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PERCEPTUAL DISCRIMINATION OF TONE QUALITY ASSOCIATED WITH SITAR JAWARI

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Abstract- *A critical factor in the richness of a sitar's sound is the Jawari, which refers to the bridge on the instrument's sound plate. The actual extent of contact of the strings with the curved surface of the bridge is known to significantly influence the perceived tone quality. Expert musicians use their auditory skills to guide the process of jawari (filing the bridge) to achieve the desired sound quality between the two extremes of Band (closed) and Khula (Open). Based on field recordings of isolated strokes collected at the Kala Academy, Goa, this study aims to study the reliability of perceived differences between the two categories of Jawari in sitar. We present the results of a subjective experiment where multiple recordings of first 3 strings of 13 sitars were presented to 7 experts to identify the jawari. Based on annotations by experts it was observed that the experts' comments were largely in agreement with each other about the type of Jawari of individual strings. Further, observations of the acoustic signal spectra computed from recordings of the string pluck indicate significant differences between the two types of jawari and suggest that a computed spectral feature can largely discriminate the two.*

1. INTRODUCTION

The sitar is a traditional Indian classical instrument made up of seven main strings and 11 or 13 sympathetic strings [1]. There are two types of popularly played sitar. They are referred to as the "Kharaj Pancham Sitar" string set up, which was the sitar played by Pandit Ravi Shankar, invented by Sitar Ratna Rahimat Khan of Dharwad Gharana, and the "Gandhar Pancham Sitar", invented and played by Ustad Vilayat Khan of Etawah Gharana[2]. The Kharaj Pancham sitar is a traditional one consisting of 4 main playing strings and 3 strings for the drone. 4 strings in different octaves are tuned to Sa, tonic in C# or D is popular these days, which is a personal choice of the musician, 2 strings are tuned to Pa with respect to the tonic Sa and 1 string is tuned to Ma with respect to the tonic Sa. The other type of sitar "Gandhar Pancham Sitar" has a small difference from the Kharaj Pancham, in that, the third and fourth string is replaced with a single steel string which is set to Ga with respect to the tonic Sa. For fine tuning purposes there are beads attached to the four main playing strings. The sympathetic strings are basically used for resonance effect. These strings are heard in reaction to the main playing strings, only when the instrument is perfectly tuned.

Unlike the guitar and several other popular stringed instruments, the sitar is not a machine made instrument. The timbral quality of different sitars depends upon the make of the instrument. Since it is popularly hand-made, the tonal quality differs for each sitar. This difference in tonal quality could be attributed to the adjustment of the bridge level, termed popularly as *Jawari* amongst sitar makers and sitar players, and the quality of the raw pumpkin and the wood, which has been deployed in making the sitar. Every instrument has its natural pitch. There is a certain pitch, unique to each hand-made sitar, on which the instrument sounds excellent. It is supposed to be the musician's responsibility to discover the right pitch for his instrument. However, if a standard has to be followed when it comes to sitar, most popular sitars are played in D tonic today. When the sitar became popular people started recognizing the sound of sitar with reference to Late Pandit Ravi Shankars sitar. But, when the same audience was exposed to Late Ustad Vilayat Khan's sitar, the audience found that his sitar tone is quite different from Late Pt. Ravi Shankar's (brighter in sound). This difference between the sitars of these two virtuosos could be attributed to the *Jawari*. *Jawari* determines the tone quality of the

instrument. *Jawari* is the relation between the bridge, which is placed on the sound plate and the strings, which are laid on the bridge, which together change the tone of the sitar depending on the extent of contact with the surface of the bridge. If there is a distance between the string and the surface of the bridge, it could lead to an undesirable tone, whereas if the string touches fully to the surface it tends to be muffled. A balance between these two extremes leads to the production of cleaner sound. This balance is a subject of trial and error in which the sitar makers file the bridge under the supervision of the sitar player till the desired tone quality is achieved. The influence of the taraf and *jawari* devices has been scarcely investigated, even though players consider both the taraf's response and the *Jawari* effect as fundamental to the instrument's sound [1].

The physical factors which contribute to the *Jawari* of a sitar are as follows:
a.) Positioning of the bridge on the plate (*tabli*) - Improper positioning of the bridge on the plate will lead to a bad *jawari* of the sitar.
b.) The levelling of the string laid onto surface of the bridge, if there is no proper levelling it will lead to dampening or jarring of the sound.
c.) The material of the bridge- Earlier, the popular materials that were used for making the bridge were camel bone, ebony, rosewood, ivory, buffalo horn, tamarind wood and staghorn. Nowadays, Teflon is popularly used.
d.) Rusting or improper maintenance of the string- If the strings are rusted or sometimes twisted due to not replacing them over a long period of time, this could affect the *jawari* of the instrument.

From the sound perspective, three most important factors which will determine in going from a bad *jawari* to a good *jawari* would be:
a.) Sustenance of sound- More the sustain, better the *jawari*
b.) The musical thirds and fifths of the string in action should be audible to a sensitive ear
c.) Clarity in the tone, which is a function of a.) and b.)

For the sitar to be considered playable, the choice of tonal quality, i.e. band or khula, must be attained similarly on all the strings. That is, all the strings on a given sitar must be in the same state of *jawari*. It is therefore of interest to examine how experts use their hearing to detect the jawari from a single pluck of the string in question. An agreement between experts would suggest that the acoustic signal corresponding to the pluck contains reliable cues to the state of the jawari. Eventually, it may be possible to exploit this understanding to develop means of automatic feedback on the state of jawari that can benefit less experienced players.

In this work, we present a data collection exercise that involved a large number of different instruments on which expert judgments of tone quality were obtained via the recordings of individual string plucks. The expert judgments were used to label the strings in one of three categories. The acoustic characteristics of the extreme categories were compared.

2. DATA COLLECTION AND PERCEPTION TESTING

The player was requested to play the first 3 strings of the instrument in his natural way of striking, without the effect of the sympathetic/resonating strings contributing to its sound. The effect of the sympathetic strings was blocked using a thin cloth to block the vibration of the resonating strings and *chikari* (drone), and play only the 3 playing strings until the entire sound of the string faded away, in order to measure the duration of the string vibration and to hear the musical thirds and fifths. It was ensured that the room be relatively quiet, that is, not too reverberant; e.g. a living room with furniture, drapery, etc. and a sufficient pause was maintained between strokes. The microphone was positioned in a good way with respect to the sound source (e.g. on a microphone stand like the way it is used in a concert). Sampling rate was at 44.1 kHz, mono, 16-bit PCM. The recording was monitored using the display feature of the microphone in order to ensure that the signal was not clipped.

The first 3 strings of each 13 sitars were recorded. The recordings were carried out using the Zoom H2n portable recorder. Also the average temperature in Goa at the time of recording was around 29 degrees celsius, with the minimum being around 26 degrees and maximum around 31 degrees celsius. 5 repetitions of Da stroke were recorded. The recordings were carried out in the presence of an expert and the qualitative comments were noted on the quality of sound produced by individual sitars whether they belong to the *band jawari* or *khula jawari* category or neither *band* nor *khula*. These same recordings were played to 6 other professional sitar players and they were asked to comment on the sound and the annotations were noted.

Also, the naming convention for each audio sample was done in the manner of Recordingnumber_Locationwhererecorded_SitarID_SitarType_Strokesamplenumber

3. OBSERVATIONS

On some Sitars, which were in good condition, when the experts were asked to comment on the quality of sound from the 3 different strings some strings sounded *Khula* while some sounded *Band* on the same sitar. This aberration was attributed to improper *Jawari* or improper leveling of the bridge(which was a result of improper filing). Post segmenting single stroke samples for *Band*, *Khula* and neither *Band* nor *Khula*, the total dataset across the 13 sitars was categorized as follows:

1.) Completely *Band* (in which all the three strings sound Band or good levelling of bridge and Band) - 1 Sitar
2.) Completely *Khula* (In which all the three strings sound Khula or good leveling of bridge and *Khula*) - 4 Sitars
3.) Partly *Band* Partly *Khula*(In which few strings sound *Band* and few *Khula* or bad leveling of bridge) - 8 Sitars

These Sitars were grouped into the above categories using the annotations provided by the experts. For instance, single strokes from different strings of a particular sitar were played before the 7 experts separately and all of them commented on the sound as *Band* and there were some discrepancies where 1 or 2 experts commented Between *Band* and *Khula* and the rest 5 commented as *Band*. In this case, the majority was considered. Also, we attempted to find a visual way of differentiating between the two types of *Jawari*, and the experts were asked to comment on the same. The experts noted that it was quite necessary for them to hear the sound of the instrument and they could not comment on the *jawari* type by just visually analyzing it. Below are the figures of 3 different sitar bridges and it can be seen that it is very difficult to comment on the type of jawari by visual examination alone.

Figure I. Bridge of Sitar 1

Figure II. Bridge of Sitar 2

Figure III. Bridge of Sitar 3

4. ACOUSTIC ANALYSIS

The dataset was first filtered to only retain samples which had been rated consistently by at least 6 out of the 7 experts as belonging to one of the two categories – Khula or Band. Further, the data was separated into three sets, one for each of the three strings- Pa, Sa and Ma (in the order of increasing pitch). Each such set included all the samples corresponding to a particular string obtained from the different sitars. Upon preliminary observations of short-time spectra computed on the waveforms, the primary region of interest was found to be a short segment immediately following the stroke onset. The exact duration of the audio signal region needed for accurate analysis was found to depend on the string type and possibly even the instrument itself. For the higher pitched 'Ma' string, a half-a-second segment of the audio sufficed, whereas, for the lower pitched 'Sa' and especially the 'Pa' strings, the segment needed to extend up to nearly 1.5 seconds after the onset in several cases, in order for all the salient information of the Khula samples to be captured.

In order to better capture the temporal changes in the harmonic content, a short-time analysis was carried out over this chosen region using overlapping windows nearly 100 ms long, with a 50 percent overlap between consecutive windows. The spectral centroid over the entire frequency spectrum was computed on each window and the mean centroid value across windows was used as the single feature representing a string. The spectral centroid location corresponds to the perceived brightness. Next unsupervised k-means clustering was applied separately on the samples of each pitch string. The number of clusters was set to 2.

Fig V shows a plot of the spectral centroid values computed for every sample in the dataset. The dashed line marked for every string in the plot is the separation boundary obtained from the clustering algorithm, i.e., since the clustering was performed using a single feature, the cluster boundary is a single value equal to the mean of the cluster centers. Hence, in a testing scenario, points lying above the boundary would be grouped into one cluster (Khula) and those below it to the other cluster (Band). The numbers on the dashed lines indicate the value of the boundary in Hz. It appears that there is a strong dependence on the *jawari*- influenced spectral difference of the pitch of the string.

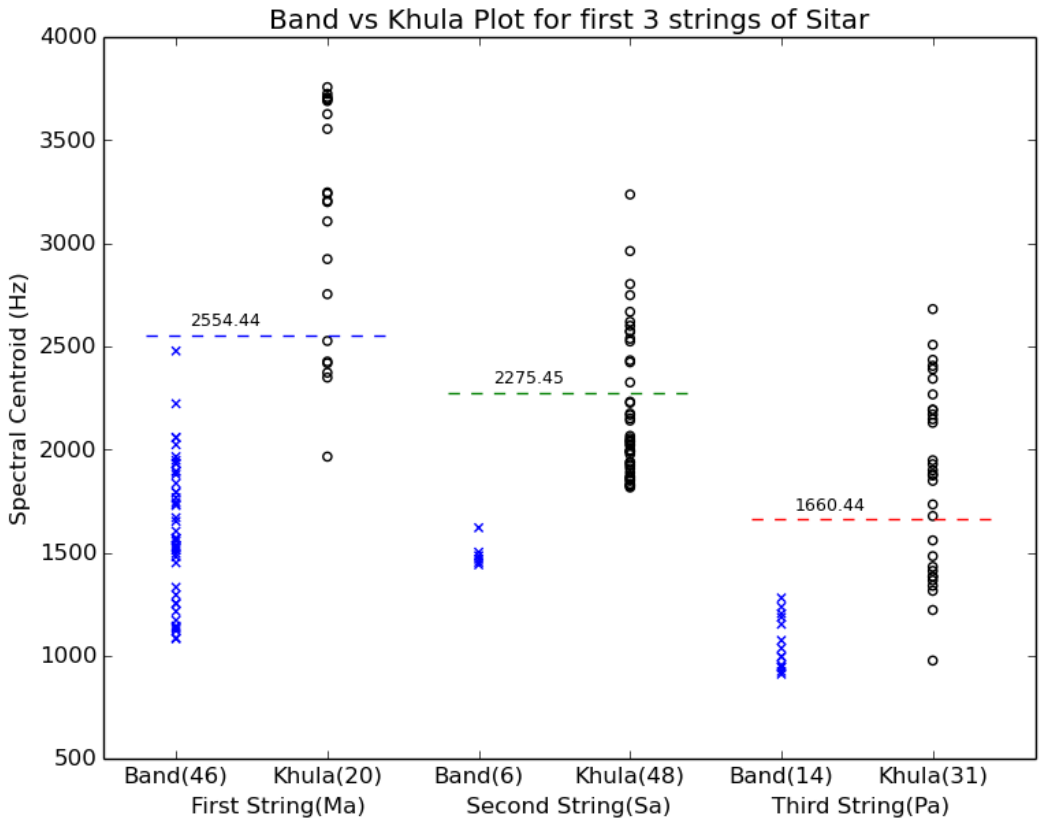

Fig V. Plot of the spectral centroid values computed for every sample in the dataset, with the 'x' marks representing 'Band' samples (from the ground truth) and the hollow circles representing 'Khula' samples (from the ground truth). The dashed lines separate the tokens based on unsupervised clustering into 2 clusters.

As can be seen in the plot, the clustering was not completely accurate. The Band samples of the 'Ma' string that lie very far from the corresponding cluster center (close to the boundary) and the 'Khula' samples of the same string lying in the 'Band' cluster, indicate the inadequacy of brightness alone in identifying the Jawari type. However, another point to note is that since the ground truth is based on perceptual evaluation, another test may be necessary to ascertain the exact nature of those samples (so that they indeed belong to one of the two extreme classes and do not lie in between) and in order to rule out the possibility of any unintended biases in perception during annotation.

The Band samples of the 'Sa' and 'Pa' strings seemed to be well identified by their centroid values. In case of the 'Sa' string, although the Khula samples are quite well separated from the Band ones, the boundary is not low enough because of the number of 'Band' samples being low. In case of the 'Pa' string, the outlying Khula samples were observed to all be from a single sitar and were found to represent an interesting case of factors other than the jawari type affecting the nature of the sound. This is because some samples from the same sitar lie above the boundary as well, and the difference between these two kinds of samples is noticeable in the sound produced. One possible reason for this difference is the slight changes that could have occurred while plucking the string.

4. CONCLUSION AND FUTURE WORK

From the observations of this experiment, it can be concluded that the filing of the *jawari* is a crucial factor in defining the type of *jawari*. The majority of the sitars from the total of 13 belonged to the partly *Band* partly *Khula* category highlighting the importance of proper filing of the bridge. Spectral differences corresponding to the perceived quality differences were identified and examined for discriminative power. It appears that there is a strong dependence of the pitch of the string on the *jawari*- influenced spectral difference. Several other spectral features of the two types of *jawari* will be studied in order to discriminate them more reliably.

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