THE PERSIAN MUSIC AND THE SANTUR INSTRUMENT

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ABSTRACT

Persian music has had a profound effect on various Eastern musical cultures, and also influenced Southern European and Northern African music. The Santur, a hammered dulcimer, is one of the most important instruments in Persia. In this paper, Persian music and the Santur instrument are explained and analysed. Techniques for fundamental frequency detection are applied to data acquired from the Santur and results are reported.

Keywords: Non-western Musicology, Persian, Iranian Music, Santur, Santoor, Dulcimer, Dastgàh, Quartertone, Interval, Fundamental Frequency detection, Pitch.

BACKGROUND

Most of the efforts in music processing are focused on Western music while there are a variety of subtle points in the Eastern musical systems. This section provides the background material on Persian Music including a brief historical review and explanation of the musicological concepts.

1.1 A Brief History of Persian Music

The origin of Persian music traces back to the earliest written histories. According to legend, king Jamshid is credited with the Invention of music.
The two Greek historians, Herodotus and Xenophon, mention the use of martial, ceremonial and ritual music in Iran during the Medes (900- 550 B.C.) and Achaemenids (559 – 331 B.C.) dynasties [1]. Remains of an Achaemenids Clay Horn have been found recently and are held in the museum of Pars in the city of Shiraz [2]. During the Achaemenids, Persian territory from China to Egypt and Greece made a common cultural platform. During the Hellenic era from 331-238 B.C. the Macedonians ruled over the former Persian Empire and this cultural platform remained unchanged. The Macedonians were later defeated by Iranians and the dynasty of Parthians ruled from 238 B.C. to 224 A.D. In this era, sort of popular musicians emerged who could create the poem, compose the music and perform it at once.

The peak period for ancient Persian music occurred during the Sàsànids dynasty (224-652 A.D.). Bàrbod, the most brilliant musician of the court of Khosro Parviz, devised a musical system [3,4], containing seven modal structures which were called the Khosravani (Royal Modes) as the days of a week, thirty derivative modes or modulations which were called the Lahn corresponding to days of a month, and three hundred sixty melodies called the Dastàn for each day of the year. There were also music hymns with which the Gàt'hà of the Avestà (the Zoroastrian holy book) were sung. During this period, music was so important that one of the kings, Bahràm-e Gur (421-439 A.D.) invited 1200 musicians from India to contribute to the musical programmes in Persia [4].

The Arab conquest in the 7th century A.D. spread the Persian Instrumental and vocal music throughout the Islamic empire. Two major schools of music were developed from the Persian music: One in Baghdad and the other in Cordoba which sprang into the North African and the Flamenco music [4]. Persian musicians and musicologists brought their musical concepts and instruments to the furthest points in the empire. An interesting event is the migration of Master Zaryàb along with his sons and daughters from Persia to Spain to teach the instrumental, vocal and dance techniques. He brought the Persian lute or Barbat (Ud) to the Spain which was then evolved to the present day Guitar [4]. Some of the famous musicians and musicologists of Persia in the Eastern Muslim Empire are: Farabi (A.D. 950), Ebne Sinà or Avicennà (A.D. 1037), Ràzi (A.D. 1209), Safioddin Ormavi (A.D. 1294),Qotbeddin Shiràzi (A.D. 1310), and Abdol-Qàder Maràqi (d.circa 1460) [3, 4].

This era was followed by the disastrous Mongol invasion in the 1200s, which brought the Persian Musical concepts to the East [4].

The new golden age of Persian civilisation began with the Safavids dynasty (1499-1746 A.D.), during which the music chambers of the Àli Qàpu and the Chéhél sotun palace in the city of Esfehàn were made. In this and previous eras, musicians were patronized by nobility. However, from that time until the 1850s, Persian music lost its official significance and was frowned upon [3].

In recent decades, Persian music has again found broader dimensions. An urge to create new traditions and an interest in the unique musical structures has emerged. However, the national music of Iran may be represented by the tradition of the past tinged with 19th century performance practices.

1.2 The Persian Composition

Persian music is often dichotomised into urban (music of the large cities) and ethnic music (music of the different ethnic groups living in smaller cities, villages, and mountainous areas). The first uses more ornamentations and free rhythms. Farhat describes the ethnic music with its

simple melodies and a rhythmic directness [3]. The ethnic music is more preserved and is closer to the ancient tradition. They both follow the same intervals and modes (sec. 1.3 and 1.4) and rely to a large extent on improvisation.

There are three instrumental forms and one vocal form in urban music. The instrumental forms are Pishdaràmad, Chàhàrmezrab, and Reng. Pishdaràmad was invented by a master of the tar, Darvish Khàn, and was intended as a prelude to the Daràmad which is the opening section of a Dastgàh. It may be in duple, triple, or quadruple time, and draws its melody from some of the important Gusheh of the piece (sec. 1.4).

Chàhàrmezrab is a solo piece with a fast tempo, and is usually based on the melody immediately preceding it. The third instrumental form is the Reng, a simple dance piece which is usually played at the conclusion of the Dastgàh. The vocal form is called the Tasnif. It has a design similar to the Pishdaràmad, and is usually placed right before the Reng. The Persian music is mainly unison, where the instruments in an ensemble play the melodic scheme and relies highly on the improvisation [3].

1.3 The Persian Intervals

In analogy with the Western tempered music, Vaziri suggested a division of the octave to 24 equal Quartertones. He defined the Sori (♯) and Koron (♭) symbols to show half-sharp and half-flat quartertones [6]. This system is widely used by musicians. Here we use "q" to show the Koron, and "s" to show the Sori.

A preferred option was suggested by Farhat [3]: Considering some intervals between a semitone and a whole tone, and an interval greater than a whole tone to the 12 semitones in tempered Western music.

In fact, only a few quartertones exist in each Persian Scale and all the scales (Dastgàh) in Persian music (section 1.4) can be performed with 13 different notes, 7 of which are the diatonic notes, 3 are semitones and 3 are quartertones [2]. The 13 principal notes with which all the Persian Dastgàh can be played on a Santur are:

Mi–Fa-♯Fa- #Fa– Sol-#Sol-La-♭Si–Si -Do-♯Do-#Do-Re

1.4 The Persian Dastgàh system

Persian music is based upon a set of 12 modes, called the Dastgàh system: Shur, Abu' Atà, Bayàt-e Tork, Afshàri, Dashti, Homàyun, Bayat-e Esfehàn, Segàh, Chahàrgàh, Màhur, RàstPanjgàh, and Navà [3, 4].

There is a tonal centre or centre of pitch gravity for each Dastgàh, which is called the Shàhed. Each Dastgàh has a number of derivatives, called the Gushé. Moving from a Dastgàh to a Gushé is the usual way for modulation in Persian music. Most of the time, it occurs with a change in the Shàhed, but it may change the tuning too. Some of the Gushé are independent, but when called through another Dastgàh, will play the role of a Gushé. For example the Delkash Gushé of Bayàt-e Esfehàn is absolutely a Shur from a fifth interval.

Performance in each Dastgàh starts with an opening section, which is called the Daràmad. Then, modulations to other modes (Gushé) occur, during which the Shàhed note gradually moves upward. Finally, a Cadential phrase called the Forud, brings the mode back to the initial mode of the Dastgàh.

In terms of the rhythm, the urban Persian music consists of either free-rhythmic pieces (Avàz) or rhythmic songs, typically in 2/4, 4/4, or 6/8. Complex rhythms like 5/8 and 7/8 are mostly used in the ethnic music.

1.5 The Santur

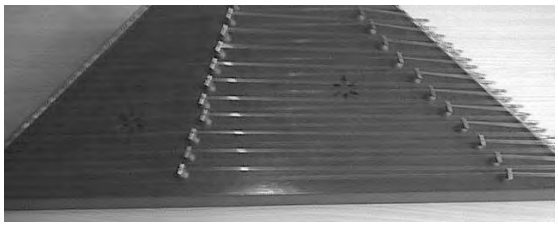
1.5.1 The history

The Santur is a trapezoidal string instrument, played by a pair of delicate hammer sticks. This instrument originated in Iran, and was later brought to India, China, Thailand, Greece, Germany (and other countries), where it is called Santoor, Yang-jin, Khim, Santouri, Hackbrett respectively. It is often referred to as a dulcimer in English. The Santur is one of the most popular instruments in Persia. In a typical Persian ensemble, the Santur performer usually sits in the middle and assumes a leadership position.

1.5.2 The Santur structure

The pair of hammer sticks, or the Mezràb, are held between the index and the middle fingers and are used to hit the strings. The Mezràb are usually coated by a piece of cotton or leather. The body of the Santur is made of walnut and the Mezràb are made of either walnut or Narenge (a citrus wood). Figure 1 shows a Santur and its peripherals.

Four strings are vibrated for each note. They are pulled between the string holders (figure 2-a) and the tuning pegs (figure 2-b), and sat on a bridge between these two ends (figure 2-c). The notes can be tuned by turning the tuning pegs, using a tuning key which is also used as a hammer to hit the tuning pegs. The bridges are movable and can continuously change the pitch of a note by several whole steps.



(1-a)

(1-b)

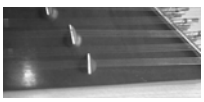
(1-c)

Figure 1 a) Santur b) Sticks (Mezràb) c) Tuning Key

There are two sound holes on the soundboard (figure 2-d). They serve to enhance the sound quality. Modern Iranian Santurs most often consist of 9 bridges, although 11 or 12-bridge Santurs can be found too.

(2-a)

(2-b)



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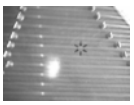

(2-d)

Figure 2 a) Bridges (Kharak) b) Sound holes

There are three note regions on a Santur. The first octave, or the yellow notes, are made of brass and are located on the right side of the Santur; the second Octave notes, denoted white notes, are in the centre and made of stainless steel. The extension of the second octave notes pass over the bridges and terminate on the string holders in the left end. These are called behind-the-bridge white notes. An 11-bridge Santur has a tone Range from C3 (130.8 Hz) to F6 (1396.9 Hz). The fundamental frequencies (F0) can be calculated with reference to a known tone, f_1 using $f2 = f1 \times 2^{(d/24)}$ where d represents the distance in quartertones of f_2 from f_1.

The F0 of a string is a function of its length l, string 's pulling force F, string material constant μ and a constant K, as given by Eq. (1).

$$f = \frac{K}{2l}\sqrt{\frac{F}{\mu}} \qquad (1)$$

The resonance body of a Santur is hollow, but there are wooden columns that keep the instrument from disruption. They bear the force exerted by the strings over the bridges on the upper surface of Santur.

All Dastgàh may be played on a Santur in different keys. Figure 3 shows the tuning system for an 11-bridge Santur. Abu'Atà, Dashti, Bayàt-e-Tork and Afshàri which are all derivatives of Shur, have the same tuning.

DSP ANALYSIS

Using a computer with a sound card, and an ordinary microphone, samples of 16-bit precision at 44.1 kHz sampling rate where recorded. The samples were performed by the first author on a Santur instrument. The analysis in section 2.2 is done on a database consisting of 10 samples for each of the 13 Persian notes explained in sec. 1.3. It was recorded with the same conditions, but a sampling rate of 16 kHz [4].

1.6 Analysing an A4 note and a 2 octave arpeggio

Figure 5 shows the logarithm of the Spectrum of an A4 note (F0=440 Hz) [2]. They show the variation of harmonic content through time. The amplitude of a harmonic component may change due to the resonance characteristics of the strings, the instrument body and the room acoustics.

Figure 6 shows the harmonic content of a 1024 point frame of the same signal. To bypass the transient, the analysis window for figure 6, starts at sample no. 4500. The F0 and the major harmonics can be seen.

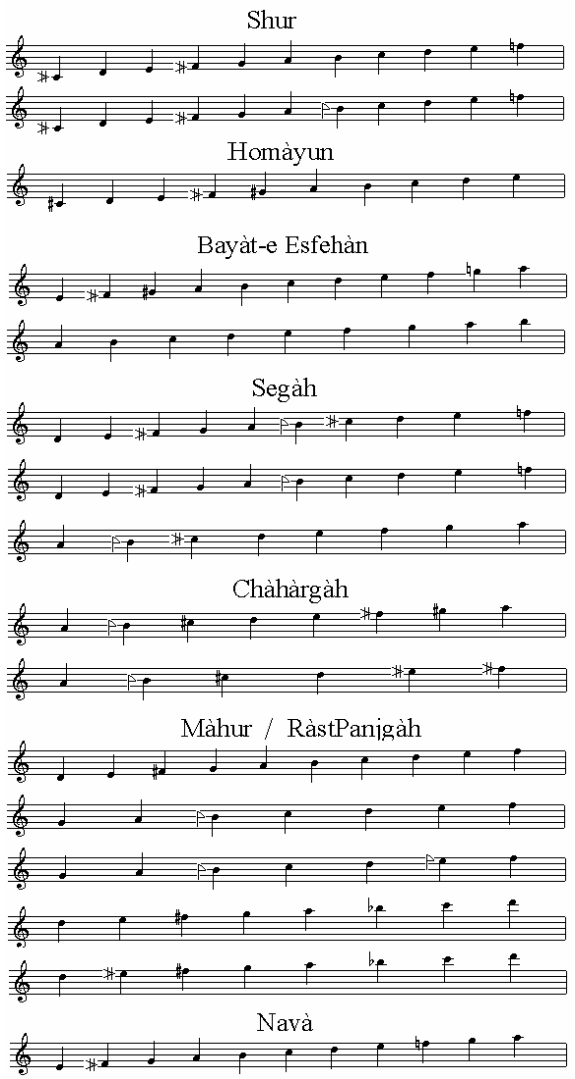

Figure 4 The tuning system on Santur[1]

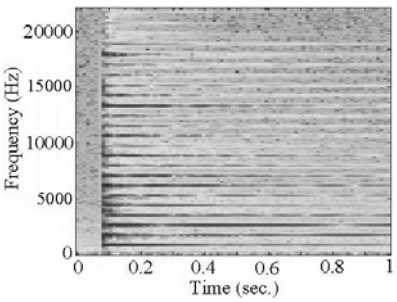

Figure 5 Spectrum of the note A4

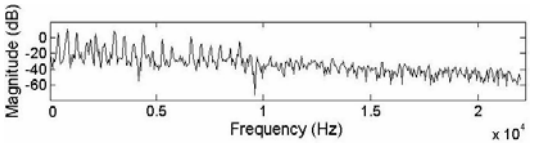

Figure 6 Frequency domain representation of A4.

In Figure 7 the Spectrum of a two-octave A4 minor arpeggio is shown. An array of the following notes was played: A3-C4-E4-A4-C5-E5-A5 F0 for the array of

[1] More information on the modes can be found in [3, 4].

Hertz respectively [2]. A 1024 point window has been used. The change in the harmonic content can be seen.

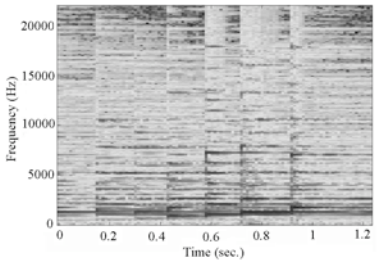

Figure 7 Spectrum of a two-octave A4 minor arpeggio.

1.7 Fundamental Frequency Detection

Here, the fundamental frequency is calculated using the cross correlation between the test samples and a set of reference patterns [2, 5]. Analysis of Santur signals shows that different notes have different timbres and even samples of the same note vary in spectrum when played with different dynamics and with different Mezràb [2].
To provide a constant-shape pattern, a uniform reference pattern was made for each note, with 1's at the position of the fundamental frequency and the harmonics. If this pattern is cross correlated or convolved with the spectral transform of the signal, a maximum occurs at the position of the fundamental frequency [5].

In practice, the overtones are not exactly at the integer multiples of a the F0. So a pattern with components having a thickness *t*, was chosen to cope with the inharmonicities (figure 8) [2].

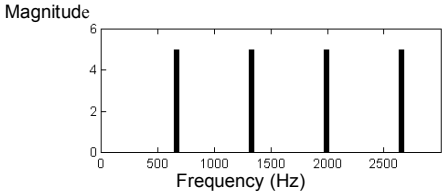

Figure 8 The pattern for E5 considering 4 harmonics with thickness *t*.

The fundamental frequencies were calculated using patterns like that in figure 8, a sampling frequency of *Fs*=8000 Hz, different lags, window widths of *N*=512, *N*=1024 and *N*=2048; number of harmonics, between *n*=1 *to n*=8 and thicknesses between *t*=1 to *t*=13, the maximum recognition rate was 96.15% which occurred at a window width of, *N*=2048, thickness *t*=9, number of harmonics *n*=4 and lag, *l*=250. Figure 9 shows the recognition rate when as a function of the thickness when all the other variables are optimized.
Additional tests were done, using patterns with different shapes, component thicknesses, and number of harmonics [2]. The highest recognition rate was obtained using an increasing width pattern as shown in figure 10, where the width of the i^{th} component is *i* times the width of the first component. Using this pattern, with the same conditions as the previous test, the recognition rate increases to 96.92%. For the test samples taken at *Fs*=16 kHz this occurs when the pattern has *n*=6 harmonics and the thickness of the first component is *t*=5. Among the 130 test notes, there were only 4 mistakes. One E4 was recognized as an E5 which is an octave error; one F#4 as Fs4; one Bq4 as B4 and one C5 as Cs5 which they are all proximity errors between the neighboring quartertones.

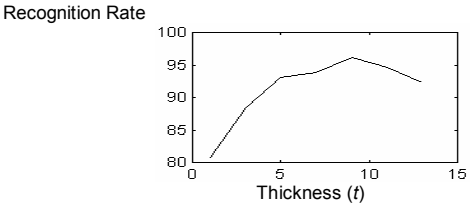

Figure 9 Recognition rate versus thickness

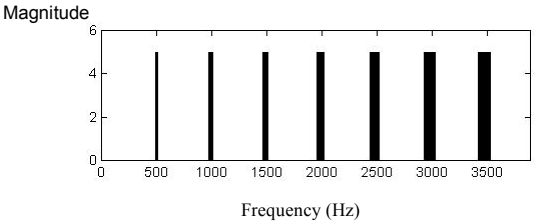

Figure 10 Increasing-width pattern for E5 with 7 harmonics.

CONCLUSION

The Persian Intervals and Scales are similar to those of various cultures like Kurdish, Azeri, Guilaki, Baluchi, Turkish, Arabian, Greek, etc… So, any analysis on Persian music may be extended to a wide range of cultures.

In this paper, Persian music and the Santur instrument were introduced and an algorithm for the calculation of fundamental frequency was implemented. Future work may be on studying the different rhythmic patterns, and determining the scale, key or genre of a piece. Such work will enable a more complete understanding of how music processing algorithms need to be adapted to different musical styles and structures.

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