Using the Golden Section to Design a Kamanche

SHAHAB KHAEFI (1), MITRA JAHANDIDEH (2), AHANALI JAHANDIDEH(3),
MASOUD KHAEFI(4)
(1) Department of Music, Art University, Karaj, Tehran, IRAN
Shahabhkhaefi@gmail.com
(2) Department of Music, Faculty of Fine Art, Tehran University, Tehran, IRAN
M_jahandideh@ut.ac.ir
(3) Ahanroud@yahoo.com
(4) Department of Music, Guilan University, Rasht, Guilan, IRAN
Masoudkhaefi@gmail.com

Abstract: The kamānche is a Persian bowed string instrument related to the bowed Rebab, an earliest spiked fiddle which is ancestor to most modern European and Asian bowed instruments. Kamanche is played in many different cultures and areas, such as Iran, Azerbaijan, Armenia, Turkey and etc. It is played vertically with a variable-tension bow in the manner of the European viol. On the other hand, the golden section (also known as Golden mean, divine proportion or ratio) is a ratio defined by the number phi (Φ=1.618033988…). It has been used in designing some musical instruments but for the first time, we used it to design a Persian musical instrument. The rational underlying this study was to use golden section in designing a Kamanche. Computer Aided Three-dimensional Interactive Application (CATIA) multi-platform CAD/CAM/CAE commercial software was used to draw the mentioned designs.

Keywords: Kamanche, Spiked Fiddle, Golden Section, Musical Instrument Design, CATIA Software

1 Introduction
The Renaissance was an enormous cultural progress which brought about a period of scientific revolution and artistic alteration, at the dawn of modern European history. It marks the transitional period between the end of the middle Ages and the start of the modern age. The Renaissance is more often thought to have begun in the 14th century in Italy and the 16th century in northern Europe. The Renaissance artists applied the Golden section widely in their paintings and sculptures to attain balance and beauty. Musical instrument designing also did not exempt of this category, and Golden section was applied in designing musical instruments by the greatest luthier of Cremona, Stradivarius. Unfortunately it was not applied in traditional instruments. We use Golden section in designing a Kamanche as a Persian traditional instrument and hope it will flourish in other traditional instruments. Until now, no designing procedure or acceptable ratios have been proposed for this musical instrument. The rest of the paper is organized as follows.

The representation of Kamanche, Golden section and CATIA software marshally will be given in Sections 2, 3 and 4. Section 5 describes our methodology to designing a Kamanche by using the Golden section.

2 Kamanche

2.1 History

The Kamanche or Kamāncha is a Persian bowed string instrument related to the bowed Rebab, played with a variable-tension bow. The word "Kamanche" means "little bow" in Persian (Kaman, bow, and -che, diminutive). It is extensively used in the musical culture of Iran, Turkey, Azerbaijan, Uzbekistan, Armenia and Turkmenistan, with slight variations in the structure of the instrument.

Kamanche is being seen in celebration and war scenes paintings, from Mongol and Timurid periods. Kamanche was one of the most important instruments in the Safavid and Qajar periods. It was an instrument which was used in celebration scenes of Safavid era. A wall fresco at Chehel Sotoun Palace in Isfahan shows a Kamanche player among a group of court musicians at the royal court. This wall painting depicts a banquet scene of Shah Abbas II in honor of Nader Mohammad Khan emir of Turkistan in 1646 (Figure 1). Also, another wall painting at Hasht Behesh Palace in Isfahan shows a woman playing the Kamanche (Figure 2).

A Tasnif – a vocal piece played in the modal system of Persian classical music – has been remained from the Zand period which is related to Lotf Ali Khan Zand (the last king of this dynasty), sang with Kamanche and Ney. Eugene Flandin, an Italian-born artist who lived in Paris, was sent to Iran on a mission in 1840 to collect information about Iran’s political situation. He talked about kamanche in his observation from Fat’h Ali Shah – second Qajar king of Persia – court; and described it a kind of Violin called Kamanche.
There were so many groups of jiggers called 'Dáste' in Zand and Qajar periods which some of them were courted and the others non-courted. The most famous of this Dastehs were master Zohreh and master Mina Dasteh in Fath Ali Shah monarchy. Zohreh and Mina were two famous singer and player women in this period which used Kamanche as one of the most important instruments in their Dasteh; although from the era of Lotf Ali Khan, the last king of the Zand dynasty, these Dastehs decreased but Kamanche stand up as one of the most important instruments in these groups. All these explanations revealed importance of Kamanche in Persian music history but from the end of Mozafaridin shah monarchy, the importance of kamanche decreased by coming violin to Iran. In last decades, by efforts of Ali Asghar Bahari, kamanche revived among Persian instruments.

2.2 Structure

The kamanche has a long neck including fingerboard which kamanche maker shapes it as a truncated inverse cone for easy bow moving in down section, peg box in both side of which four pegs are placed, and finial (Figure 3). Its body also has a lower spheroid chamber made from gourd or coconut shell or wooden staves such as blackberry, blackberry root, walnut, pear, maple, cherry or sourcherry – depending upon the geographic region where Kamanche maker lived – as a sound box, which is usually covered on the playing side with skin.
from a lamb, goat, deer or fish (Figure 3). At the bottom of the instrument protrudes a sort of spike to support the kamanche while it is being played (Figure 3). Therefore in English the instrument is sometimes named the spiked fiddle. It is played while sitting down and it is held like a viol. The end-pin can rest on the knee or thigh while seated in a chair. The kamanches appearing in antique Persian paintings have three strings. It is suspected that the fourth string was added in the early twentieth century as the result of the introduction of the European violin to Persia. Kamanche is usually tuned like ordinary violin (G, D, A, E) but it may alter depending on Persian music Dastghahs and the region of the country where it is played.

3 Golden section
3.1 History

The number \( \phi = \frac{1 + \sqrt{5}}{2} = 1.61803398 \ldots \) is named the golden ratio. It is also famous as, golden mean, golden section, divine proportion or divine ratio. The term golden section appears to first have been applied by Martin Ohm in his textbook Die Reine Elementar Mathematik in
the 1835. The first one who applies this term in English is James Sulley in his article on aesthetics in the 9th edition of the Encyclopedia Britannica in 1875. It seems that the symbol "Φ" was first applied by Mark Barr at the beginning of the 20th century in honor of the Greek sculptor Phidias, who as a number of art historians declared, made wide application of the golden ratio in his works.

It can be supposed that the golden section has perhaps been discovered and rediscovered during the history, which make clear why it goes under a number of names. Early user of Phi such as: Phidias (500–432 BC), a Greek sculptor and mathematician, deliberated phi and used it to the design of the Parthenon. Plato (428–347 BC), in his views on natural science and cosmology considered the golden section to be the key to the physics of the cosmos. Euclid (365–300 BC), in his book Elements, referred to separating a line at the point of phi as "separating a line in the extreme and mean ratio". This later gave rise to application of the term mean in the golden mean. He also related this number to the construction of a pentagram.

Leonardo Fibonacci born in Italy in 1175 AD, discovered the properties of the series the Fibonacci sequence, but it’s not definitive that he even understood its relationship to phi and the golden mean. His most notable contribution to mathematics was a work known as liber abaci, which became an influence to the Europeans for Arabic decimal system of counting over Roman numerals.

3.2 Golden Section in Music
Golden section emerges many times in music; the great classical composers like Mozart had a consciousness of the Golden Ratio and applied it to compose some of his well-known sonatas. Also Bartók, Debussy, Schubert, J.S. Bach and Satie applied the golden section in their composition. Surprisingly, musical scales are based on Fibonacci numbers and musical frequencies are based on Fibonacci ratios. Golden ratio has been applied in designing some musical instruments, for example Stradivarius applied the golden ratio in his violin, or Baginsky used the golden section in his method of constructing violins.

3.3 Geometry of Golden section
A line segment is divided into two sections such that the ratio of the original segment to the larger section is equal to the ratio of the larger section to the smaller section. If c is the original segment, b is the larger section, and a is the smaller section, then c = a + b and c/b = b/a. Thus, b is the geometric mean of a and c; the ratio is well-known as the Divine Proportion.

4 CATIA Software
CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite extended by the French company Dassault Systems and marketed worldwide by IBM. It has been written in the C++ programming language.

The software was produced in the late 1970s and early 1980s to extend Dassault's Mirage fighter jet, and then was implemented in the aerospace, automotive, shipbuilding, and other industries.

5 Methodology
Golden section has been used in designing of violin and other musical instruments but it has not been used in Persian instrument designing. For the first time, we used this ratio in designing an Iranian instrument. This ratio was used in the whole of instrument body and a kamanche was made by using obtained plans. Because of highlighted effect of sound box on the musical instrument's voice, we designed kamanche sound box by using Golden Section. Our design was drawn with CATIA software, although it can be drawn by simple design tools such as ruler and compass.

5.1 System Definition
We began by defining length A as 50 cm – conventional length among Persian kamanche makers. We divided A by Φ=1.618 repeatedly to generate some useful ratios, as shown in figure 4.

50 “total length of neck” …………………………… A=50 cm
50/1.618=30.9 “fingerboard length” ………………… A/Φ=B
30.9/1.618=19.09 “depth of sound box” ………….. B/Φ=C
19.09/1.618=11.79 “peg box; also width of skin” ………………… C/Φ=D
11.79/1.618=7.29 “Finial; also skin behind bridge” ………………… D/Φ=E
7.29/1.618=4.5 “skin in front of bridge” ………… E/Φ=F
30.9/4.5=35.4 “resonance length or distance between bridge and pawl” ………………… F+A
35.4/1.618=21.8 “width of sound box” ………... (B+F)/Φ=G
5.2 Designing Method

In figure 5, we have begun to design the cross-section of the sound box by drawing line $ab$ with length equal to $C$. Then, using the distance $D$ we located point $c$. Line $de$ with length equal to $G$ was drawn perpendicular to line $ab$, and centered on point $c$. In figure 6, we have located points $f$ and $h$ on line $de$ using $G/\Phi$. Two circles with radii $eh=hf$ were drawn with centers at points $f$ and $h$. These circles intersect line $de$ to define points $m$ and $n$. Also, at the intersection of these circles with line $ab$, point $g$ is defined. In figure 7, we have drawn arcs $st$, $tj$ and $sj$, with radii $en=dm$ centered at points $g$, $m$, and $n$. From point $b$ we drew line $op$ perpendicular to line $ab$ to complete the outline of the sound box.

6 Conclusion

The new method of designing *Kamanche* presented in this paper was based on an essential principle and that was keeping origin of the voice and the body of *Kamanche*. In order to develop the present method, other
traditional methods were also studied. The traditional methods in designing Kamanche were based on empirical methods and have not employed exact calculations. But this new method tried to design a Kamanche with precise formulas, and because of highlighted effect of sound box on the musical instrument's voice, we focused on designing sound box and then flourished it in whole parts of Kamanche. In fact, the traditional methods give their place to this novel method with more prestigious discipline with keeping them original and making a step toward more comfort. In our opinion, the made instrument has a warm voice. In comparison with traditional shape, our made instrument have gotten a more proportionate shape. Until now, no designing procedure or acceptable ratios have been proposed for this Iranian musical instrument. In addition, we expanded the Golden ratio throughout the whole instrument body. Then, based on the fact that the shape of musical instrument affects the sound, we tried to design a proportionate shape as well as possible. Some complementary acoustical experiments can help us to show the real effect of this new method on voice of Kamanche. Future works will include acoustical experiments on this Golden Kamanche.

References: