10 classes known as *Thaat*. These 10 *thaats* are listed in Table 1.3 with their equivalent scale in key C.

This table illustrates the formation of at least 10 different scales, however not all *Ragas* need to have 7 notes. A *Raga* can have any combination of 5, 6 & 7 notes. This means a *Raga* can have 5 notes while ascending and 7 notes while descending the *Sargam*. This characteristic is termed as *Jaati* of the *Raga*. A *Raga* can have the following *Jaatis* as listed in Table 1.4.

So, we can deduce the formation of atleast 90 *Ragas* using the 9 *Jaatis* for each *Thaat*. Moreover, two *Ragas* can have the same set of notes and the same *Jaati*, but still be considered two distinct ones based on which notes they use and other characteristics of the *Raga* [12]. The following sections deal with some of the

Jaati	**Ascending notes**	**Descending notes**
Odava	5	5
Odava–Shadava	5	6
Odava–Sampoorna	5	7
Shadava–Odava	6	5
Shadava	6	6
Shadava–Sampoorna	6	7
Sampoorna–Odava	7	5
Sampoorna–Shadava	7	6
Sampoorna	7	7

Table 1.4: Jaatis of Raga

characteristics of a *Raga*.

1.3.1 *Jaati*

As mentioned above, *Jaati* of a *Raga* reflects the number of notes the *Raga* has in ascending and descending manner. When the notes are in ascending order the melody is called *Aaroh* and while they descend the melody is termed as *Avaroh*. The possible *Jaatis* of a *raga* are listed in Table 1.4.

1.3.2 *Vaadi and Samavaadi*

- **Vaadi**: It is the main note of a *Raga*. *Vaadi* is the note that is used the most in the *Raga*. Most of the melodies of a *Raga* revolve around this note, and in particular try to establish the note in the melody.

- **Samavaadi**: It is the second most popular note in a *Raga*. After the *Vaadi*, the *Samavadi* is given the most importance while rendering the *Raga*.

1.3.3 *Chalan, Samaya and Rasa*

- **Chalan**: It defines and identifies the octaves in which the *Raga* is performed.

- **Samaya**: Every *Raga* has a particular time of the day assigned to it when it should be performed. Figure 1.1 gives and overview of the classification of *Ragas* based on *Samaya*.

- **Rasa**: It denotes the emotion related to each *Raga*, the popular *Rasas* which are still prevalent today include *Veer*, *Sringaar*, etc.

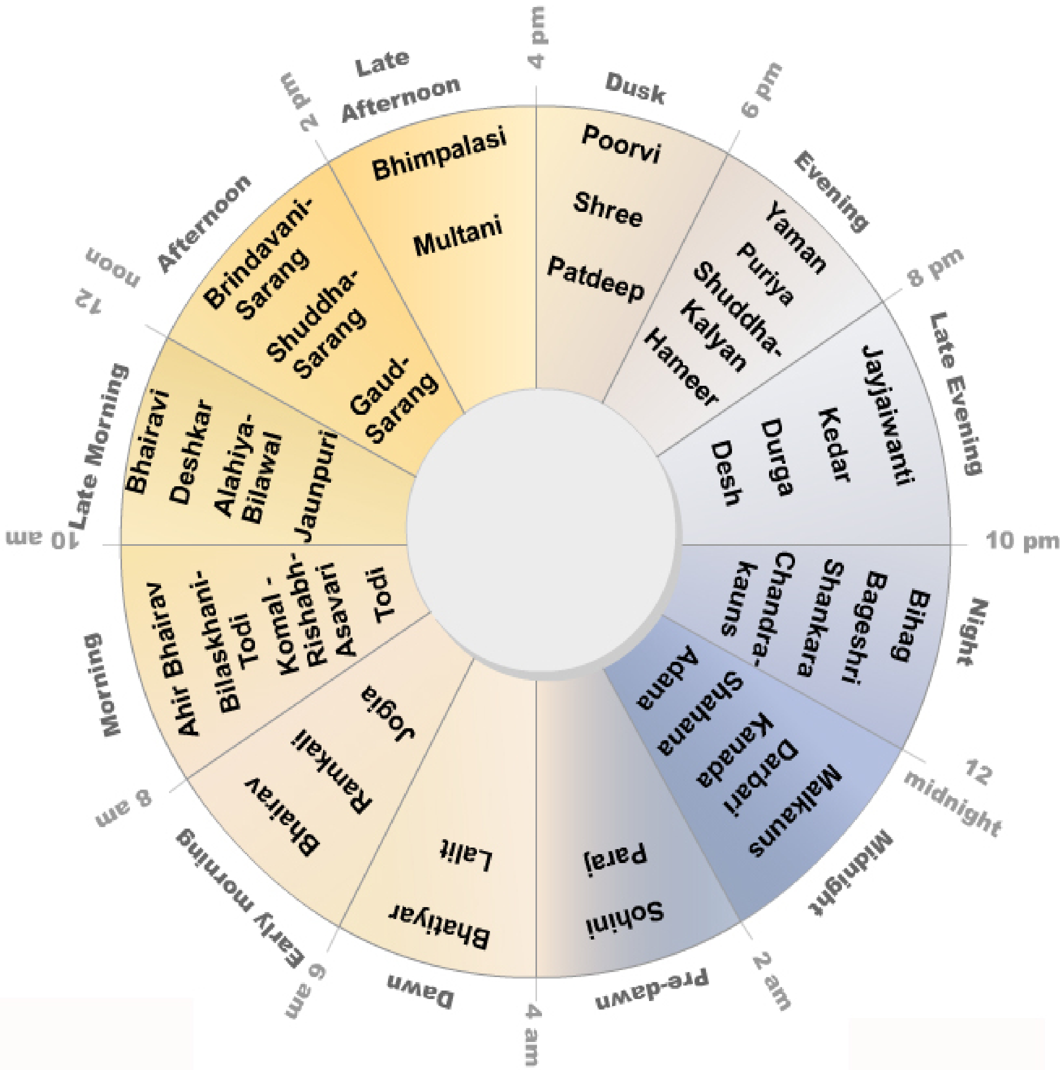

Figure 1.1: Distribution of *Ragas* based on their *Samaya*

1.4 Ornaments in Hindustani Music

Generally in Indian Music and especially in Hindustani Classical Music *Staccato* or isolated notes are almost unheard. With the exception of very few instruments, the notes in Indian music are not static in nature. While performing, each note is linked to the preceding and the succeeding note using one of the ornament types found in this type of music.

In fact, ornaments are called *Alankara* in Hindustani music which in Sanskrit means "Beautification", thus the ornaments are essential for the beauty of Indian *Ragas*. The term *Alankara* can be found in ancient texts. One of the earliest treatises is the *Natyashastra* written by the sage *Bharata* between 200 BC and 200 AD. Later on, description of *Alankaras* can also be found in the *Sangeet Ratnakar* by *Sharangdev* (circa 13th century) and *Sangeet Parijat* by *Pandit Ahobal* (17th century). The classification of *Alankaras* relates to the structure of *Ragas* and its aesthetic aspect. Not only *Alankaras* provide the beauty & exoticness to Hindustani Music but it also characterizes and differentiates *Ragas*. The four important Ornaments in Hindustani Music: *Kan, Meend, Andolan* and *Gamak* are explained in the following sections.

1.4.1 *Kan*

Kan are the grace notes used in Hindustani Music. They are usually used to link different notes while performing. *Kan* is never pronounced fully and is played or sung in a very subtle manner. The use of a note as a *Kan* with respect to another note highly depends on the *Raga*. In fact, the usage of a note as a *Kan* on another note sometimes is the differentiating feature between two *Ragas*. Often, a *Kan* is also used as a starting point for the *Meend* ornaments. The pitch contour of a *Kan* is presented in Figure 1.2.

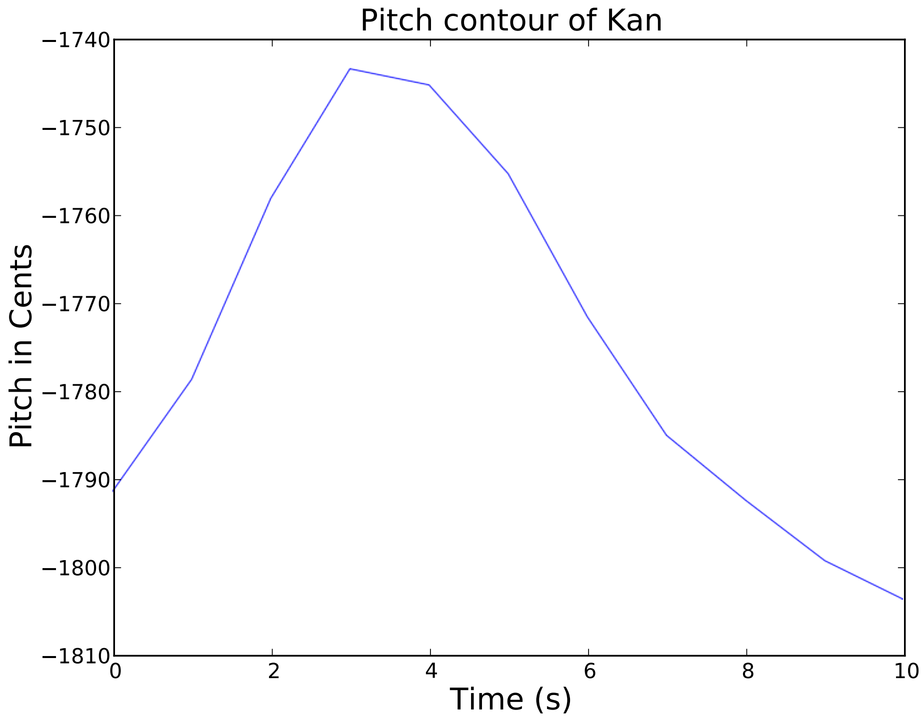

Figure 1.2: Pitch contour of a *Kan*

1.4.2 *Meend*

Meend in its simplest form can be compared to a glide between two notes. But, this glide can be between two notes or between two notes in two different octaves. Moreover, the speed of this glide can change while the glide is being performed. Also during the glide, it can rest on some notes for a short span of time and then carry on.

Meend is one of the toughest ornament in Hindustani music because its behavior between two notes depend completely on the rules of the *Raga*. Its duration and speed of the *Meend* are also notable. *Meend* has some sub-classifications, two of them are listed below:

- ***Ghaseet*:** When the *Meend* is performed on a string instrument in such a way that the note is glided just after plucking, it is called *Ghaseet*.

- ***Soont*:** It is a fast paced *Meend* performed by vocalists.

The pitch contour of a *Meend* is presented in Figure 1.3.

1.4.3 *Andolan*

An *Andolan* is a gentle swing or oscillation that starts from a fixed note and touches the periphery of a different note. During these oscillations, it touches the various microtones that are present between the notes. The note on which *Andolan* is performed is called *Andolit Swar* i.e. "Note with Andolan". Not every note in a *Raga* can be used for *Andolan*, moreover the choice and amount of *Andolan* for a note highly characterizes a *Raga* as well. The pitch contour of an *Andolan* is presented in Figure 1.4.

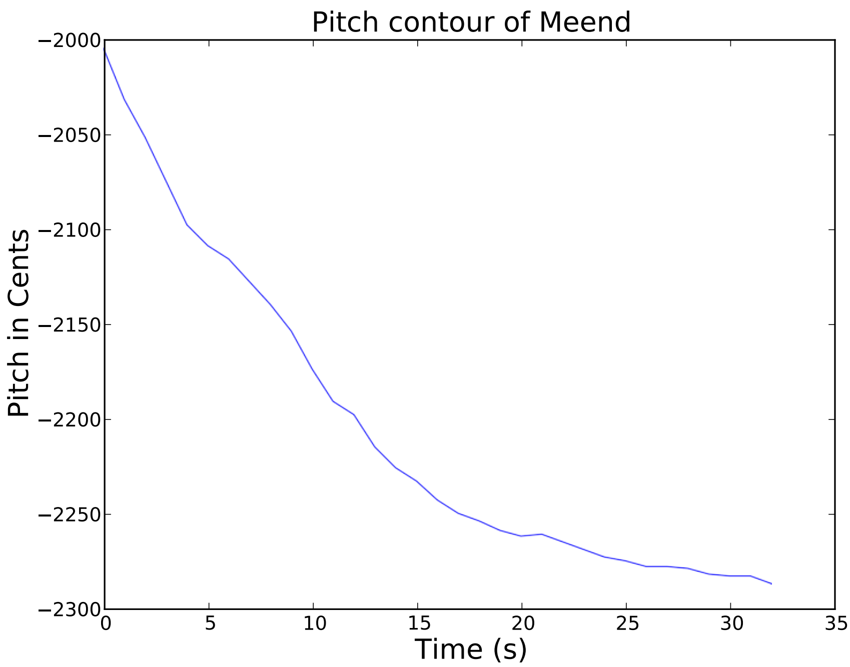

Figure 1.3: Pitch contour of a *Meend*

1.4.4 *Gamak*

A *Gamak* is a fast paced oscillation between two notes delivered with deliberate force and vigour. The *Gamak* is easily distinguishable from *Andolan* because of its fast speed and well-defined beginning and end points. Also, while the oscillations in *Andolan* are microtone based, the oscillations of *Gamak* are oriented with notes. The pitch contour of a *Gamak* is presented in Figure 1.5.

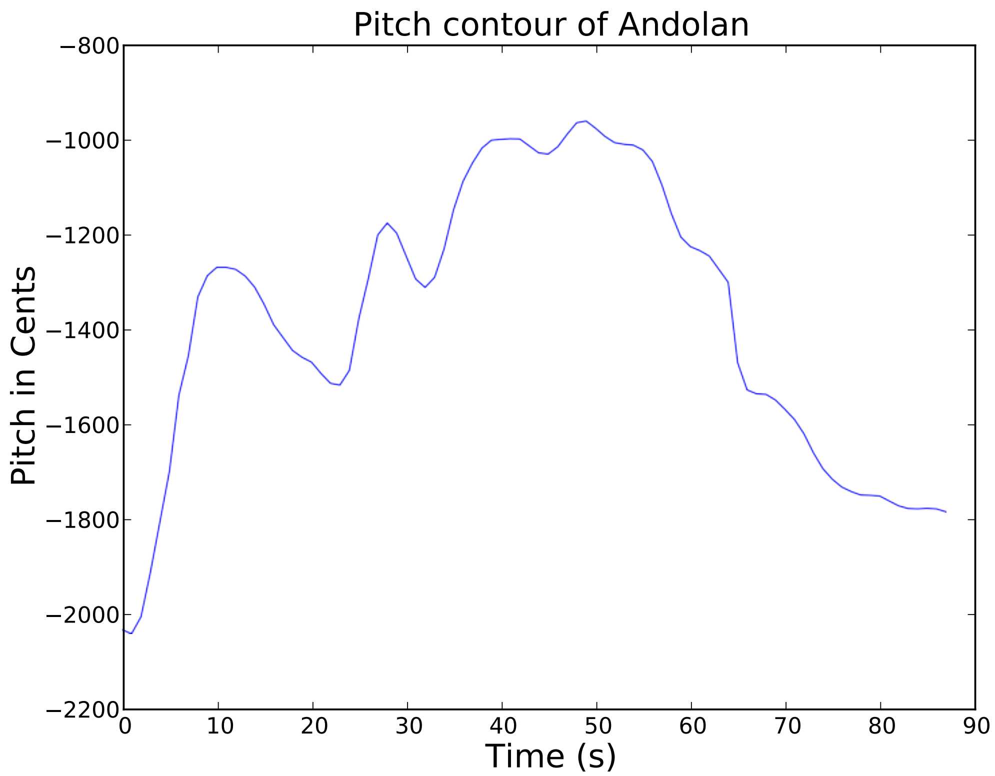

Figure 1.4: Pitch contour of an *Andolan*

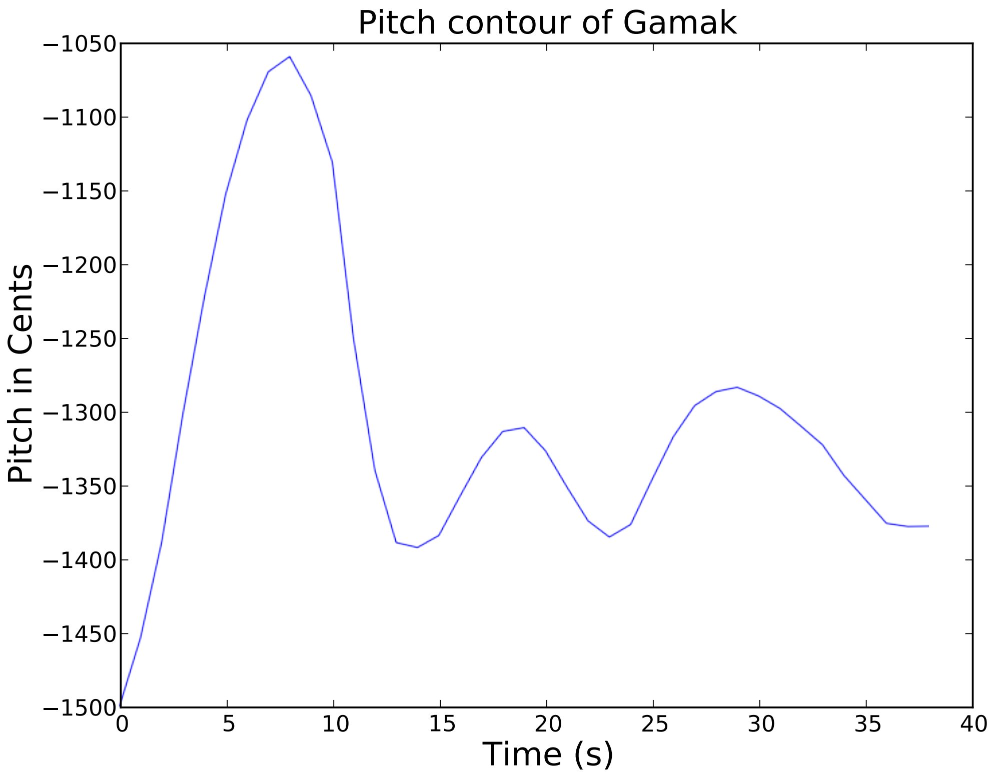

Figure 1.5: Pitch contour of a *Gamak*

Chapter 2

State of the Art

2.1 Research on Indian Classical Music

Since the concept of analysis of music using signal processing paradigm came into existence, little work has been done on Indian music in general and specially about Hindustani classical music. One reason for Hindustani music to be virgin in terms of technological research orientation can be the lack of knowledge about Hindustani music in researchers of this field. Apart from this reason, another possible reason could be the difference in basic concepts between Western & Hindustani music.
Recently, some research has been done to analyze and visualize the tonality of Hindustani music by analyzing its pitch and using classification techniques like Kohonen's Self organizing map [6].

Also, recognition & classification of *Ragas* has been approached by using Chroma Features, Pitch–Class and Pitch–Class Dyad distribution of the *Ragas* with the help of machine learning techniques as described in [7].

As explained in [13], pitch information is of utmost importance in research related to Indian Music, and pitch tracking of Indian classical music is one of the cornerstone for research in this field.[14] discusses the various forms of a single note in Carnatic Music and the usage of this analysis for constructing melodic atoms used for reproduction of the melodic line of Carnatic music.

2.2 Research on Ornaments

Till date, ornament analysis, classification & detection has not much been researched in general. One of the early work [5] related to automatic ornament transcription of classical lute has been done using *AudioSpectrumEnvelopeD, AudioSpectrumBasisD* and *AudioSpectrumProjectionD* MPEG-7 descriptors and Hidden Markov Models. Off late, some work related to ornaments in Irish music has been researched. In particular, ornaments in Irish flute and fiddle has been researched using methodology that involves calculation of energy envelope, fast onset detection techniques combined with comb filtering as described in [9] [10].

2.3 Application of past research

From Section 2.1 we can deduce the importance of pitch information of Indian Classical Music in research. Secondly, since the methods described in Section 2.2 use energy based descriptors and onset detection systems, these approaches were not fruitful in analysis of ornaments of Hindustani music, primarily because the notes in Hindustani music are seldom *Staccato* thus there is no considerable change in energy when an ornament is performed in Hindustani music.

Chapter 3

Motivation

As little work has been done in researching ornaments of Hindustani Classical Music, ornament detection seems an interesting topic since a lot of characteristics of this kind of music rely on the use of different ornaments.
Moreover, the ornament analysis methodologies that have been done so far depend on energy-based onset detection approach [9] [10]. This particular approach fails with the case of Hindustani Music because of the reasons explained in Section 2.3.

Also, since the current singer evaluation systems lack the features to analyze these expressive styles that are present in the Indian music in general, the performance of a system like this can be considerably increased if the ornament analysis is incorporated into them. Moreover, these analyses could be applied to voice synthesis systems like Vocaloid [3] to improve the performance of the system to mimic Indian music.

Chapter 4

The Methodology

This chapter discusses the overall methodology related to the approach of analyzing and classifying the ornaments as shown in Figure 4.1. Figure 4.9 shows a detailed flowchart of the methodology discussed in the following sections.

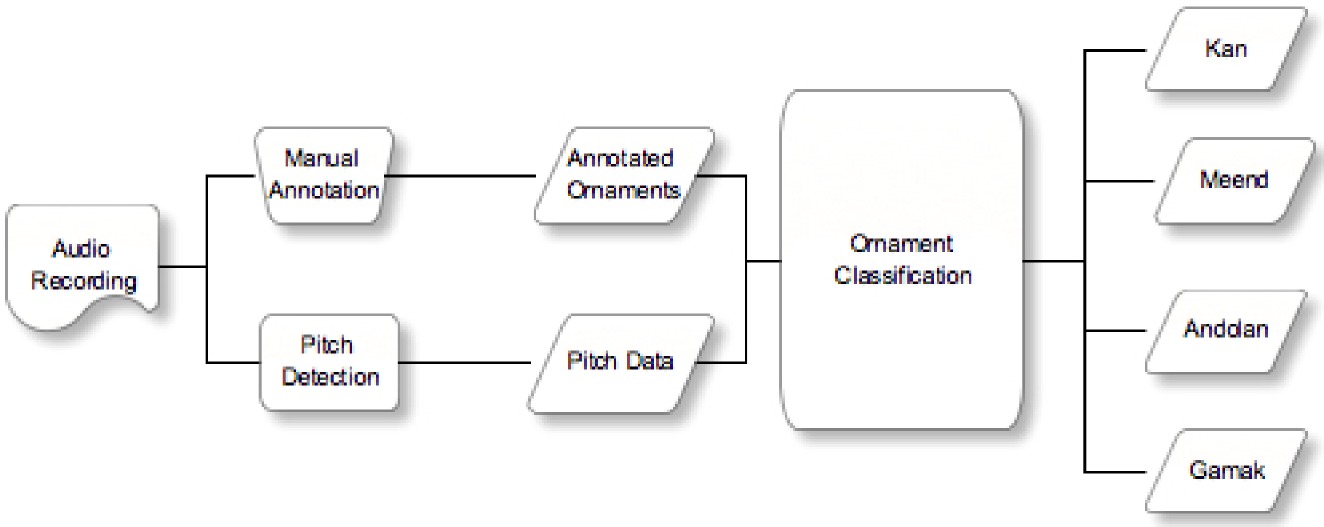

Figure 4.1: Flow diagram of the proposed methodology

4.1 Manual Annotation

The first step of the methodology deals with the manual annotation of the ornaments from various recordings of Hindustani music. The annotations were done

Ornament	Instances
Kan	27
Meend	28
Andolan	17
Gamak	21

Table 4.1: Database of Ornaments

using labels indicating *Ornament Type*, *Start time* and *End time*. Figure 4.2 shows a sample screenshot of the annotation process where **A_s** denotes the starting label for *Andolan* type of ornaments while **A_e** depicts its ending label, similarly **M_s** & **M_e** are used for annotating *Meend*.

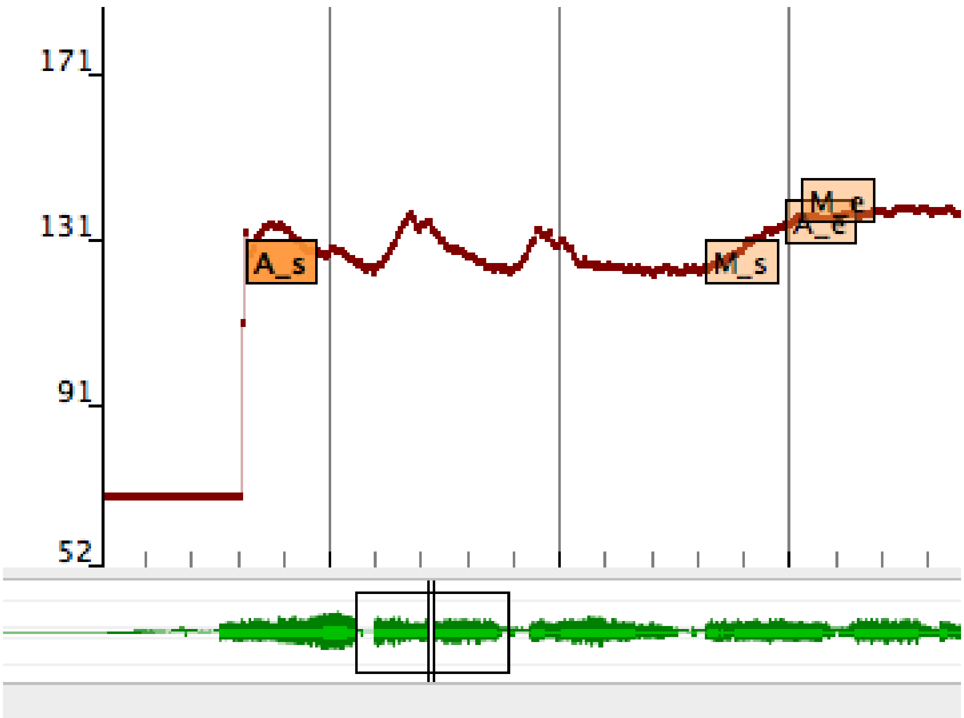

Figure 4.2: Screenshot of the manual annotation process

The collection of recordings consisted of different male/female singers, both development & exposition parts of a performance and various *Ragas* different from each other. The total number of instances for each ornament type can be found in Table 4.1.

4.2 Pitch Detection and Octave Error Removal

The pitch information of the selected recordings were extracted using Yin algorithm for fundamental frequency estimation as described in [8]. The values of the detected pitch were then converted to Cents to have an equal division of 1200 cents per octave.

One of the major problem with every pitch detection algorithm including the Yin algorithm is the wrong octave detection termed as *Octave Errors*. In these type of errors, the detected pitch is one or more octave higher or lower than the actual fundamental frequency. Apart from the *Octave Errors*, since the performer of Hindustani Music often uses a *false-fifth* to improvise the performance, *fifth* and *octave-plus-fifth* errors are also observed in the detected pitch.

Since the output of pitch detection errors are prone to *octave errors*, an algorithm described below based on a threshold of *"Note-Jump"* was devised to remove these octave errors and any possible *fifth-errors* & *octave-plus-fifth* errors.

Algorithm 1 Algorithm for removing octave and fifth errors

```
for All pitch samples in a pitch trajectory do
  if Difference between the next and current sample is greater than 400 then
    Subtract 700, 1200, 1900, 2400, 3600 from the next sample
    Select the value which is closest to the current sample
    Make this value as the corrected pitch for the next sample
  end if
  if Difference between the next and current sample is greater than -400 then
    Add 700, 1200, 1900, 2400, 3600 to the next sample
    Select the value which is closest to the current sample
    Make this value as the corrected pitch for the next sample
  end if
end for
```

The algorithm above uses the threshold of 400 cents (2 tones) to decide if a pitch sample is erroneous or not. Figure 4.3 compares the erroneous pitch curve and its corrected version using the algorithm described above.

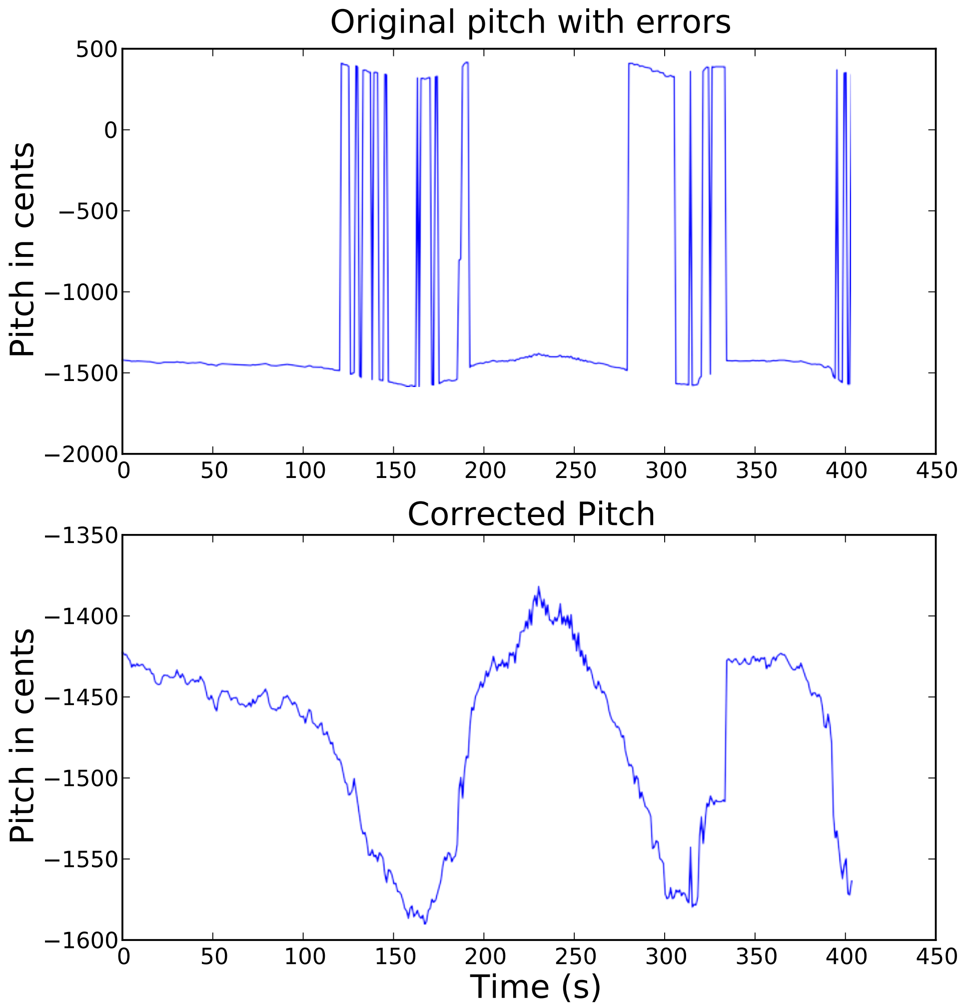

Figure 4.3: Erroneous pitch Vs Corrected pitch

4.3 Periodicity Analysis

Figures 1.2 & 1.3 depict the non-periodic nature of the *Kan* and *Meend* type of ornaments. While figures 1.4 & 1.5 indicate the periodic nature of *Andolan* and *Gamak*. This distinguishing feature is used to classify the ornaments into two classes based on their periodicity as follows:

1. **Non–Periodic:** *Kan* and *Meend*
2. **Periodic:** *Andolan* and *Gamak*

Furthermore, since *Andolan* is a slow oscillation while *Gamak* is a fast oscillation, they can be classified using the frequency of their periodicity. These two classifications are done using AutoCorrelation frequency.
Thus for the periodicity analysis we use two parameters of the AutoCorrelation function as explained below:

- **AutoCorrelation Strength:** This parameter is the ratio of the AutoCorrelation function value of 0th peak i.e. the peak at 0 lag to the value of the next peak i.e. the 1st peak.
- **AutoCorrelation Frequency:** This parameter is the distance between the 1st peak and zero lag. This loosely indicates the frequency of the AutoCorrelation and the original time-series.

The two parameters listed above can be visualized in Figure 4.4 while the AutoCorrelation curves for pitch of *Kan*, *Meend*, *Andolan* and *Gamak* can be found in Figures 4.5, 4.6, 4.7 and 4.8 respectively.

4.4 Dynamic Time Warping

Dynamic Time Warping (DTW) is an algorithm to measure the similarity between two time series sequences which vary over time or speed. The DTW algorithm finds

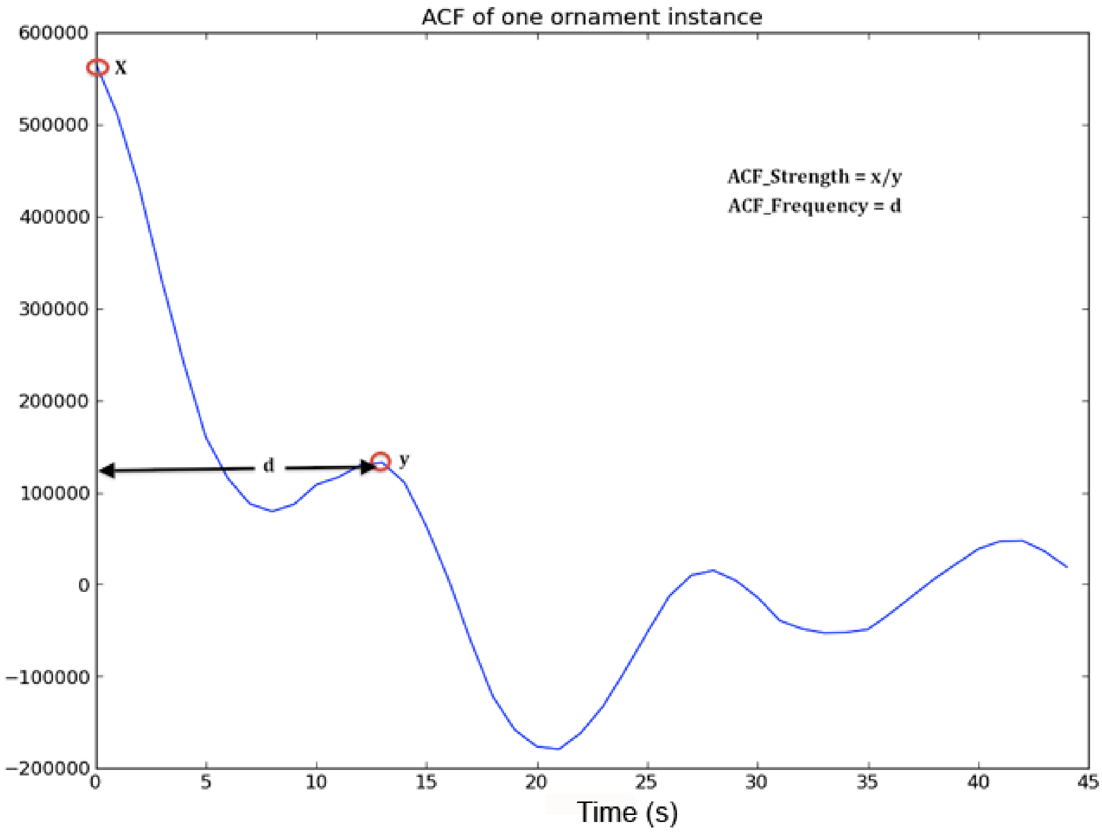

Figure 4.4: AutoCorrelation Strength & Frequency

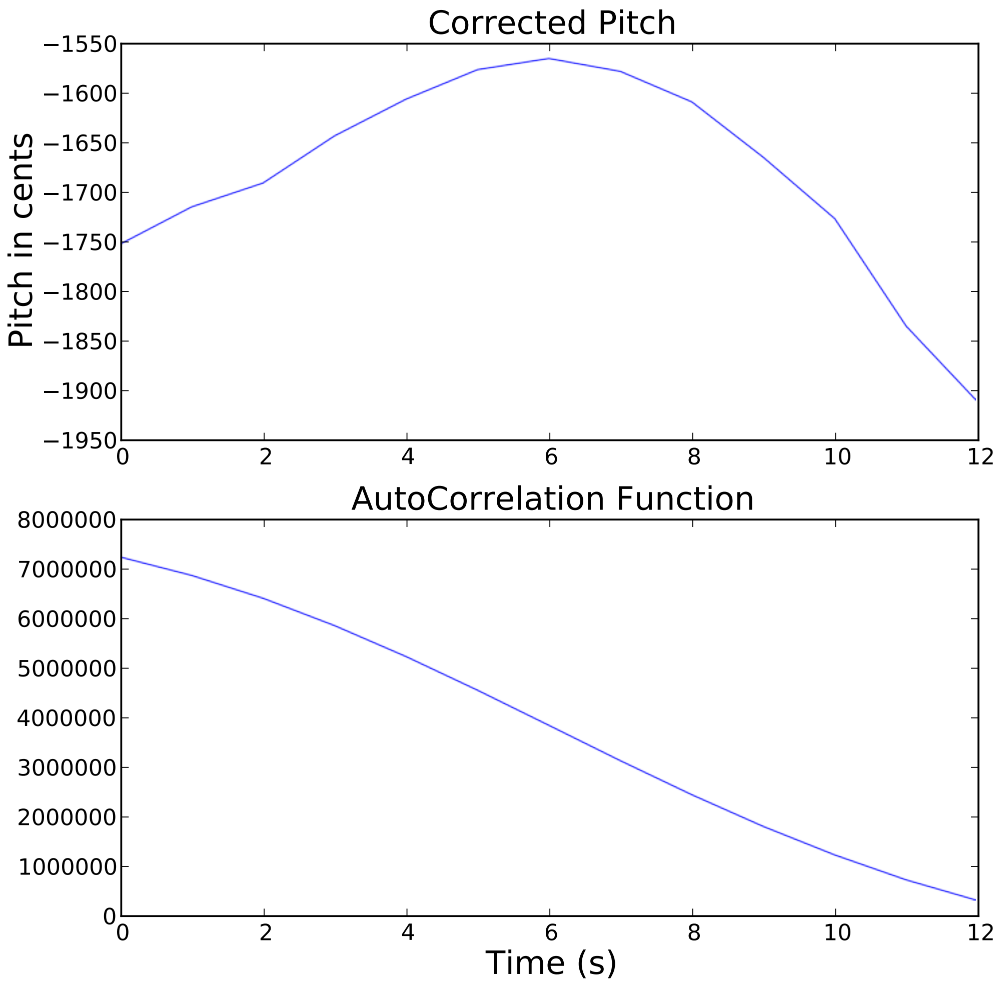

Figure 4.5: Pitch & Autocorrelation of Kan

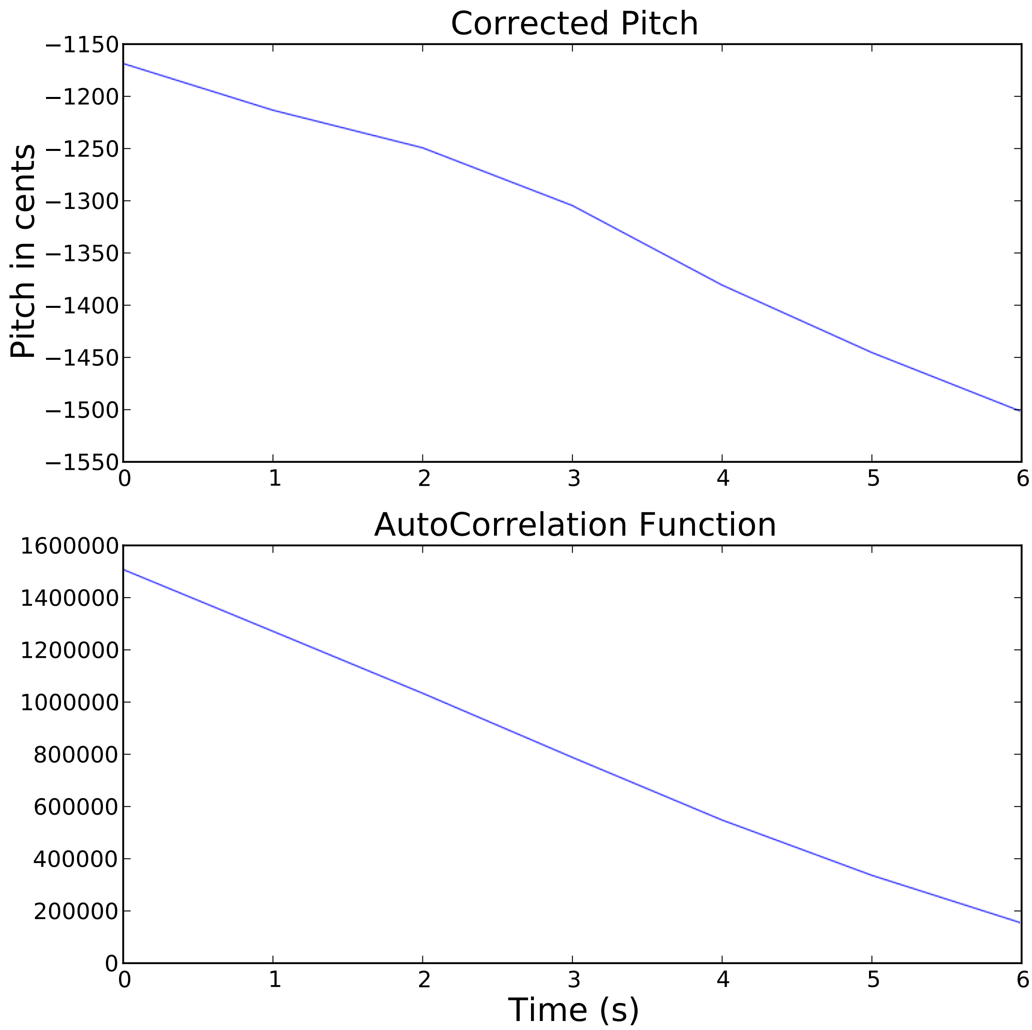

Figure 4.6: Pitch & Autocorrelation of Meend

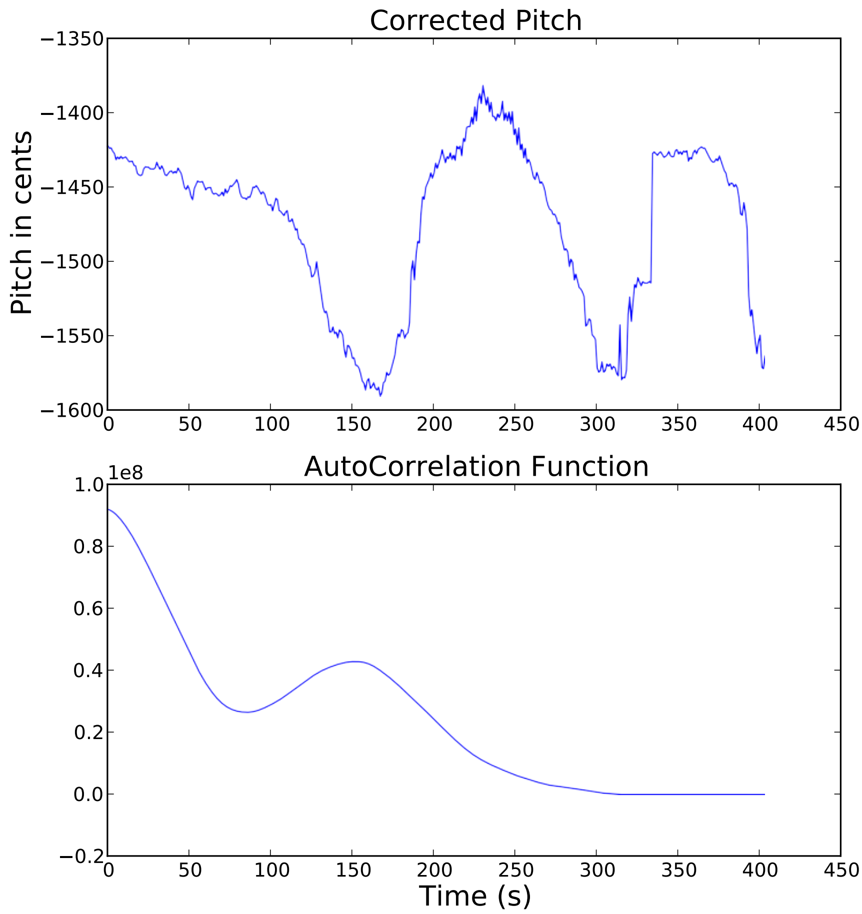

Figure 4.7: Pitch & Autocorrelation of Andolan

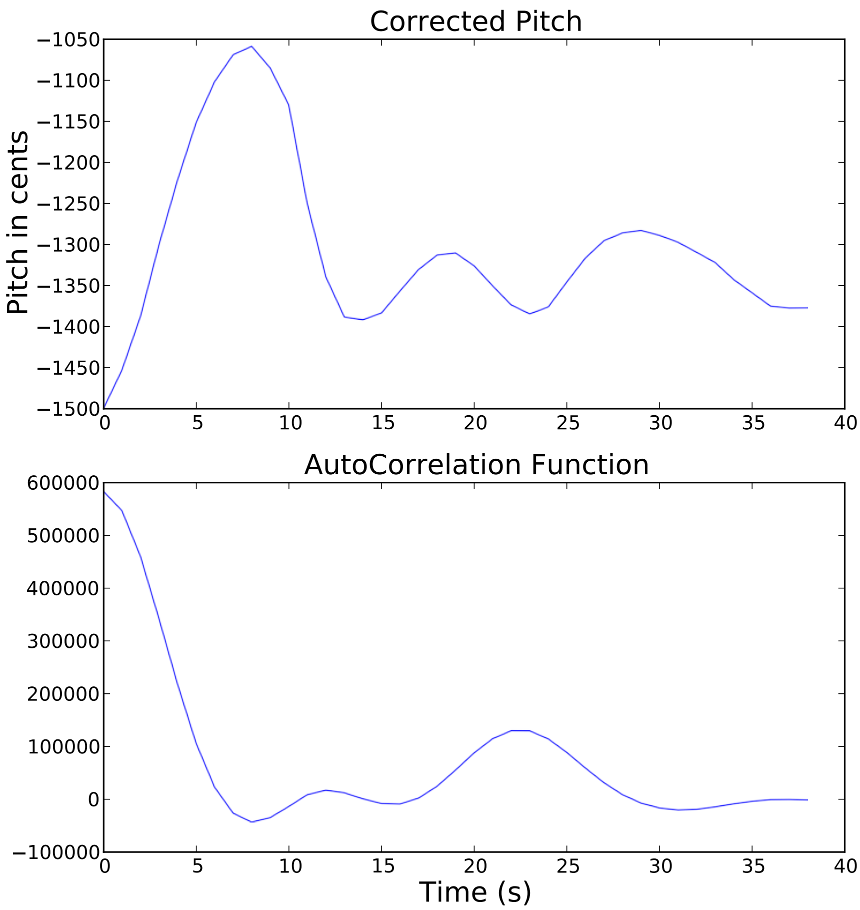

Figure 4.8: Pitch & Autocorrelation of Gamak

an optimal match between two time series sequences. These sequences are first warped non-linearly in the time domain to align over an equal time. Then similarity between them is computed by finding the sample to sample distance between these two warped time series.

In the current methodology, we perform Dynamic Time Warping of the *Kan* & *Meend* ornaments in order to classify them. Dynamic Time Warping classification index "**c**" is calculated for each pair of ornaments to differentiate them.
The algorithm for the DTW done in the current work is described below in Algorithm 2:

Algorithm 2 Dynamic Time Warping between Kan & Meend

```
for Each pair of ornament m & n do
    Calculate distance matrix between m & n
    Calculate the distance matrix between m & inverted n
    Calculate the DTW cost index c for both the distance matrices calculated above

    Select the Least c for each pair
    Normalize the value of c by the lengths of m & n
end for
```

The concept behind Algorithm 2 is to compare the pitch trajectory of each *Kan* ornament with the pitch trajectory of each instance of the *Meend* ornaments. This is done by calculating the distance matrix between the samples of the pitch trajectory between all possible pair of ornaments. For each pair, two distance matrices are created, one by just warping both ornaments while the second by inverting one of the ornament of the pair and then warping both of them. The DTW cost index "**c**" for both the distance matrices are computed and the lowest among the two is selected, which is then normalized by the lengths of the ornaments of the pair.

Combining the procedures described in Sections 4.2, 4.3 and 4.4, the overall process for the methodology can be depicted as Figure 4.9:

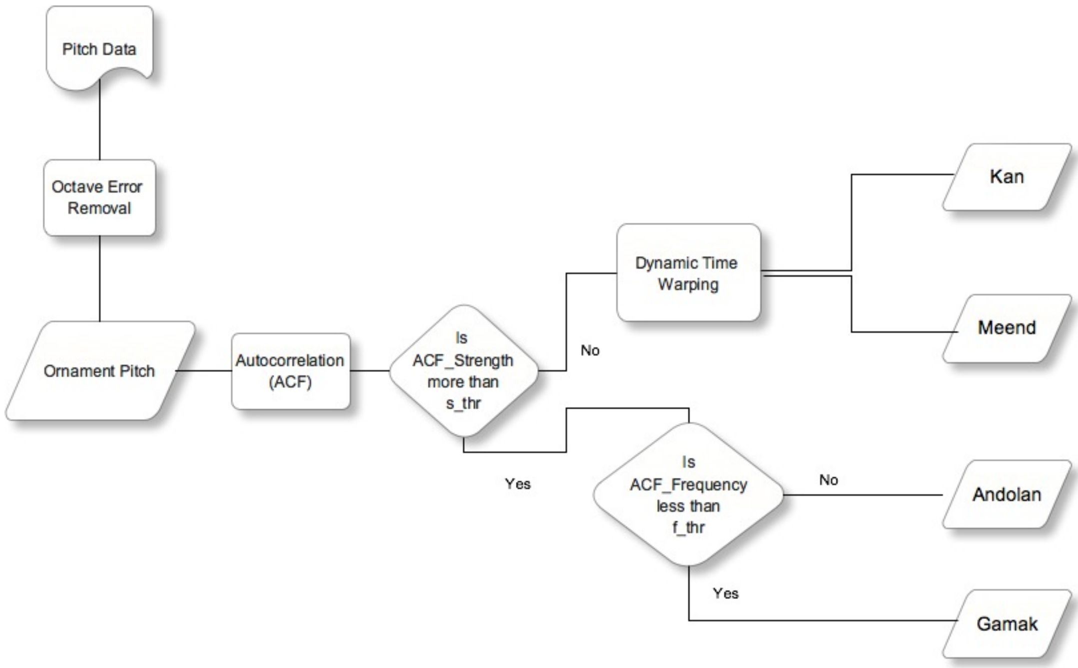

Figure 4.9: Detailed flow diagram of the methodology

Chapter 5

Results

The results obtained after the application of the methodology described in Chapter 4 and explained in Figure 4.9 are presented in this chapter. The results can be visualized in Figures 5.1 and 5.2 and Table 5.1.

5.1 Classification

5.1.1 Kan-Meend vs. Andolan-Gamak

Since the classification between these two classes of ornaments are based on the periodicity measure of the ornaments, the AutoCorrelation Strength described in Section 4.3 is used to differentiate them. Figure 5.1 shows the distribution of AutoCorrelation Strength of ornaments to classify them.

5.1.2 Andolan vs. Gamak

As described in Section 4.3, AutoCorrelation Frequency is used to classify the *Andolan* & *Gamak* ornaments. This is possible because the rate of oscillations of *Andolan* & *Gamak* are different. Figure 5.2 depicts the division of *Andolan* & *Gamak* ornaments on the basis of the parameter AutoCorrelation Frequency.

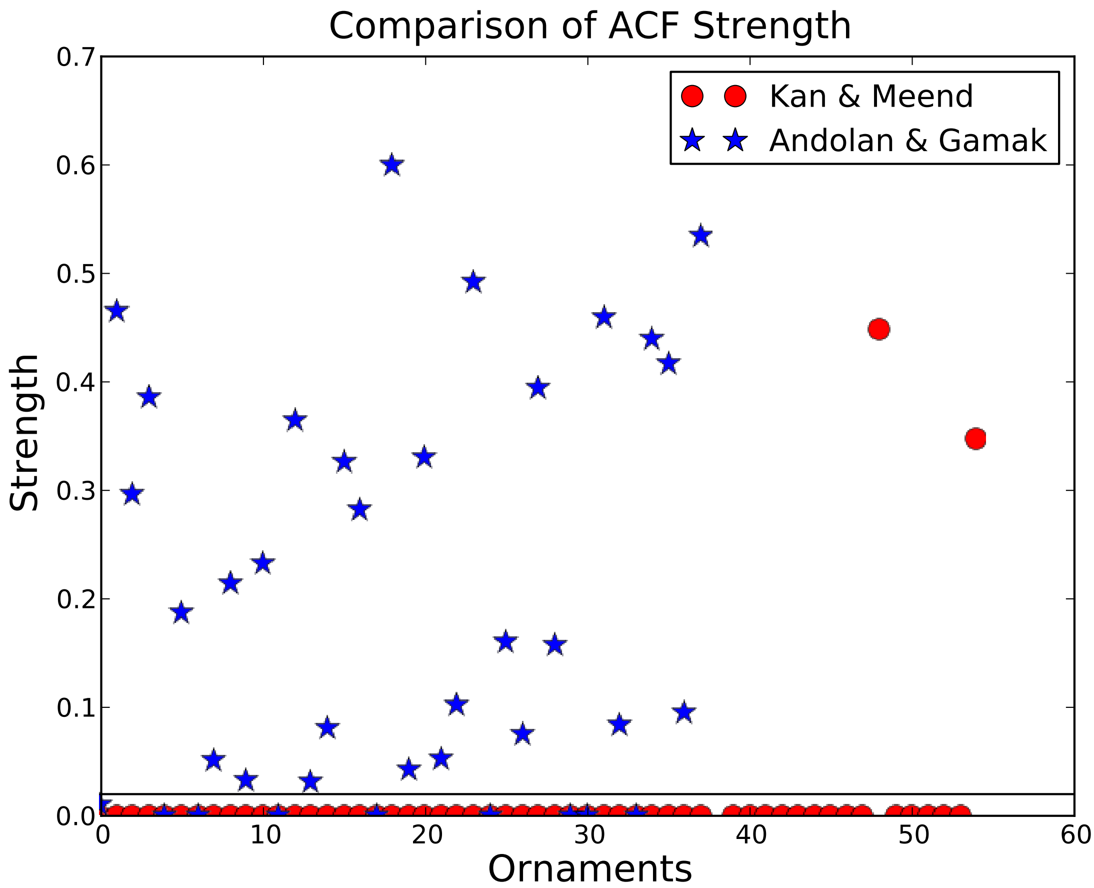

Figure 5.1: Classification of Kan-Meend Vs Andolan-Gamak

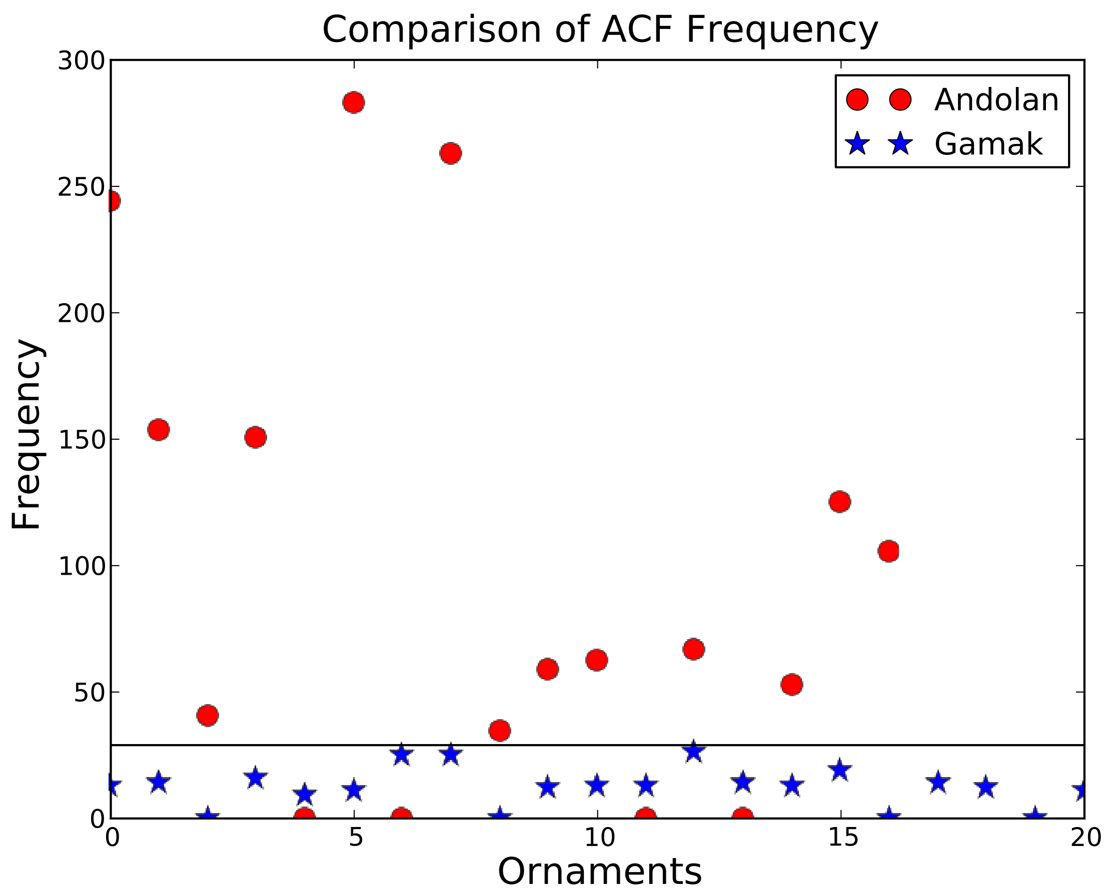

Figure 5.2: Classification of Andolan vs. Gamak

In Figures 5.1 and 5.2, the separation line is plotted to visualize the classification between the shown classes. It can also be seen that some of the samples are wrongly classified. The reason behind these fallacies can be primarily accounted to the errors that remain to the pitch information even after the application of the octave error removal algorithm described in Section 4.2. Also, some of these errors are due to non-periodicity of the some exceptional samples.

5.1.3 Kan vs. Meend

The result of Section 4.4 can be visualized in Figure 5.3. The figure shows the Dynamic Time Warping classification index "**c**" between each pair of *Meend* & *Kan* type of ornaments. It can be visualized that when an ornament is compared to itself "**c**" is equal to 0 and is represented by *Dark Blue*. Likewise, similar ornaments result in a lower "**c**" value and thus are represented by *Shades of Blue*. In the same way, the dissimilar ones having a high value of "**c**" are thus represented by a different shade approaching the other end of the RGB scale. Summarizing the color code bar, *Dark Blue*: Equal, *Red*: Very Dissimilar.

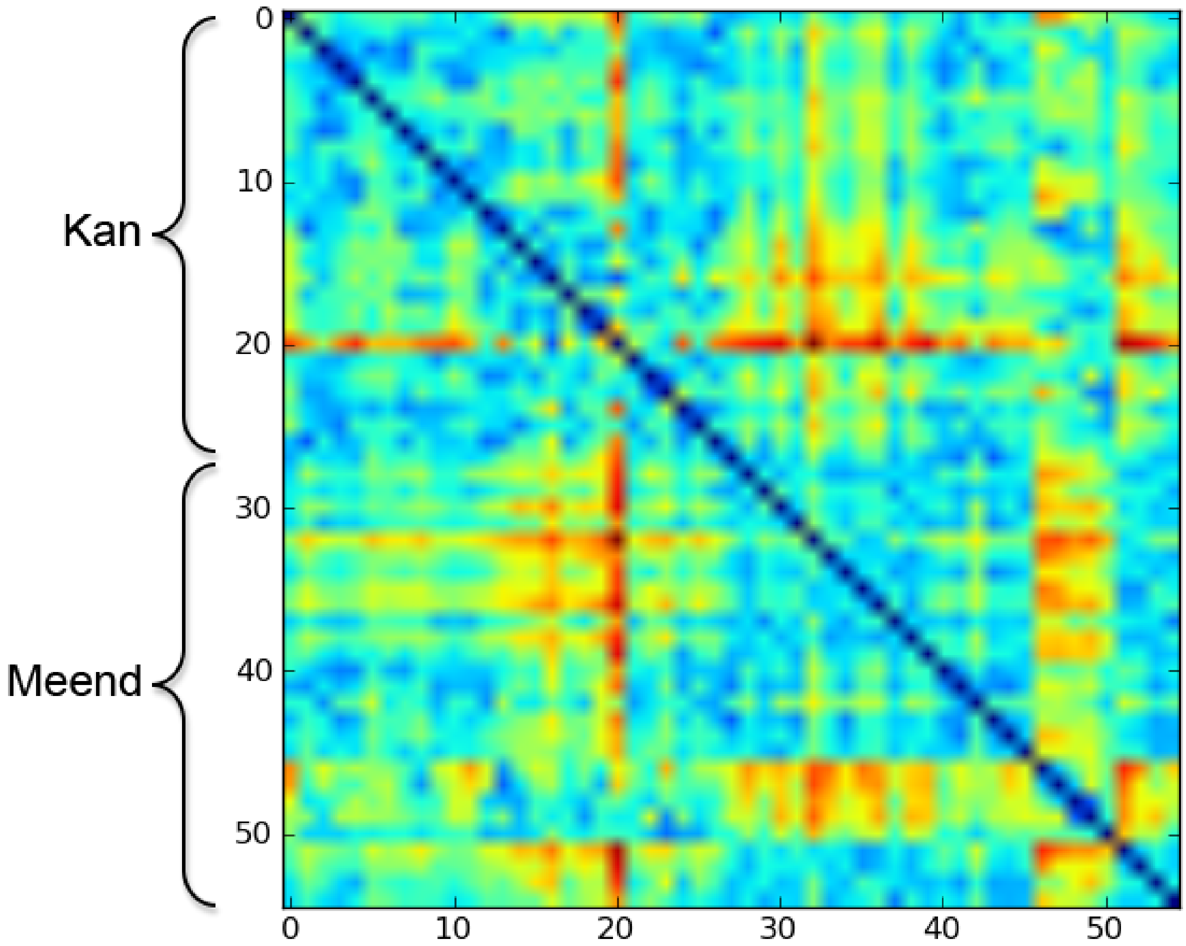

Figure 5.3: Dissimilarity Matrix of Kan Vs Meend

Ornaments	Classification Result
Kan–Meend vs. Andolan–Gamak	88.7755 %
Andolan vs. Gamak	86.8421 %
Kan vs. Meend	85.4545 %

Table 5.1: Classification results

5.2 Classification using a SVM

Support Vector Machines (SVM) as introduced in [4] are supervised learning methods to analyze data for recognizing patterns and classifying them. Basically SVM is a classifier and builds a statistical model based on training data to predict the classification of an unknown new sample. In the current work, *Linear Kernel* has been used for the classification based on the periodicity features that distinguishes first *Kan-Meend vs. Andolan-Gamak* and then *Andolan vs. Gamak*. For classifying *Kan* & *Meend* using the Dynamic Time Warping cost matrix, *Radial Basis Function Kernel* has been used.

Classification results obtained using *Leave one out* cross validation method for all the problems are summarized in Table 5.1

Chapter 6

Conclusion & Future Work

In the current work, a methodology for analyzing & classifying the major four type of ornaments in Hindustani Classical Music viz. *Kan*, *Meend*, *Andolan* and *Gamak* has been researched using the pitch information of this music. This has been possible by taking into account the fact that Hindustani Music, contrary to Western Music is primarily monophonic in nature and is based on melody rather than harmony.

Apart from the classification results presented in Chapter 5, during the work, a novel approach to correct octave errors in pitch detection presented in Section 4.2 was devised and tested with this kind of music.

In future, it would be a big leap in this domain, if this classification methodology could be taken ahead for development of a real-time ornament detection & segmentation system. Continuing on the work, this segmentation system can be applied to automatic singer scoring systems to increase the efficiency of these systems with respect to Indian Music. Moreover, since similar *Ragas* of Hindustani Music can be differentiated on the basis of ornamentations, a system can be developed for the purpose.

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