The Shapes of Sound. Organic Geometries, Harmonic Ratios and Ethnic Design

Domenico Mediati

Abstract

The matrices that define natural shapes have organic conformations, characterized by softness and flexuosity. Such peculiarities derive from inherent functional needs and frequently manifest as polycentric curves.
The shapes of natural space have often been adopted by artists, decorators and architects over the centuries. However, there is one particular field in which man has intensively applied these organic conformations. Shapes derived from nature, from the study of harmonic ratios, and from the laws of sound propagation have been used in the production of musical instruments since ancient times. They are often the result of autochthonous traditions, closely linked to a folk culture. Materials, shapes, and colors characterize them as ethnic design objects, in which the sound function does not forgot decorum.
The paper aims to highlight the connection between organic geometry, proportional ratios and the conformation of musical instruments: emblematic examples of a folk design that spontaneously combines art and technique, innovation and tradition, listening and vision. It is a process of analysis that, through direct survey, structure-from-motion techniques, three-dimensional modeling, and the study of geometries, aims to document ethnic shapes and traditions: traces that, over the centuries, have triggered processes of innovation based on experimentation 'poor' in material but rich in creativity.

Keywords: organic geometries, proportional ratios, polycentric Curve, ethnic design, musical instruments.

Visual and sound harmonies

A widely accepted interpretation of Genesis chapter IV attributes the origins of music to two half-brothers, Jubal and Tubalcainus, sons of Lamech and descendants of Cain. The former is defined as "the father of all zither and flute players" [1], while Tubalcainus as "the father of those who work copper and iron" [2]. In essence, they represent a musician and a blacksmith, or the convergence of two vocations –one artistic and the other operative– that make possible the enchantment of musical art.
This intertwining was highlighted by Franchino Gaffurio (1451-1522), one of the most important theorists and musicians of the 15th century. At the beginning of his *Theorica musicae*, he wrote: "Josephus and the Holy Scriptures relate that Jubal of the tribe of Cain first produced refined music with the zither and organ" [3] [Gaffurio 1492 cited in Grandi 2011, p. 29]. In 1558 Gioseffo Zarlino (1517-1590) resumed this concept in his treatise *Institutioni harmoniche*: "*Percioché (come dicono Mosè, Gioseffo, et Beroso Caldeo) avanti che fusse il diluvio universale [la scienza della musica] fu al suono de' martelli trovata da Iubale della stirpe di Caino*" [Zarlino 1558]. Numerous illustrations described this event, helping to propagate a tradition that would be widely spread throughout the Middle Ages and early Renaissance (fig. 1).
The relationship between the vibrations of Tubalcainus' hammers and Jubal's musical ratios is found in the famous episode narrated by Giamblico of Chalcis (c. 250-c. 330), in a different form and with a different protagonist. In

the *Vita di Pitagora* he wrote: "while [Pythagoras] was passing in front of a blacksmith's workshop, by divine fate he heard hammers which, beating iron over the anvil, produced echoes in perfect harmonic agreement with each other, except for a single pair. In those sounds he recognized octave, fifth and fourth chords and noted that the interval between fourth and fifth was itself dissonant but nevertheless capable of filling the difference in pitch between the two. Rejoicing that with the help of a god his purpose had come to fruition, he entered the workshop and after many trials discovered that the difference in the pitch of the sounds depended on the mass of the hammers" [Giamblico 300] [4]. Pythagoras understood that with four hammers having masses in ratios of 6, 8, 9 and 12, the full range of harmonic ratios with their intervals could be reproduced.
Boethius (475-524) also narrated this episode in *De institutione musica* (c. 520). Here, he tells that Pythagoras later replaced the masses of the hammers with a monochord: an instrument in which the length of the single string was varied according to the harmonic ratios described above. Thus, lengths geometric, which were more easily measurable, replaced masses.
Beyond the actual authorship on the discovery of harmonic ratios, it is certain that Pythagoras dealt with the criteria used by the musical instrument makers of his time, focusing on the mathematical ratios behind the sounds. The relationship between Jubal and Pythagoras is obvious [5]. Both deduced the sound range and numerical ratio laws of the harmonic system from the chiming of hammers on the anvil, highlighting a close relationship between music, mathematics and geometry. However, Pythagoras went further, developing a theory of harmonic ratios that closely relates music and shape, searching for the laws that link the sound and visual arts to the harmony of nature.
Franciscus Junius stated: "I will never tire of repeating […] the well-known sentence of Pythagoras: it is absolutely certain that nature never diverges from itself. Thus, it is. Now, those numbers which have the power to give to sounds the concinnitas, which is so pleasing to the ear, are the same which can fill our eyes and souls with admirable joy. Therefore, from the very music that has made numbers the object of deep investigation, and moreover from the objects in which nature has given high evidence of itself, we shall derive all the laws of determination" [Junius 1637, III, 2, 2]. Therefore, number allows us to grasp the harmonic ratios of nature by transforming them into visible and audible form. Converting harmonic ratios into geometric ones is to seek a material and spiritual connec-

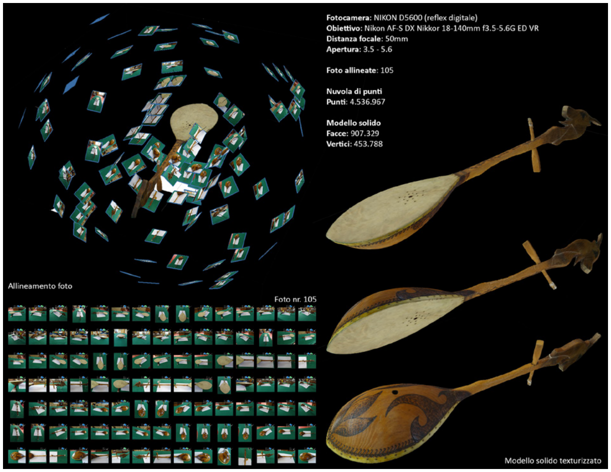
Fig. 1. From left: Jubal holding a psalter, second half of the 14th century. Vienna, Bibl. Naz., Cod. Nr. S.N. 2612, f. 25v; Jubal holding a psalter, 15th century. The Hague, Bibl. Naz., MMW, 10 B34, f. 23v; Jubal and Tubalcaino, 15th century. The Hague, Bibl. Naz., MMW, 10 C23, f. 26v.

tion between man and cosmic space. The number is the single matrix that joins the different ways of expressing this connection: "*quei medesimi numeri certo, per i quali avviene che il concento de le voci appare gratissimo ne gli orecchi de gli uomini, sono quelli stessi che empiono anco e gli occhi e lo animo di piacere meraviglioso* […] *caveremo dunque tutta la regola del finimento da musici, a chi sono perfettissimamente noti questi tali numeri: e da quelle cose oltra di questo, da le quali la natura dimostri di cosa degna et onorata*" [Alberti 1485, Book IX, chap. 6]. For Alberti, too, the link between music and shape is entrusted to a common tool for the elaboration of thought and creativity: number, that element that structures proportional relationships.
Musical instruments are the tangible sign of such a virtuous connection. They are capable of generating harmony in sound form, but they are also handiworks that reveal a free creative ambition and a deep connection with the laws of the cosmos and natural space.

From organology to ethnomusicology

The first systematic classification of musical instruments was by François-Auguste Gevaert (1828-1908) with his Traité général d'instrumentation (1863). He introduced a classification into four categories, depending on the vibrating material that makes the sound [6]. A few decades later, Victor-Charles Mahillon (1880-1922) also took up this approach. In the *Catalogue descriptif et analytique du Musée Instrumental du Conservatoire Royal de Musique de Bruxelles* (1880-1922) [7] he reintroduced Gevaert's quadripartite classification, which was to be the foundation of the classification theories still in place today [8]. However, this system of cataloguing had a narrow field of application. In fact, it was mainly used to catalog the instruments of Western classical music excluding many instruments that had, instead, a relevant importance in the development of instrumental techniques.
Toward the end of the 19th century, *comparative musicology* was born. This discipline intertwined with the coeval ethnographic studies and expanded the geographical and cultural limits of classical musicology. It was dealing with the oral musical traditions of all peoples, particularly those outside Europe. The studies of Erich Moritz von Hornbostel and Curt Sachs provided a crucial impetus for this innovative approach. In 1914, in an article entitled *Systematik der Musikinstrumente Ein Versuch* [9], the two scholars published a cataloging system that, with appropriate adaptations, is still the one widely used today for the classification of musical instruments. It is based on the way the vibration that produces sound is generated. The four first-level categories –*aerophones*, *chordophones*, *idiophones* [10], *membranophones*– branch off into further groups and subgroups allowing for constant updating and the inclusion of additional classes and subcategories [Sachs 2011, pp. 539-555] [11]. Compared to Mahillon's model it offered the advantage of greater flexibility, allowing any instrument to be included without cultural or geographic barriers. This facilitated a widening of horizons that led to the rediscovery of cultural, musical, and ethnographic traditions previously placed on the margins of official culture. Beginning in 1950, comparative musicology studies would take the name "ethnomusicology". A lexical mutation that coincided with a redefinition of research methods. Two figures, hitherto separate, became unified: that of the practitioner who collected documents in the field and that of the scholar who processed them. This led to a greater awareness of the close relationship between popular culture, local traditions, musical events, figurative traditions, and the shape and decorum of musical instruments.

Fig. 2. Lahutë, popular fidula, northern Albania. Structure-from-motion survey technique (shooting data and model processing), (survey and graphic elaboration by the author).

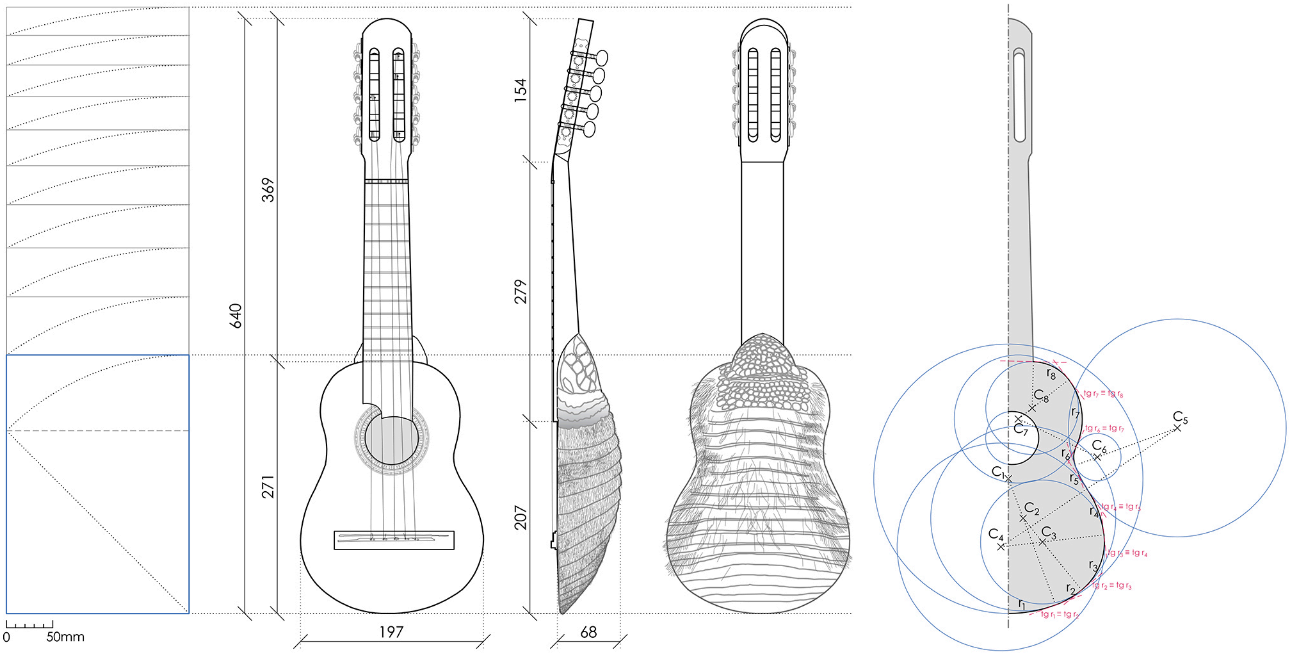


The shapes of sound

The importance of proportional ratios in sound modulation was evident from classical antiquity. The *tetrachord* expressed the consonances on which the Greek musical system was based: octave, fifth and fourth. They can be expressed by the progression 1:2:3:4. In addition to these simple intervals, the tetrachord also contains the two composite chords known to the Greeks: the octave plus fifth (1:2:3) and the two octaves (1:2:4). This discovery made people believe that they had finally found the harmonic law governing the universe, upon which would be based the symbolism and numerical mysticism that would influence human thought for the next two millennia. The tetrachord becomes materially concrete in the Greek lyre, mythologically attributed to Hermes. The length of its four strings reproduces the 1:2:3:4 progression, becoming a favored musical instrument in classical Greece.

The length of strings or the vibrating air column, the mass of idiophone bodies or the tension of membranes, respond to precise physical and proportional laws that have always allowed complex tonal variations. However, the focus on proportional ratios goes far beyond the purely sonic aspect. Precise proportional ratios are often found in the shapes of musical instruments, indicating a focus on visual as well as sonic harmony.
The graphic analyses that follow were carried out on some instruments housed at the *Museo dello Strumento Musicale di Reggio Calabria*. The surveys, initially made by direct and photographic methods, have recently been implemented with modern structure-from-motion techniques (fig. 2). Both methods have allowed for 3D models, orthogonal projections, and analyses of shapes and geometric arrays. Some of these tools were destroyed or damaged in an arson fire on November 4th, 2013, so the corresponding drawings represent the only documentation still available [12].

Fig. 3. Armadillo charango, plucked lute, Argentina. Soundbox made from the armor of an armadillo. Orthogonal projections with polycentric curve and proportional ratios (graphic elaboration by Domenico Mediati, Filippo Carmina, and Michele Casella).



Geometric proportions and harmonic ratios

The outlines of the soundboxes of some chordophones are inscribed in well-defined dynamic rectangles. This reveals an often uncultured and unconscious attention to established formal and geometric balances. Such is the case with the armadillo *Çharango* in figure 3, which belongs to the category of plucked lutes. It is an instrument widespread in Argentina's Andean region and is derived from the *vihuela de mano*, introduced to Latin America in the 16th century during the Spanish conquest. The *Çharango* consists of a soundbox, a short arm, and five double strings. At one time, the soundbox was made from the armor of an armadillo, now no longer used because it is a protected and endangered fauna.

The specimen shown here was destroyed in the November 4th, 2013 fire. It is an instrument of complex and uncommon workmanship. It features a soundbox inscribed in a dynamic rectangle with a side ratio of 1:√2. Its polycentric conformation is drawn on a wooden plank that acts as a support for the armadillo carcass, shaped with a slight curvature to meet functional and sonic needs. The same dynamic ratio is also found in the soundbox of the *Lahutë* shown in figure 4a. It belongs to the folk fidule category and comes from northern Albania. *Lahutë*

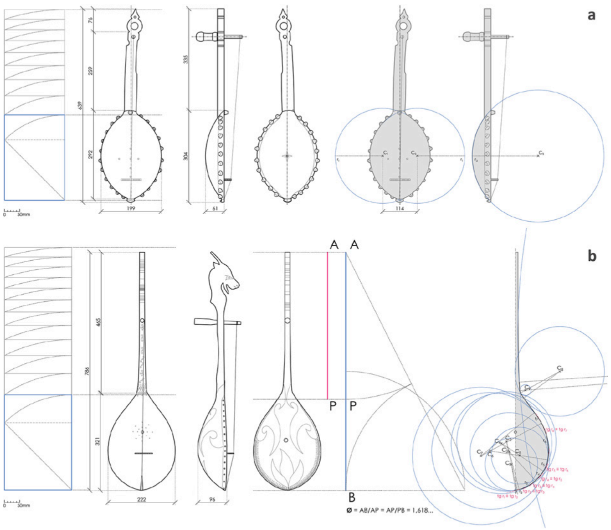


Fig. 4. Top: Lahutë, folk fidula, northern Albania (graphic elaboration Domenico Mediati and Evangelia Almaliotou). Bottom: Lahutë, folk fidula, Kosovo (fig. 4a). Below, orthogonal projections with polycentric curves and proportional ratios (graphic elaboration by Domenico Mediati, Vincenzo Romeo and Nicodemo Spatari), (fig. 4b).

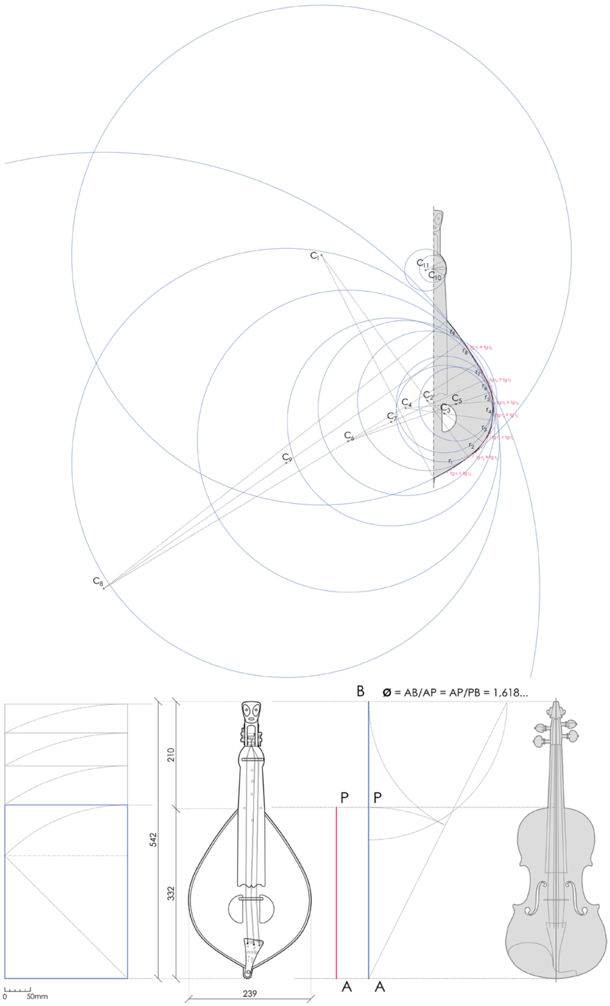
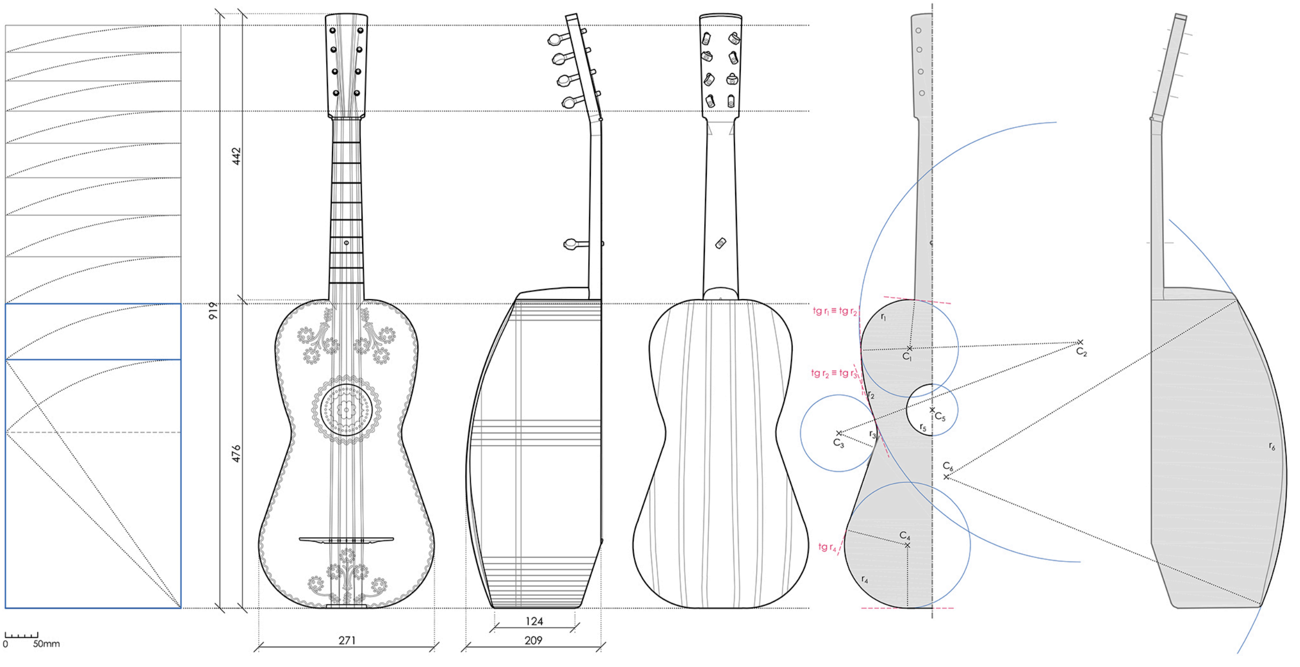


Fig. 5. Crete lyre, popular fidula, Crete. Orthogonal projections with polycentric curve and proportional ratios (graphic elaboration by Domenico Mediati and Maria Montagna Barreca).

are bowed lutes, in which the body and neck are made of wood. The intersection of two circles, whose centers are about 114 mm apart, geometrically defines the frontal profile of the exemplar in figure 4a. Seen from the side it shows a slight curvature of the soundbox that will be bridge by an animal skin membrane. The single taut string is space via a conspicuous and scenic wooden key. Rubbing the string via a special bow produces the sound.
The *Lahutë* of figure 4b also has a soundbox inscribed in a dynamic rectangle with ratio 1:√2. However, its wooden structure has a more complex profile, with two polycentric curves: one with centers ranging from C_1 to C_7; a second consisting of only two circles whose centers are C_8 and C_9. The two curves are connected by a straight section. In addition, the depth of the soundbox has a more pronounced curvature than the *Lahutë* of figure 4a. The terminal shape of the deer head neck is particularly suggestive. Moreover, the total size of the instrument, the length of the neck, and the height of the soundbox set a relationship approaching a golden ratio: Ø = AB/AP = AP/PB = 1.618... The same proportion is found in the *Crete lyre* in figure 5. It is an arm lyre that, beginning in the 15th century, represents an evolution of the folk *fidula* and can be considered a significant anticipation of the violin. Its shape differs little from medieval models and resembles that of the *ribeca* in its polycentric pyriform case with curved bottom [13]. The golden ratio between total size, case, and arm still is generally maintained in modern contemporary violins.
A more unusual proportional ratio is found in the Bisignano *chitarra battente* (figs. 6, 7). It is a typically Italian instrument, the type of which dates back to the 17th-18th centuries. It has a very voluminous soundbox with a curved bottom. A funnel-shaped parchment bellows is applied over the resonance hole and inserted into the case. Besides acting as a vibrating *membrane* it is also a choreographic decorative

Fig. 6. Chitarra battente, plucked lute – historical guitar, Bisignano, Italy. Orthogonal projections with polycentric curve and proportional ratios (graphic elaboration by Domenico Mediati and Elisa Gentile).



element that characterizes the instrument. Its soundbox has a very distinctive shape: squat when viewed from the side but very slender when viewed from the front. It is quite different from that of contemporary guitars. The ratio of the maximum width to the height of the case is very close to a dynamic 1:√3 rectangle, a proportional ratio that was common in Baroque and early classical guitars of the 18th century but is generally no longer found today.
Its volumetric conformation is more precise and defined than the chordophones previously shown in this section. It reveals a construction process based on precise schemes and models, although handcrafted. In opposition, the volumetric irregularities present on the two *Lahutë* and the *Crete Lyre* reveal an approach more related to empirical procedures and formal models handed down by tradition.

The 'organic geometries'

The curves of natural shapes respond to organic conformations, characterized by softness and flexuosity. This peculiarity reveals intrinsic functional needs and often shows itself with polycentric curves. They are characterized by the absence of cusps and points of discontinuity. The circumferential arcs that define their profile are aggregated to ensure the continuity of the curve. This characteristic is guaranteed by an essential geometric condition: at their point of contact (or point of bending of the polycentric) two adjacent arcs admit the same tangent line [14]. This allows for continuous polycentric profiles that give rise to complex shapes with an extraordinary geometric and formal quality. In fact, the organic shapes of nature have often been used by artists, decorators and architects over the centuries. One of the fields in which man has intensively applied such geometric conformations is precisely that of lutherie and, more generally, in the manufacture of musical instruments. From the earliest times, organic shapes, derived directly from natural space, the study of harmonic ratios and the laws of sound propagation, have been widely used in their production.
The most classic examples are found in the conformation of the soundboxes of stringed instruments, skillfully shaped by luthiers so as to give continuity to the surfaces. In their spatial development, polycentric curves often give rise to double-curved surfaces; sometimes shaped with extreme precision, other times achieved by more empirical craft processes.

Fig. 7. Chitarra battente, plucked lute – historical guitar, Bisignano, Italy. Views from the 3D model (graphic elaboration by Elisa Gentile).

They derive from converging needs: sonic necessities related to the reflection and propagation of sound, functional constraints depending on the posture with which the musician forks the instrument and formal choices revealing the sedimentation of figurative cultures closely linked to the instrument's land of origin. These artifacts disclose a synthesis of multiple aspects –form, history, function, tradition– that allow the creation of design objects with an amazing expressive quality. They are often the result of traditions closely linked to a folk culture. Materials, shapes, and colors characterize them as ethnic design objects in which sound function does not forgo decorum. The polycentric profile of the soundboxes helps proper sound amplification, but it is also the hallmark of many instruments. They are the result of an unconscious and 'uncultured' search for complex geometries, closely related to the shapes of nature.

In the most ancient instruments, as well as still today in primordial peoples, the soundbox is often made from remnants of natural elements: shells, animal armor, coconut rinds, emptied and dried gourds, etc. It is a spontaneous process of reuse that enhances nature's waste, senses its expressive and functional potentiality and transforms it into sound objects of high craftsmanship.

The *kora* in figure 8 is a lute harp from West Africa, Sahel area. Its soundbox consists of a gourd that has been cut, hollowed out, and covered with animal skin, usually antelope or cow skin. A wooden handle is inserted into the soundbox to which two rows of strings are anchored: 10 on one side and 11 on the other. Originally these were made of leather but nowadays they are made of nylon or harp strings are used.

The cut of the gourd results in a soundbox whose profile is similar to an elliptical shape. It is a natural element that, with appropriate workmanship, responds perfectly to harmonic

Fig. 8. Kora, lute harp, West Africa, Sahel Zone. Left: orthogonal projections. Right: photos (graphic elaboration Giacomo Giuseppe Franchini and Michelangela Vela).

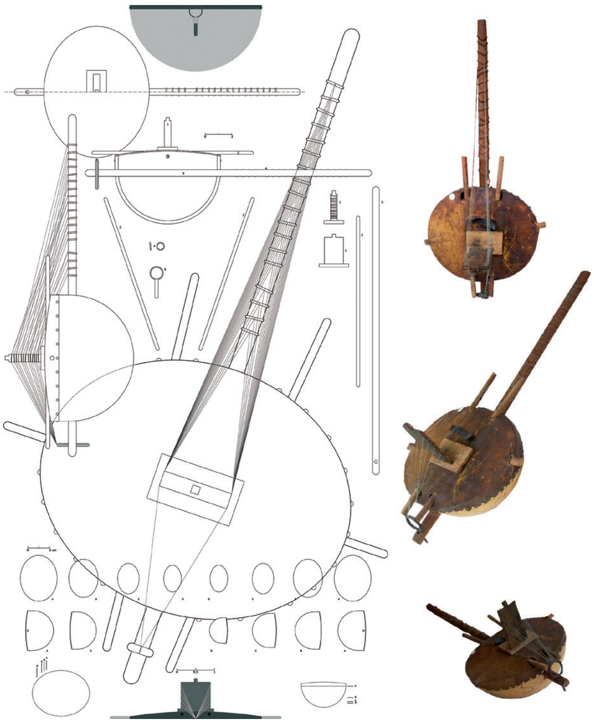
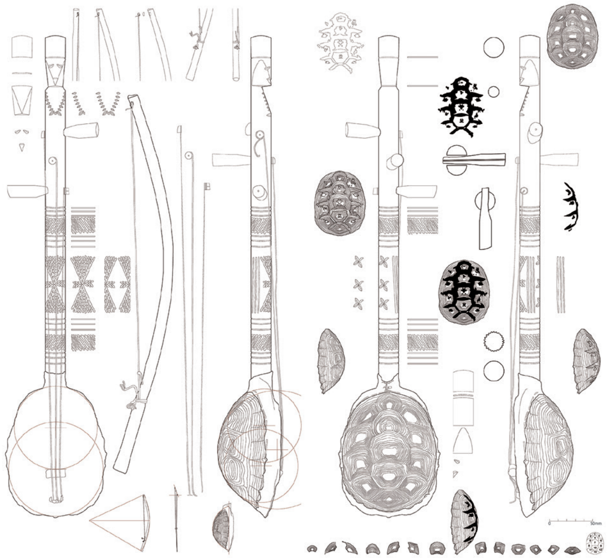


Fig. 9. African violin, folk fidula, North Africa. Soundbox made from tortoise carapace. Orthogonal projections (graphic elaboration by Caterina Candido).



needs, minimizes production processes by adapting them to autochthonous artisanal labor, and ensures an extremely interesting formal rendering.
Sometimes, animal armor is used, as already illustrated in the case of *Çharango* (fig. 3). The *African violin* specimen in figure 9 is most interesting. Its soundbox is made from the carapace of a tortoise, covered with a layer of stretched and stitched leather. A carved wooden handle, painted red with blue ends, is attached to the body. The ethnic carvings, the vivid colors of the neck and the perfect connection with the carapace make this instrument a very striking example (fig. 10).
In contrast to Western traditions in which instruments show chromatic sobriety, in instruments of African origin, color plays a key role. Its folk culture is rich in strong sensory stimuli that manifest musically in engaging rhythmic expressions. This characteristic is not exclusive to the musical field but we can also find it in craft productions. In them, predominantly geometric carvings and decorations are flanked by bright colors capable of generating strong visual stimuli: perceptual energies derived from the light intensity typical of the environmental context.
The textile tradition in Africa has an ancient history, evidenced by artifacts found throughout the continent. Turning and weaving techniques have been preserved over the centuries. *Kente* cloth, produced by the Akan ethnic group, dates back at least to the time of the Ashanti empire that took the place of the Ghana empire, which fell in the 1200s. Such fabric consists of brightly colored interwoven stripes with special symbolic meanings: royal yellow is a sign of beauty and fertility; brown represents health; and blue symbolizes peace and harmony. It is a

Fig. 10. African violin, folk fidula, North Africa. Soundbox made from tortoise carapace. Views from the 3D model (graphic elaboration by Caterina Candido).

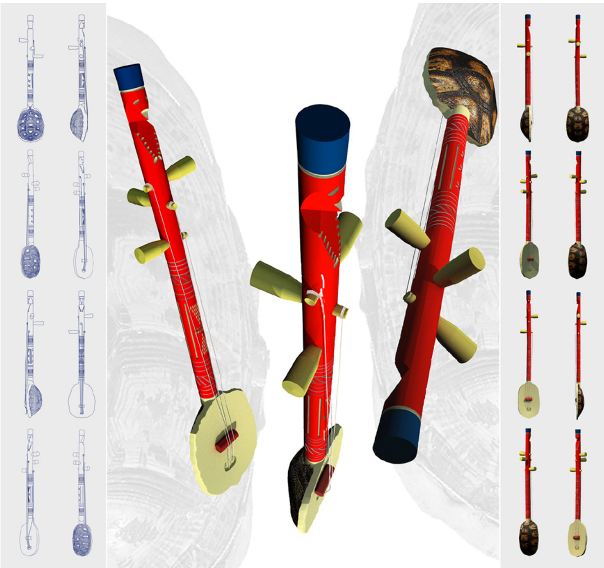


Fig. 11. Tamani, hourglass tubular drum, Mali. Orthogonal projections with polycentric curve and proportional ratios (graphic elaboration Domenico Mediati, Francesco Coscarella, and Xavier Hottot).

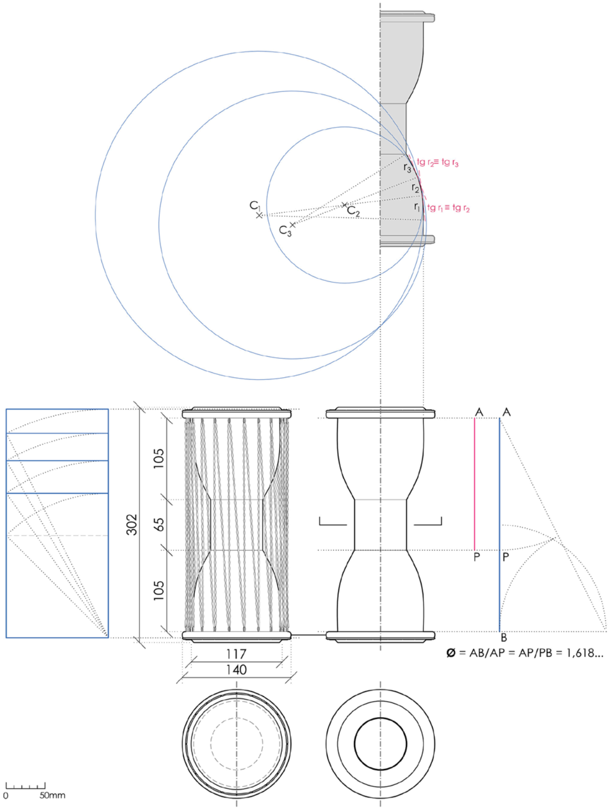


Fig. 12. Tamani, hourglass tubular drum, Mali. Left: views from the 3D model. Right: photos (graphic elaboration Francesco Coscarella and Xavier Hottot).

technique that also spread to neighboring Northwest African countries, giving rise to similar productions.
The characteristics of these fabrics –chromatic intensity and geometric decorations– are also found in some musical instruments from the area. The Tamani shown in figures 11 and 12 is a tubular hourglass drum, probably from Mali. It is also called a 'talking drum' because the sounds it produces recall the tonal qualities of some Malay languages. The Tamani has an hourglass-shaped central body made of wood, often covered with typical traditional decorations. Its profile has a polycentric curve with three arcs of C_1, C_2 and C_3 centers (fig. 11). The present exemplar has a fabric covering that recalls the textures and colors of *kente* fabric. Two membranes stretched by laces are attached to either end of the hourglass. The musician places the instrument under the armpit and through more or less arm pressure stretches or loosens the membranes while striking the instrument with a curved stick. In this way it is possible to articulate sounds according to a wide tonal range.
The instrument, which is small in size, has surprising sonic power. Its musical qualities are perfectly matched by its formal and chromatic harmony. The body of the hourglass is marked in height by three partitions according to a precise golden ratio, while the figure circumscribing the front view of the hourglass is very close to a dynamic rectangle with ratio of sides $1:\sqrt{6}$. Everything is completed: sonorous and formal harmony, proportional balance, and chromatic articulation make the *Tamani* a representative instrument of West African musical and craft traditions. It is an ethnic design object with remarkable expressive qualities that combines visual and sonorous harmony with relevant cultural significance. The *Tamani* is the instrument favored by griots, poets and singers who in West Africa take on a social-ethical role and are responsible for preserving the oral traditions of their ancestors.

Conclusion

The shapes of musical instruments reproduce the soft geometries of nature, respond to functional needs and give perceptual emphasis to objects: they are a prelude to the sonic harmony they are capable of giving off. It is the same harmony found in the growth laws of natural products, lacking rigid rational meshes but with their own intrinsic logic based on 'flexible' geometries. The polycentric curve often defines their profiles and determines a surface continuity that generates visual and sonic harmonies. Proportional ratios –dynamic rectangles and golden proportions– express a formal balance that sometimes becomes a constructive canon. Everything is the result of unaware research and shows experiences, traditions and figurative sensibilities not yet globalized which are firmly anchored in a universal knowledge that does not give up its autonomy. Number, shape, geometry and sound are faces of the same harmony that although in a common matrix find multiple forms to express themselves. It is a primordial knowledge to be preserved, evidence of a spontaneous process of popular knowledge formation. Over the centuries, it has triggered processes of innovation leading to the most sophisticated technical and formal expressions, rooted in experimentations 'poor' in material but rich in creativity.
The surveys and representations presented in the paper show overt or underlying relationships and aim to highlight proportional ratios and connections between organic geometry and the conformation of musical instruments: emblematic examples of an ethnic design that spontaneously integrates art and technique, innovation and tradition, hearing and vision. It is a process of analysis that, through survey, 3D modeling, and study of geometries aims to give shape and meaning to the sound and design of tradition.

Acknowledgements

This paper is an implementation of research carried out by the author together with Rosario Giovanni Brandolino [Brandolino, Mediati 2013]. Here, surveys with structure-from-motion techniques of some of the specimens analyzed were carried out and the topics of proportional ratios, polycentric curves and organic conformations were explored.

Notes

[1] *Genesi*, 4,21.

[2] *Genesi*, 4,22.

[3] Original text: "*musices disciplinam* […] *Iosephus ac Sacre Littere Iubalem, de stirpe Chaym, cytara et organo primum instituisse ferunt ex numeraro malleorum sonitu exquisitam*".

[4] When the mass of one hammer was twice the mass of the other (1:2) the sound produced was the octave (*diapason*); with a ratio of 2:3 the fifth (*diapente*) was obtained; with a ratio of 3:4 the sound reproduced was a fourth (*diatessaron*); with a ratio of 8:9 the tone was obtained.

[5] References to the relationship between Jubal and Pythagoras are in Book III of the Etymologiae of Isidore of Seville (560-636): "*Moyses dicit repertorem musicae artis fuisse Tubal [Jubal], qui fuit de stirpe Cain ante diluvium. Graeci vero Pythagoram dicunt huius artis invenisse primordia ex malleorum sonitu et cordarum extensione percussa*" [Isidore of Seville 1476, III, 16/1]. Transl.: "Moses says that Tubal [Jubal], of the line of Cain, invented music before the Flood. However, the Greeks say that the principles of this art were discovered by Pythagoras from the sound of hammers and strings being stretched and struck".

[6] Air column (aerophones), string (chordophones), membrane (membranophones), the body of the instrument itself (autophonics).

[7] The catalog, published between 1880 and 1922, consists of five volumes with a total of 2,300 pages. It analyzes and classifies the entire collection, consisting of 3,300 instruments, in the museum of the Royal Conservatory of Brussels.

[8] The proposed categories are as follows: vibrating string instruments (chordophones); vibrating air instruments (aerophones); vibrating membrane instruments (membranophones); self-vibrating instruments (autophones).

[9] The essay was published in the volume *Zeitschrift für Ethnologie*. In 1961, the Galpin Society Journal published a translated version in English.

[10] The term 'autophonics', present among the categories proposed by Mahillon and Gevaert, is replaced in the Hornbostel-Sachs classification with idiophonics. This choice comes from the intention to avoid misunderstandings between terms that have very similar meanings: autophonics are instruments that emit sound totally automatically (e.g., music boxes, pianolas); idiophones produce the sound vibrations with the body of the instrument itself.

[11] For a concise but exhaustive discussion of classifying methods of musical instruments, see: Oling, Wallisch 2007, pp. 29-38.

[12] Among the instruments destroyed in the 2013 fire here are: the *Armadillo Charango* from Argentina (fig. 3) and the *Chitarra battente* from Bisignano (figs. 6, 7).

[13] The ribeca is a medieval instrument of Arabic origin (***rebāb***), which arrived in Europe via Spain. Before reaching its final name, it took on the names *rebel* and *rubeba* [Modena 2010, p. 126].

[14] For an in-depth study of polycentric curves, see: Ragazzo 2011.

Author

Domenico Mediati, Department of Architecture and Territory, Mediterranea University of Reggio Calabria, domenico.mediati@unirc.it

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