Fidular

Supplementary PDF

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fidular: a modular system for fiddles from Southeast Asia, East Asia and the Middle East

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ABSTRACT

fidular is a modular fiddle system that enables components like resonating chamber and strings to be easily interchanged across bowed string instruments from Southeast Asia, East Asia and the Middle East with unprecedented cross-compatibility. This paper first summarizes the essential components common to a variety of Asian fiddles. The information was gained firsthand through an apprenticeship with luthiers in northern Thailand and interviews with fiddle makers from Vietnam, Myanmar and South Korea. The acoustics of these fiddles are highlighted in context of the well-documented physics of western bowed instruments such as the violin. The paper then implements a modular fiddle design that strictly adheres to both acoustic mechanisms and original forms of traditional fiddles, while opening the door for radically new chamber designs and hybrid acoustic-digital chambers. These claims are evaluated in context of a functioning prototype of *fidular*.

Author Keywords

Modular instruments, traditional fiddles, bowed string instruments, Thai Saw, Vietnamese Danho, Korean Haegum, Chinese Erhu

ACM Classification

H5.5 Sound and Music Computing

1. INTRODUCTION

From 3D-printed flutes [1], carbon fiber violins [2] to hybrid acoustic-digital guitars [3], musical instruments have been augmented and re-imagined in incredible ways using new scientific tools, fabrication methods and sensor technologies.

These innovations however, have largely been limited to Western musical traditions. Barbosa et al. [4] underscored how Digital Music Interfaces (DMI's), for example, rarely fall outside of European and North American traditions. Likewise, in physics, research on the acoustic mechanisms of traditional instruments [5,6,7,8] pales in comparison to textbook literature on Western instruments like the violin [9] and guitar [10].

Lack of research, coupled with declining cultural interest in traditional music, have left traditional instruments like the Chinese *Banhu* and Japanese *Kokyu* fiddles, let alone the relatively unheard-of Thai *Khim* and Vietnamese *Danbo* dulcimers, in a state of "innovation stasis".

This worrying trend is slowly changing. Young and Fujinaga's *AoBachi* is a DMI that wirelessly tracks a performer's gestures while performing on the Japanese *odaiko* drum [11]. Barbosa et al. developed the *Giromin* and *Pandivá* interfaces in context of popular music in the Brazilian Northeast [4].

In Korea, Kapur et al. augmented the traditional *haegum* fiddle and *janggu* drum with Arduinos and sensors [12]. In Japan, Takahashi et al. implemented an electric *koto* [13] while in India, Borkar invented and performs on an *e-sarod* [14].

However, not much attention has been given to re-designing these instruments at a structural level. Traditional fiddles for example, have remained largely unchanged in design and material for centuries.

Consider Zoran et al.'s radical guitar design with a replaceable resonator, the *Chameleon Guitar* [3]. Piezo pickups on the interchangeable resonating panel connect to an embedded DSP chip that computes the final and complete sound. Zoran's earlier concept design, the *re-Acoustic guitar* [15], proposed a guitar with six interchangeable resonators for each of the guitar's six strings. User can customize the material, appearance and sonic qualities of each chamber using digital fabrication. Bernadac's *3Dvarius* [16], the first 3D printed violin, features new internal and external structures optimized for 3D printed materials.

The author was inspired to integrate this spirit of structural innovation with traditional bowed fiddles from Southeast Asia, East Asia and the Middle East.

2. MODULAR FIDDLES

2.1 Context

Readers may be familiar with the *Erhu* or "Chinese Violin". The two-string bowed instrument produces a high pitched sound and is the most well-known of traditional Asian fiddles.

In this paper, we define "fiddle" as a bowed instrument with these prototypical features (Figure 1A): 1.) a resonating chamber or tube 2.) a front panel or skin stretched across the chamber top 3.) a long shaft with tuning pegs 4.) a set of two and sometimes three strings and 5.) a bow (not pictured).

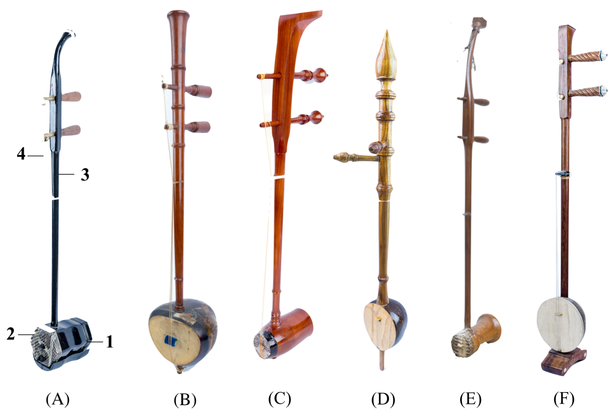

Fig. 1 Traditional bowed fiddles

The *Erhu* (A) is just one of many fiddles from across East Asia, Southeast Asia and the Middle East sharing these ubiquitous features. Figure 1 shows the Thai *Saw-U* (B), *Saw-Duang* (C), *Sloh* (D), Vietnamese *Danho* (E) and the Chinese *Banhu* (F).

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2.2 Existing technologies

Few technologies exist for traditional fiddles. To the author's knowledge, Kapur et al.'s *eHaegum* is one of few published works on augmenting traditional fiddles [12]. Chan developed an origami-like *erhu* with collapsible chamber and foldable shaft [17]. Opapand modified the Thai *Saw-U* with a new bridge design [18]. Some fiddle makers have experimented with guitar and violin pickups in fiddle chambers [19].

However, none of these examples seek to modularize traditional fiddles in the cross-cultural manner proposed here. Patents describing modular instruments [20, 21], have yet to propose mechanisms for traditional fiddles.

2.3 Novelty

This paper presents a modular fiddle system, *fidular,* that enables components like resonating chamber and strings to be easily interchanged across traditional bowed instruments with unprecedented compatibility. Through a purely acoustic mechanism, users can quickly swap the mellow coconut of the Thai *Saw-U* for the snakeskin chamber of the Chinese *Erhu*, all while retaining the brass strings of the Iraqi *Joza,*

The process of re-designing common mechanisms across traditions, such as shaft and tuning pegs, was informed by firsthand experience from an apprenticeship with luthiers in northern Thailand, interviews with fiddle makers from Southeast and East Asia and the author's prior work on violin acoustics [22]. The paper focuses on fiddles from Southeast Asia such as the Thai *Saw* and Vietnamese *Danho*—which have remained largely absent from research in acoustics and new musical instruments—as well as fiddles from East Asia and the Middle East due to near-identical acoustics and structural components.

In this paper we discuss a.) common fiddle structures and acoustics b.) the motivation, process and considerations behind *fidular's* design c.) an evaluation of the functional prototype and d.) the new technologies *fidular* opens up for traditional fiddles. An acoustic analysis alongside FEM simulation is beyond the scope of this paper and is separated into a manuscript for future publication [23].

3. BOWED FIDDLES

3.1 Overview

A fiddle's distinct timbre comes from a culture's unique combination of materials and geometries. Table 1 summarizes different material combinations from a collection of fiddles [40, 41, 42]. The author had first-hand access to fiddles marked with an asterisk while developing *fidular*.

Table 1. Fiddles from East Asia, Southeast Asia and Middle East

Name	English	Origin	Skin	Chamber
ซออู้	***Saw-U****	Thailand	Calf	Coconut
ซอด้วง	***Saw-Duang****	Thailand	Snake	Wood
ຊອອູ້	***Saw-U****	Laos	Calf	Coconut
ទ្រអ៊ូ	***Tro****	Cambodia	Calf, Snake	Coconut, Wood
Đàn hồ	***Danho****	Vietnam	Lizard	Wood
الربابة	*Rebab*	Indonesia	Parchment	Wood
جوزه	*Joza*	Iraq	Sheep	Wood
کمانچه	*Kamancheh*	Iran	Fish, Goat	Wood
胡弓	*Kokyu*	Japan	Cat	Wood
해금	***Haegum****	Korea	Wood	Lacquer, Wood
板胡	***Banhu****	China	Wood	Coconut
二胡	***Erhu****	China	Snake	Wood

Moreover, the choice of string—steel, thread, silk, brass or nylon—also contribute to differences in timbre.

Under the *Hornbostel-Sachs* instrument identification system, the fiddles in table 1 are classified as "spike lutes" or "spike fiddles" under code 321.31 [24]. The "spike" refers to the shaft penetrating the chamber. For brevity, the author uses "fiddle" to denote this family of bowed instruments.

3.2 Physics

It is crucial to differentiate between *cosmetic* differences and *acoustic* differences in fiddle shapes. Skin material changes timbre while ornamentations on the tuning peg have no effect.

To the author's knowledge, there are no publications detailing the acoustic mechanisms on how fiddles produce sound. Research exists for *plucked* string instruments including the Indian *sitar* [8] and Persian *setar* [7], but not *bowed* string instruments. Although Zhao et al. and Wu et al. published measurements of Sound Power Level (SWL) from Chinese fiddles like the *Zhonghu, Erhu* and *Yehu* [5,25,26], these studies only measure final output of sound in an anechoic room.

There have been no published analyses on the frequency response of individual components such as the bridge nor mathematical models behind spectral peaks as found in research for the violin (Figure 2) [27, 28].

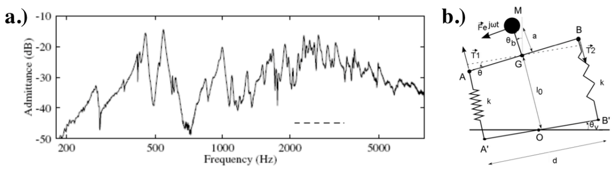

Fig. 2 Violin bridge freq. response (a), corresponding model (b)

Fortunately, many conclusions on the acoustics of fiddles can be drawn from the rich literature of violin physics. Although an independent study on fiddles is greatly needed, comparisons between the two instruments were crucial in informing the design process.

Briefly, a violin produces its sound in three steps. For a detailed treatment, the author recommends Cremer's excellent "Physics of the Violin" [9].

First, friction from a moving bow causes the string to vibrate. Unlike a plucked string that rapidly decays, the bowed string is subject to a constant force and generates a signal with many harmonics: a sawtooth wave (Figure 3).

Since the boundary conditions of the string on a violin and fiddle are identical—bridge on one end and finger holding down on the other—we can assume to first order the fiddle exhibits a similar string behavior when it is bowed.

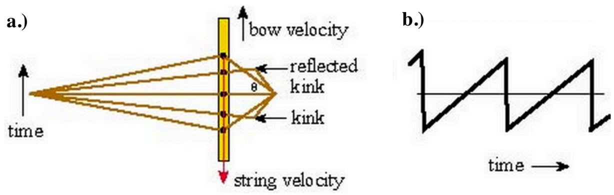

Fig. 3 String movement on bridge (a), sawtooth force on bridge (b)

Second, vibrations from the string are transferred to the bridge. The violin bridge has its own frequency response that filters the signal before it enters the body (Figure 2a).

Likewise, the various geometries of fiddle bridges from arches to simple blocks also filter the signal from the strings before reaching the resonating chamber's front skin (Figure 4).

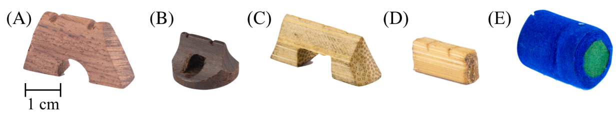

Fig. 4 Bridges of A.) Korean *Haegum* B.) Chinese *Erhu* C.) Chinese *Banhu* D.) Thai *Sloh* E.) Thai *Saw-U*

Lastly, the violin bridge drives the violin plate. The plate's eigenmodes are responsible for the various peaks in the body's frequency response. Thus the signal is filtered a second time by the body before becoming the "final sound" of the violin. At this point, the acoustics of violins and fiddles diverge significantly.

Vibrations from the fiddle bridge only drive the front skin. The shape, size and material of the skin affect its eigenmodes and the sound produced. However, the fiddle chamber does not contribute to vibrations. It is simply too thick. For example, the Thai *Saw-U* is made from wood 12 mm thick while the Chinese *Erhu* is 7 mm thick. In a violin, the entire wooden body of the instrument vibrates because the plates are only 3 mm thick and are connected by a sound post. The chamber of a fiddle cannot be treated as analogous to the violin body.

3.3 Fiddle chamber as waveguide

When one shouts to someone far away, they instinctively cup their hands around their mouths. The cupped funnel functions as a passive amplifier, focusing the sound to increase amplitude in the forward direction. The chamber of a fiddle plays a similar function, with one added feature.

Careful inspection of interior and exterior geometries of chambers from Thailand, Laos, Cambodia, China, Vietnam and Korea show marked differences.

The Korean *Haegum* has a protrusion constricting the air column near the front before opening wide at the back (Figure 5A). The Vietnamese *Danho* (A) has an air column that shrinks, then expands and terminates with a horn shaped back. The Thai *Saw-U* decreases in diameter and gently tapers outwards (C).

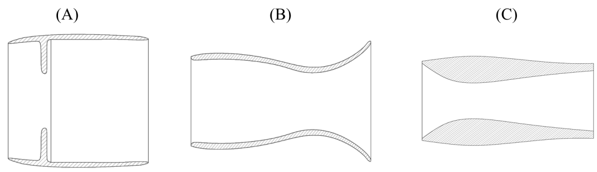

Fig. 5 Cross section of various fiddle chambers

When asked about geometry, the Vietnamese fiddle maker described how it "compressed" and "expanded" the sound waves [29]. The Korean fiddle maker stressed he "deliberately" shaped the tube this way since it directly affected sound [30].

These qualitative descriptions coupled with acoustic theory provide strong evidence to support the form and function of these tubes as *waveguides*. Waveguides in the acoustic domain have been used to increase off-axis response of speaker drivers [31] and model the propagation of air in the column of wind instruments [32]. As a waveguide system, the vocal tract is modelled as a long tube with wide and narrow sections (Figure 6) [33,34], exactly like the fiddle tube.

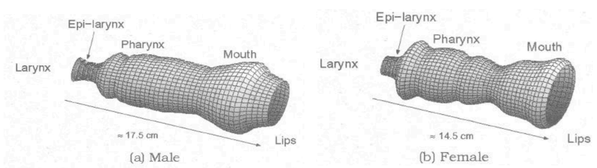

Fig. 6 Male and female vocal tracts as waveguides

Using the range of frequencies and dimensions in Zhao et al. and Wu et al.'s papers [5,25,26], we obtain wavelengths that satisfy the planar wave condition in circular waveguides ($\lambda > 1.7D$) [34]. This is not surprising given the tube dimensions are on similar length scales to vocal tracts, speaker drivers and air columns of wind instruments.

As mentioned earlier, a paper in progress [23] expands this topic with acoustic analysis and FEM simulation. The author included this discussion here to clarify the acoustic motivations behind the design of *fidular*.

The term "tube" or "chamber" will be used instead of "*resonating* chamber," a misnomer from ethnomusicology.

3.4 Relevance to design

Since the tube is a waveguide and not a resonating body; size and geometry of the tube are more important than material. Beyond wood and coconuts, one is now free to design tubes and chambers with new geometries from 3D printed polymers or machined composites.

With regards to the vibrating skin, material is more important than shape. The different densities of calf, snake and lizard skin cause different modes of vibrations. Whether the skin is circular, heart shaped, hexagonal or octagonal can also influence the modes, but the change in partials is not as significant compared to changing materials.

Various string materials alters density and thus the initial waveform shape. This transforms the final sound in the same way nylon guitar strings sound different to steel strings.

Although other components such as the shaft and tuning pegs play a role in vibrations, their contribution to the final sound—as is the case in a violin—is insignificant and can be ignored.

4. FIDULAR = FIDDLE + MODULAR

4.1 Motivation

The components of a fiddle are traditionally bonded together using glue and sawdust. In some cases, the components are held together using tension from the strings that have been tied semi-permanently and are very difficult to remove. The player is not supposed to "tamper" with the instrument beyond the craftsman.

A modular fiddle has many advantages. Rather than distinct fiddles limited to their country of origin, *fidular* unifies the various fiddles into one integrated cross-cultural system. Musicians can use different combinations of chambers and strings from across cultures to modify the fiddle's intrinsic timbre and acoustic "personality".

The process is akin to changing lenses and filters on a DSLR camera. Photographers own a collection of lenses as each one imparts a unique "visual" character and perspective to the final image. A fiddle player with cross-cultural chambers can choose the one most appropriate for a particular style or musical expression.

We imagine players developing particular bonds with a chamber's qualities beyond its cultural setting. The mellow tone of the Thai *Saw-U* chamber is particularly apt for many *expressivo* passages while the sharp tone of an Iranian *Kamancheh* chamber suits *vivace* and dance-like melodies, regardless of cultural context.

Users can upgrade and swap parts like the chamber after the crafting process is finished. *Fidular* involves musicians in customizing their instrument; even designing and manufacturing their own chambers using digital fabrication tools. The idea is similar to the *Chameleon guitar,* but *fidular* is entirely acoustic with no onboard DSP.

4.2 Design objectives

We define four design objectives in developing *fidular:*

1.) **Compatibility** - *fidular* must be "backwards compatible" with traditional chambers and "forwards compatible" with chambers made from digital fabrication and new materials
2.) **Acoustics** - *fidular* must preserve the original acoustic mechanisms of the fiddle
3.) **Modularity** - *fidular* must allow the user to easily access and change components, specifically strings and chamber.
4.) **Form** - *fidular* must retain a form as close to the original design of traditional fiddles as possible

4.3 Design process

4.3.1 Connecting chamber to shaft

To enable modularity, permanent joints between shaft and chamber were redesigned. Traditionally, the long shaft—which functions as a finger board—enters the chamber at the top, penetrates through and protrudes out the bottom. The strings are tied at the protrusion and stretched to up to the shaft's tuning pegs. Thus, all tension from the strings is supported by the shaft. None of the torque exerted on the shaft is offloaded onto the chamber. Simply attaching the shaft to chamber top will warp the chamber when the strings are tightened.

Early sketches proposed a frame with a hollow center (Figure 7a) to suspend the resonators similar to the *Chameleon Guitar*. However, unlike the standardized single-sized panels of the *Chameleon Guitar,* fiddle chambers come in various sizes and geometries. The hollow frame proved cumbersome in this regard, especially considering the set of locking pegs that would secure the chambers in place.

A second design placed a "C" frame around the chamber. The user screws the top and bottom of the chamber in between this "C" (Figure 7b). However, the screwing motion was deemed inelegant and the design too divergent from traditional fiddles with no external frame.

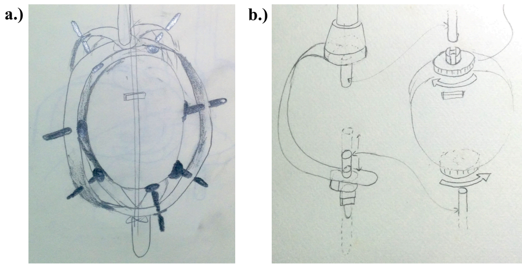

Fig. 7 Early design sketches

The third design places a metal rod inside the chamber. The shaft connects to this protruding rod at the top. This solves the problem of size as the rods are simply cut to match the chamber's height. After considering various geometries, we settled on parallel prongs for two reasons. First, it prevents the shaft from rotating about the prongs. Secondly, the prongs serve as +ve and –ve terminals for powering integrated electronics in future chambers.

The final design features (Figure 8) a shaft base with an embedded magnet (1), a battery compartment (2) and retractable parallel prongs (3, inset). The long wooden shaft (4) then attaches to the shaft base (5).

The user would attach the chamber magnetically, after which the prongs would extend as far as the chamber's base. This hides the components in the fiddle's original form. Since the prongs enter and exit where the traditional shaft would have gone, we can assume the waveguide's original acoustics are preserved.

The complementary magnet in the chamber does not disrupt the vibration of metal strings beyond the permanent magnets standardized in all electric guitar pickups.

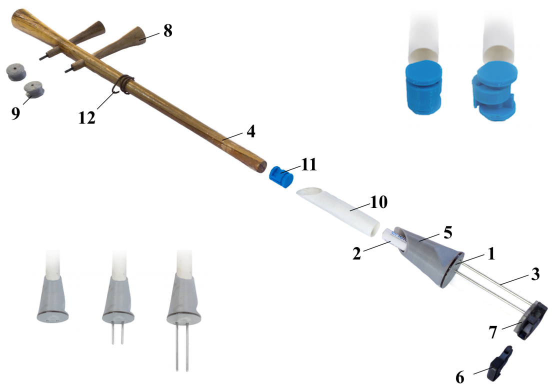

Fig. 8 Final shaft design, retractable prongs (bottom inset), shaft lock (top inset)

4.3.2 Connecting strings to shaft

The user must be able to remove the strings in order to change the chamber. The string is traditionally tied to the protruding shaft at the chamber base or threaded through a hole in the shaft. Some instruments like the *Erhu* have more modern mechanisms with metal pegs. In all cases however, the strings are not easily removed.

We propose a push-clip mechanism (Figure 8). A male clip-head (6) connected to the strings can be inserted and removed from a female clip-receiver (7) located at the chamber base. This is possible, since push-clips used in regular backpacks were strong enough to hold the string's tension in testing. Although a screw and thread mechanism is more efficient, a clip-based mechanism is more convenient and user-friendly.

Originally, the female-clip receiver attached magnetically at the chamber base and locked in place by aligning with the protruding parallel prongs. However, at full string tension, the female clip receiver was pulled off.

In the final design, the female clip receiver is bonded to the bottom of the chamber using epoxy. The shaft prongs extend into the female clip head, ensuring string tension is absorbed by the prongs and not the surface of the chamber (Figure 9a).

4.3.3 Connecting strings to tuning peg

We turn our attention to the top of the shaft. The strings are traditionally wound around the tuning peg, much like a violin.

The first design separated the tuning peg into two parts. An inner cylinder remains in the shaft and connects to a removable where the strings are threaded and wound. A slat connects the two pieces together. This design was unable to hold the string under tension.

The second design wraps the strings around a "bun" (8) that is detachable from the tuning peg (9). A hex connection was chosen—it is the industry standard for joints subject to strong rotational forces (Figure 9c). The tuning peg is held in place by friction like in traditional fiddles. This second design was successful.

4.3.4 Changing shaft and other considerations

Although the *fidular* tuning pegs with removable buns are made specifically for the *fidular* shaft, we have designed the base to accept a variety of existing shafts. In this case, the user can remove the strings from the bottom instrument to swap chambers, but will be unable to remove strings from the shaft's tuning pegs. Some musicians may prefer this "semi-modular" version as it retains their culture's distinct shaft ornamentation over *fidular*'s minimalistic design.

The *fidular* shaft connects to the base via a shaft tube (10). A locking mechanism in the shape of an offset cam allows the user to change the height of *fidular* to the user's desired fiddle dimensions (11, Figure 8 inset). In addition, the shaft base has a cutout so the bow contacts the strings at the correct angle (Figure 9b).

Traditionally, a fiddle maker wraps string or thread below the tuning pegs to collect the strings and define the open string note. This was replaced with a hook so users can easily remove the strings. Copper was chosen for pliability when shaping and rigidity when set (12).

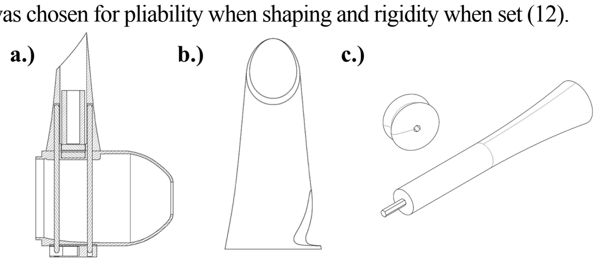

Fig. 9 (a) Cross section (b) Shaft base cutout (c) Tuning peg

4.4 Prototype Fabrication

The shaft and tuning pegs were carved from teak on a carpenter's lathe using traditional wood turning tools under the supervision of a luthier. These were then varnished with two coats. Hex connectors were hammered into both wooden tuning pegs.

The string buns, locking mechanism and shaft base were 3D printed from PLA plastic using a Makerbot Replicator 2 set to 0.1mm resolution.

The shaft tube was cut from 20mm PVC pipe.

The string clip mechanism was modified from an backpack push-clips. We designed and 3D printed an add-on that bonds to the female head using epoxy. This 3D printed add-on has holes that connect to the parallel prongs as well as an extending lip to prevent the strings from cutting into the chambers.

Only the *Sloh* resonator composed of coconut and wooden top was built the by the author. The collection of chambers tested in this paper were obtained from fiddle makers and music shops in different countries: Dunhuang (China), Bangkok (Thailand), Phayao (Thailand), Seoul (South Korea) and Hanoi (Vietnam).

To accommodate various chamber geometries, we 3D print a platform for each chamber that levels out the top (Figure 11). This ensures the shaft stands straight on the chamber. A magnet is embedded in this platform.

The magnet discs have dimensions 2mm x 20mm. The prongs are 3mm aluminum rods.

5. PROTOTYPE

5.1 Current version

The current prototype [36] is pictured in Figure 10. The exact mechanism by which the prongs extend and retract alongside other smaller details are left for a future iteration. We focused on ensuring the essential design elements produced a playable and modular fiddle satisfying the four design objectives.

Figure 10 details the transformation process. (1) We begin with the Thai *Saw-U.* (2) At the top, string buns are removed from the tuning pegs. At the bottom, the male clip is detached from the female head. The strings are now released.

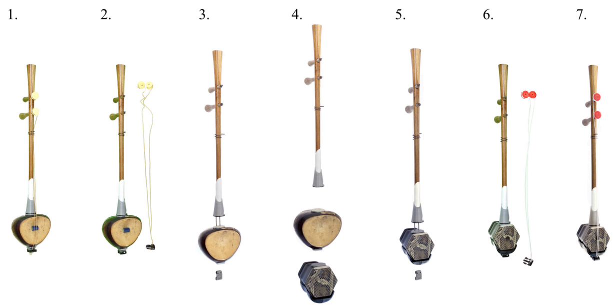

Fig 10. *Fidular* transformation process

(3) The shaft is removed from body of the instrument as the prongs retract. The shaft and chamber are now separated (4) The Thai *Saw-U* chamber is swapped for a Chinese *Erhu* chamber. At this stage, the user is free to interchange with any other chamber. (5) The shaft and prongs are re-inserted into the chamber. (6) A new set of strings are secured onto the fiddle. (7) The new fiddle is assembled and ready to play. The process currently takes a couple of minutes, including the time taken to re-tune the two strings.

5.2 Evaluation

We evaluate the prototype in context of the design objectives.

5.2.1 Objective 1: Compatibility

The current prototype of *fidular* is "backwards compatible" with all chambers tested in this paper. Due to similarities in construction between fiddles from across Southeast Asia, East Asia and the Middle East, we can reasonably assume the system is compatible with all fiddles as defined in section 2.1.

The chambers are modified with two small holes to allow entry of the retractable prongs. A leveling platform is attached to the top of the chamber and a female clip head with protecting lip is attached to the bottom. These modifications can be made on existing traditional chambers and do not alter the waveguide acoustics since the vibrating skin is left untouched.

The current prototype is "forwards compatible" with new chamber materials such as recycled tea cans and 3D printed chambers. Figure 11 shows a 3D printed chamber with a design impossible to achieve using traditional crafts. We are excited by digital fabrication and discuss this in section 6: Future Work.

Fig 11. Coconut chamber with 3D printed platform (left) and fully 3D printed chamber (right)

5.2.2 Objective 2: Acoustics

The author plays and is familiar with the tonal character of Thai *Saw-U, Saw-Duang, Sloh* and Chinese *Erhu* fiddles. When configured with the correct shaft height, string material and chamber, these instruments in *fidular* form sound very close to the original. The Thai fiddles *Saw-U, Saw-Duang* and *Sloh* have been tested informally with a couple of professional Thai fiddle players. We agree the sound and expressivity is close to the original, but somewhat softer. This is likely due to the use of components not designed for musical instruments. For example, we notice the clips and string buns holding the strings vibrate when the instrument is bowed. This dampens the vibrations and reduces the amount of energy available to vibrate the front skin. A future implementation calls for injection-molded pieces over 3D printed pieces. This will ensure joints experience no sympathetic vibrations.

The author is not familiar with the Vietnamese *Danho* and Korean *Haegum* families. Although the author can verify these chambers produce sound when mounted on *fidular*, they should be evaluated by a native musician.

As mentioned before, an acoustic study is beyond the scope of this paper, especially given the original acoustics of these instruments have yet to be studied and published, let alone compared with the acoustics of *fidular.*

5.2.3 Objective 3: Modularity

As shown in figure 10, *fidular's* new shaft and tuning peg mechanisms enables the user to easily remove and interchange components across the fiddle family of bowed instruments from Southeast Asia, East Asia and the Middle East. Traditionally, this cross cultural exchange is not possible as pieces are permanently or semi-permanently attached together.

The shaft tends to bend forwards under high tension, leaving a small gap between the shaft base and chamber top. This is a result of 3D printed pieces not fitting tightly over the prongs and can be fixed with injection-molded pieces.

5.2.4 Objective 4: Form

Fidular preserves a traditional fiddle's look and feel. There are no protrusions or external frames disrupting the original form of a traditional fiddle. Connecting mechanisms such as the prongs, magnets and hex joints are hidden within the structure of the instrument.

Different countries will craft decorations and complex inlays into the shaft, chamber and tuning pegs. These often reflect the culture's unique heritage of woodworking and ornamental motifs.

We designed the visual appearance of *fidular* to be culturally neutral. The shaft and tuning pegs are minimalistic tapers reminiscent of the ancient design of traditional fiddles. Historically, fiddle makers did not have complex tools such as a carpenter's lathe [35]. Thus, ancient fiddles often have simple forms with no ornamentation to distinguish country of origin or personal taste. This influenced the culture-neutral appearance of *fidular*.

6. FUTURE WORK

6.1 Shape-shifting waveguides

Beyond existing chambers, we look towards future chambers utilizing cutting-edge technologies. We can exploit the waveguide nature of traditional chambers with flexible chambers users can mold on-the-fly. It is now possible to 3D print rubber-like structures from flexible polymers [37]. The internal and external geometries of this flexible waveguide could be changed to match the shape of existing chambers and create new ones.

Shapeways, a 3D printing company, has demonstrated 3D printed interwoven structures (like chainmail) that can bend, twist and extend in length after the printing process [38]. By covering the outside with a flexible membrane, we can transform these interwoven structures into a shape-changing waveguide users can mold in real time to modify sound.

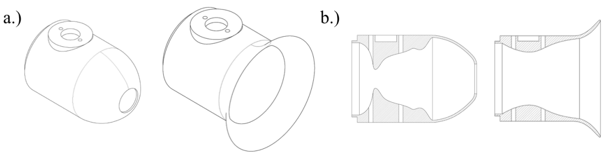

Fig 12. (a) Pliable waveguide (b) cross sections

6.2 Interchangeable skin panel

Skin material and geometry determines the initial waveform and thus has the largest effect on the final sound. We propose a chamber where users can replace the skin by screwing and unscrewing a frame over the chamber. The ease of producing these frames opens the door for novel and untested geometries. A musician would only need to carry a box of skins instead of a suitcase of chambers.

Interchangeable skins are especially powerful when coupled with shape-shifting waveguides. The next iteration of *fidular* would give users clay-like control over all aspects of chamber morphology—a truly pliable fiddle [39].

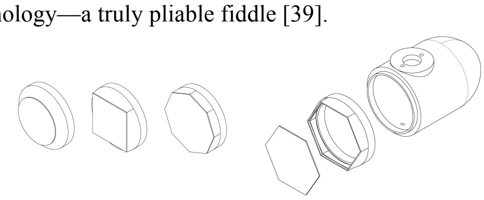

Fig 13. Interchangeable skin panels

6.3 Hybrid digital-acoustic chambers

The integrated batteries and parallel prongs can provide power to embedded electronics in electro-acoustic chambers such as Kapur et al's *eHaegum.* This keeps the final instrument portable without added attachments. The next iteration will finalize the prong mechanism and battery electronics. Multiple batteries can be stacked in the tube of the shaft itself and connect to the prongs via electrical contacts.

This enables *fidular* to be used with an exciting array of yet-to-be-invented chambers with integrated DSP, sensors, actuation and many more like those found in *augmented/hyper instruments* from Western traditions.

6.4 User studies and feedback

Blind tests with professional fiddle players from various musical traditions will help validate *fidular's* sound and expressivity. Professional musicians will be able to give valuable feedback on the interaction design and whether *fidular* is a viable instrument they would use. The author is currently meeting and sharing these designs with luthiers in Thailand to collect their feedback.

6.5 Acoustics analysis

Once the design of *fidular* is finalized, measurements and FEM simulation of chambers in both original form and *fidular* form will be conducted to verify qualitative claims.

7. CONCLUSION

In this paper, we present the first prototype of *fidular*, a novel modular system enabling fiddle components to be interchanged across fiddles from Southeast Asia, East Asia and the Middle East. *Fidular* unifies the various fiddles into an integrated system, reimagining each culture's unique timbre as colors on a cross-cultural sonic palette. We imagine fiddle players collecting unique chambers, each associated with a particular musical emotion or style that rises beyond cultural context.

An *Erhu* player from China may choose to solo with an Iraqi *Joza* chamber over the Vietnamese *Danho* for the same reason a guitarist may favor a *Taylor* over a *Fender* for a ballad. But rather than deciding the *make*; the user decides which *culture* is most suitable, tapping into the rich heritage and craftsmanship each tradition has to offer.

From a scientific perspective, *fidular* can be a platform to easily mount and test various chambers. This facilitates the acquisition of much-needed spectral data. Fiddle makers can use *fidular's* modularity to experiment with various materials without having to re-build a new fiddle each time.

Future innovations like shape-shifting waveguides and elecro-acoustic chambers are easily integrated with *fidular*. The age of mobile connectivity can create a reality where open source 3D models are uploaded and downloaded by fiddle-making and fiddle-playing communities across borders and musical traditions. The authors hope projects like *fidular* will re-vitalize interest in traditional culture—especially among the youth—and focus research, particularly in Asia, towards the amalgamation of science, art and culture in the creation of new technology.

There is much work to be done for traditional fiddles. Combining modern technologies like 3D printing with traditional technologies like woodworking, as demonstrated by *fidular,* opens the door for exciting *culture-aware* innovations.

This is the first of many papers that will explore and challenge traditional cultures from fresh perspectives: musical, acoustical, technological and beyond.

8. ACKNOWLEDGEMENTS

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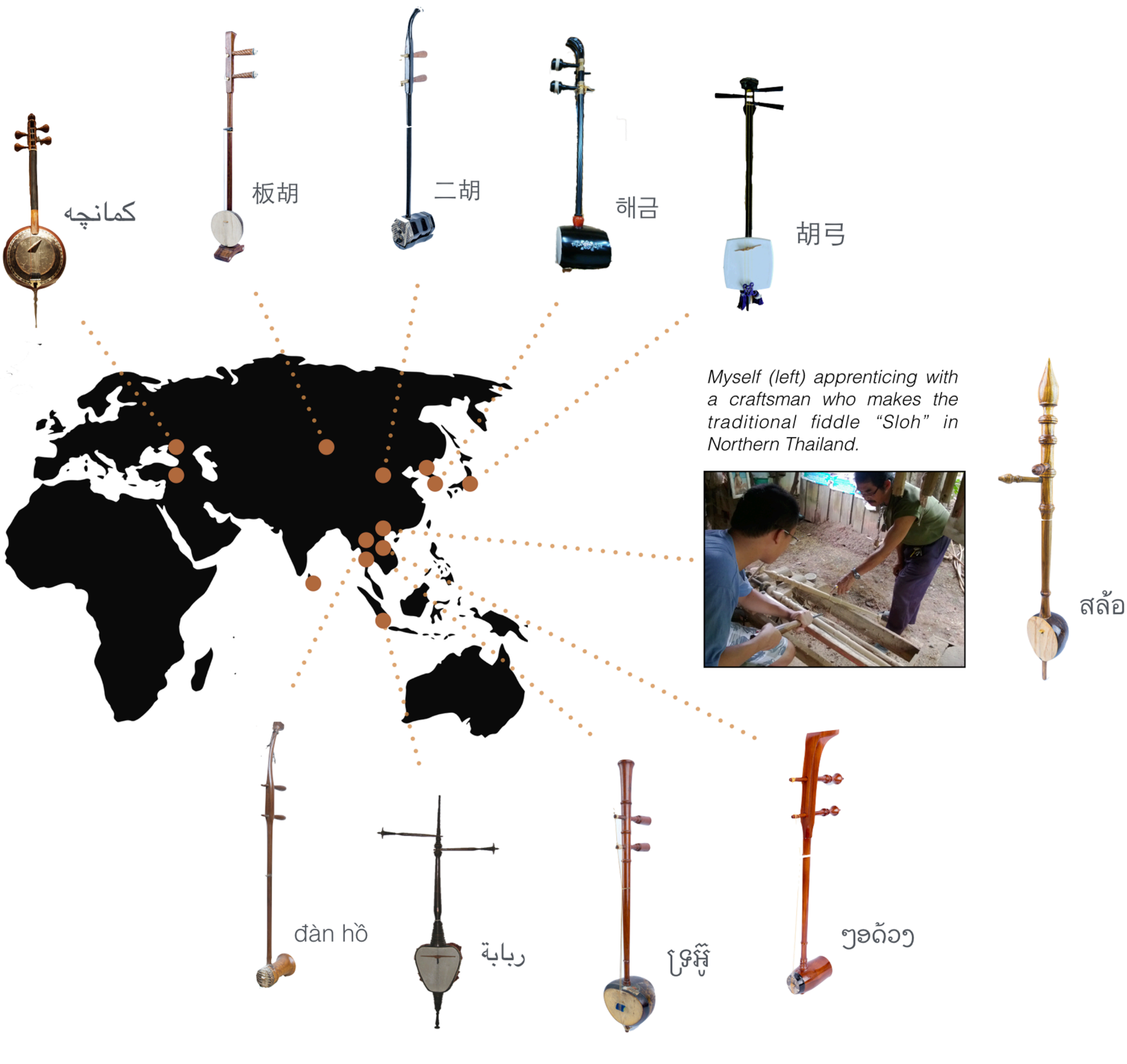


Traditional fiddles and their country of origin

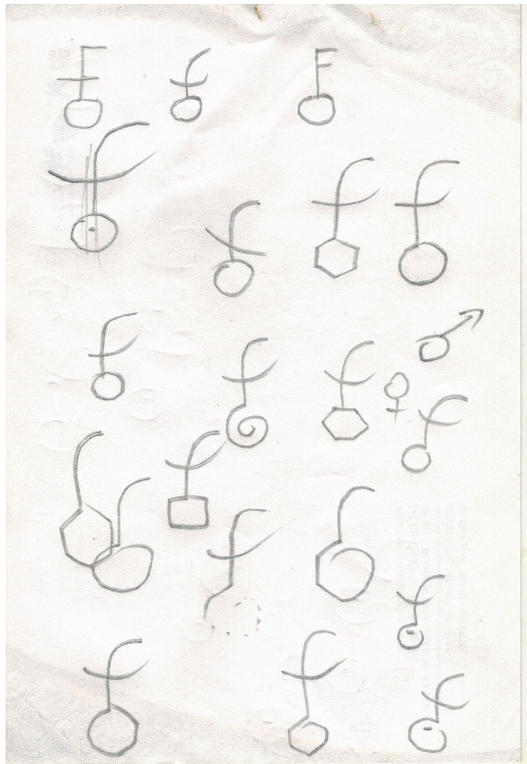
Khet Chaikam's woodshop in Mae Chai, Thailand

Coconut chambers with glued wooden panels

Myself and Khet Chaikam during the apprenticeship

Demonstrating Fidular at a local maker faire in Chiang Mai, Thailand

Testing the 3D printed fiddle chamber



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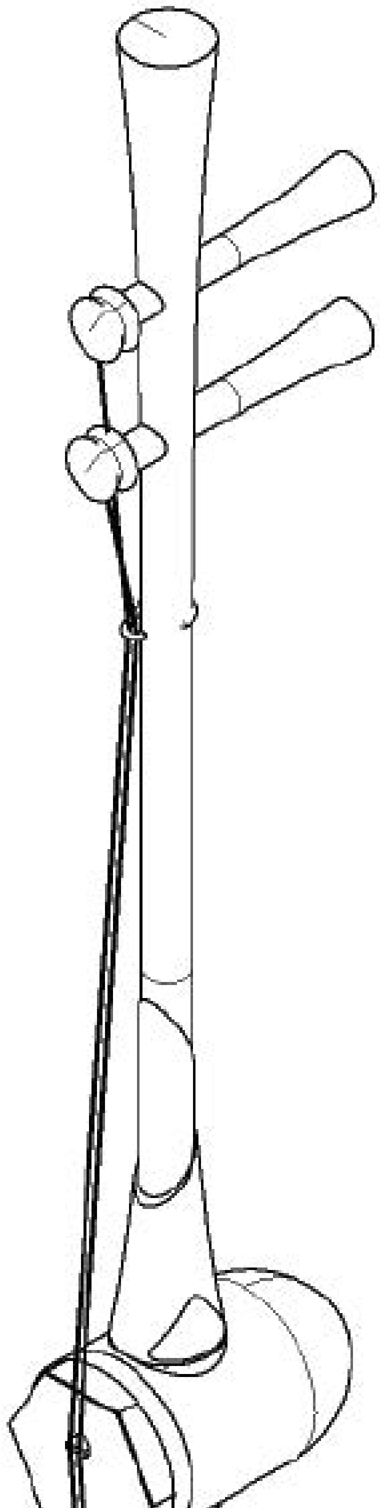
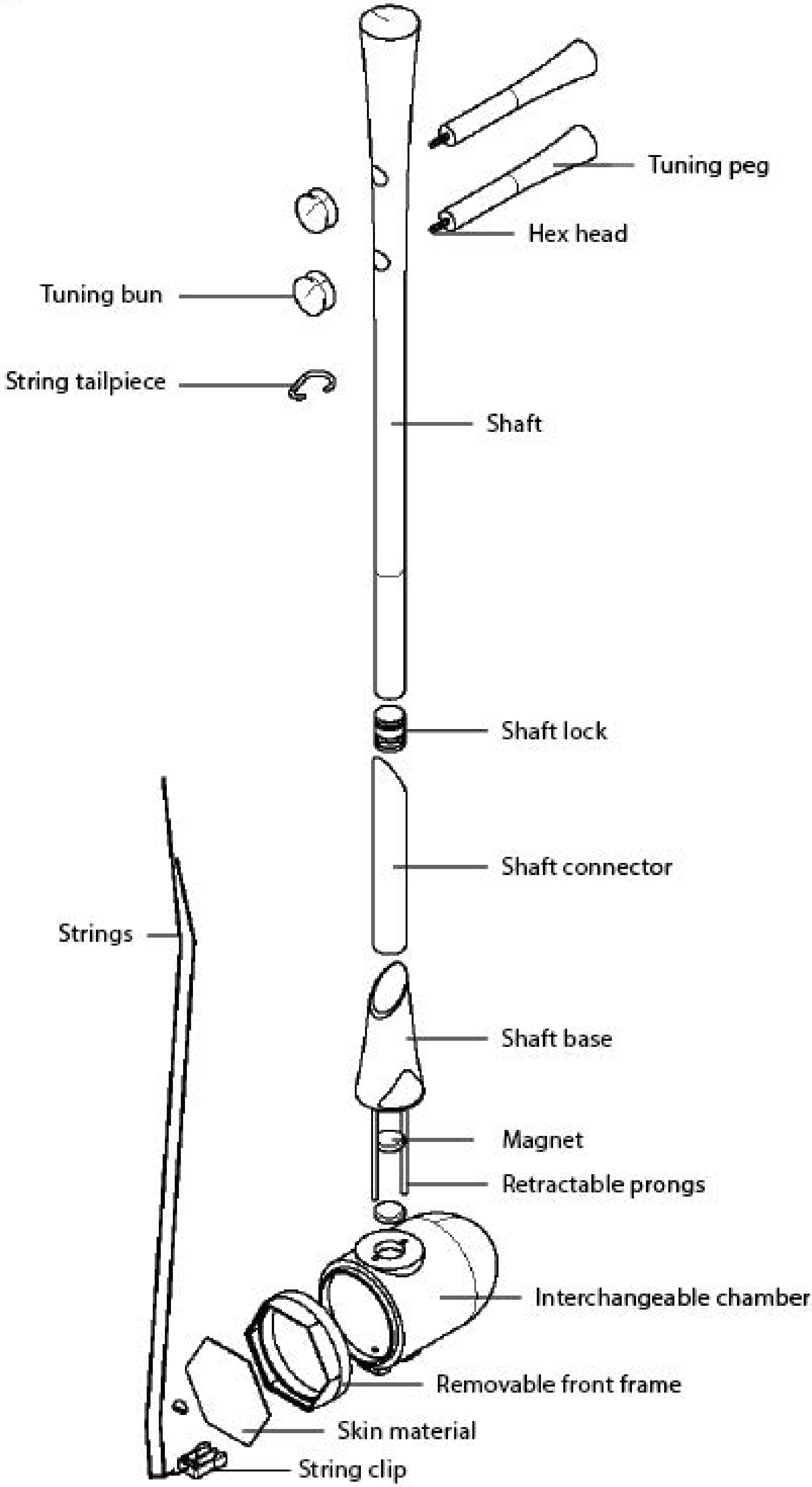
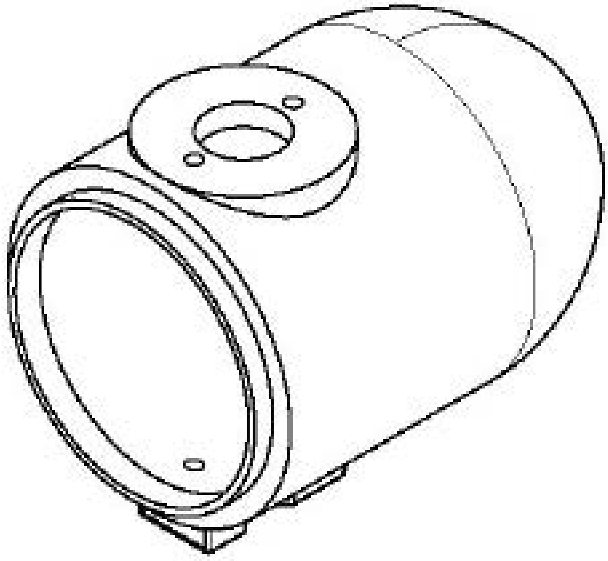
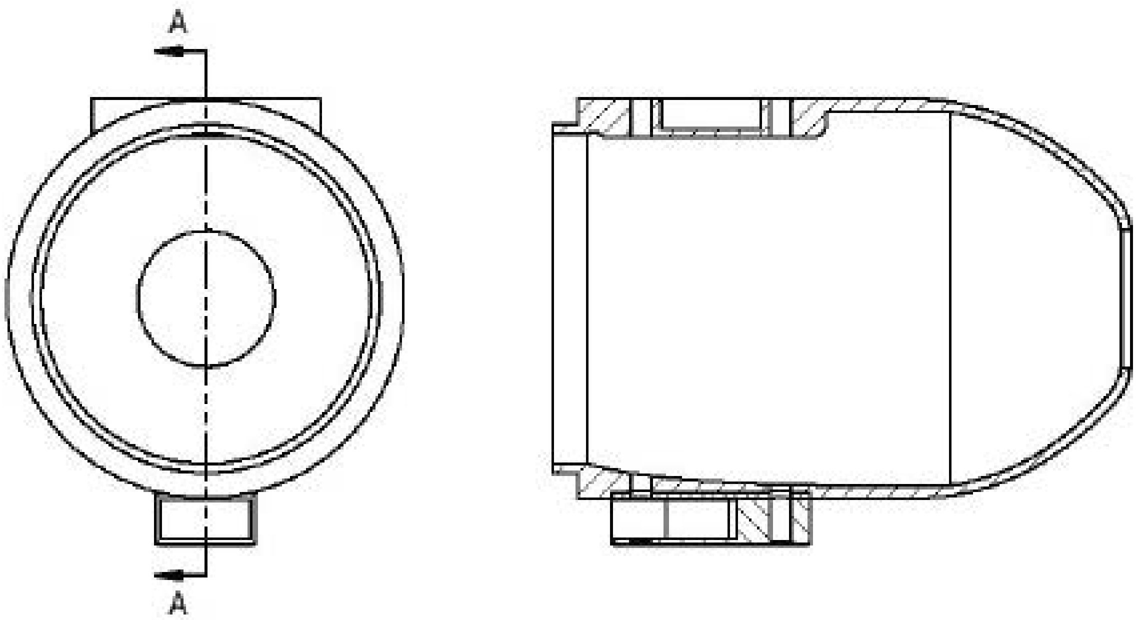
Modular Fiddle System




Tuning peg
Hex head
Tuning bun
String tailpiece
Shaft
Shaft lock
Shaft connector
Strings
Shaft base
Magnet
Retractable prongs
Interchangeable chamber
Removable front frame
Skin material
String clip

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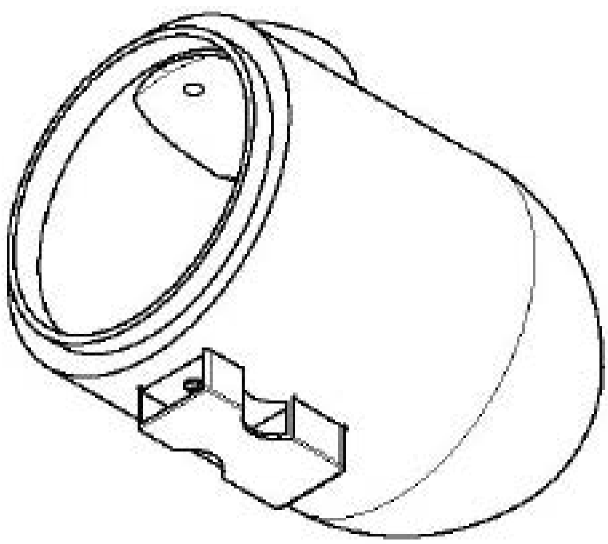

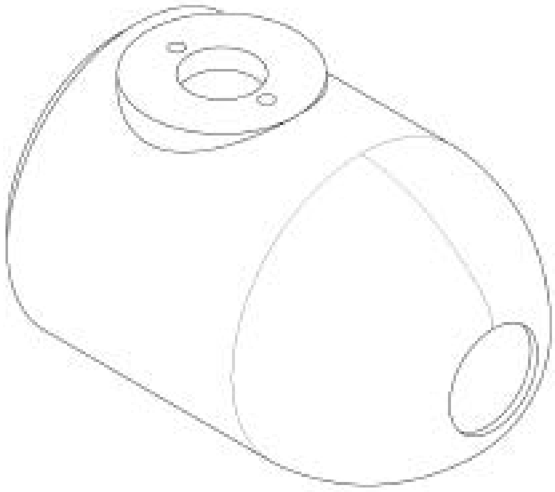

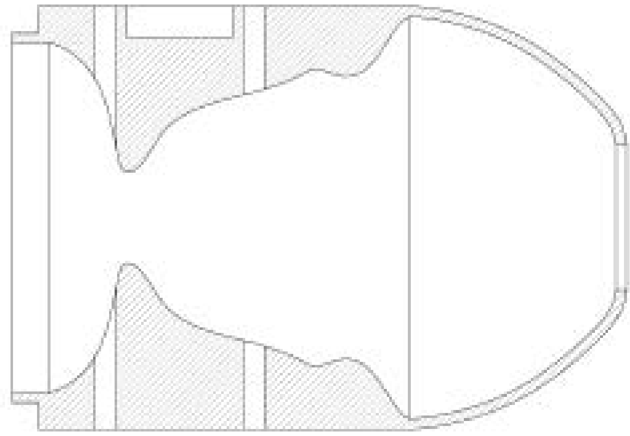

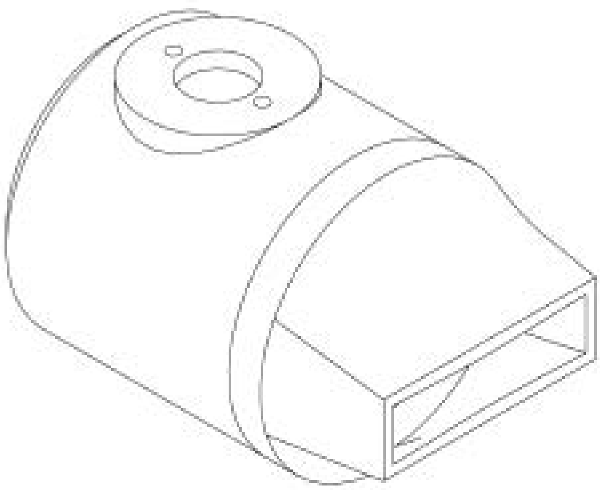

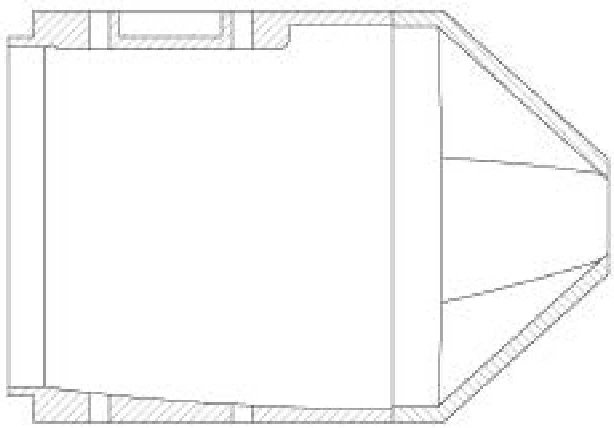

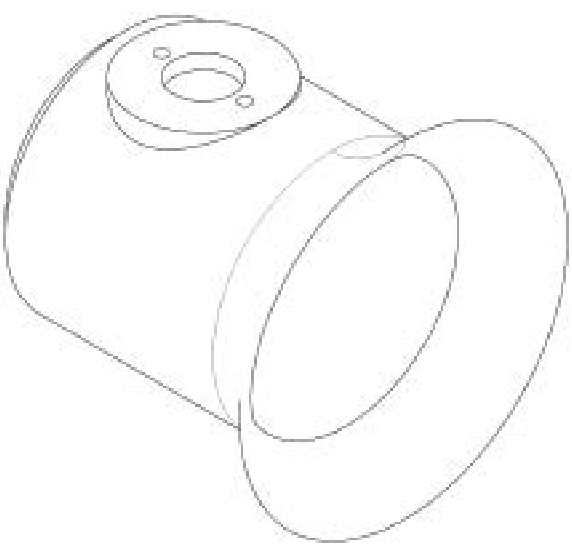

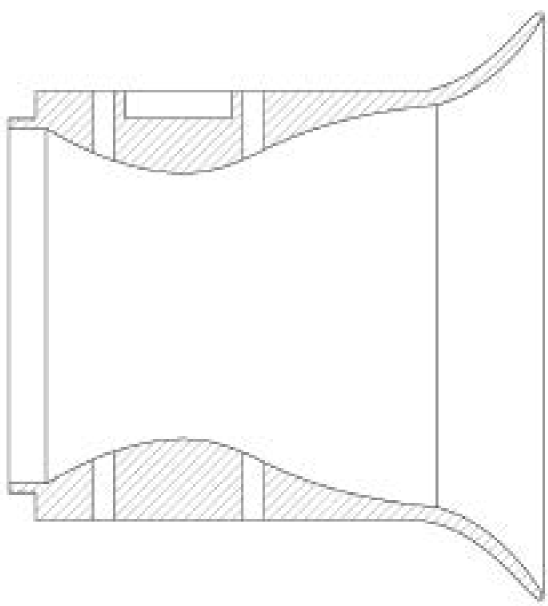

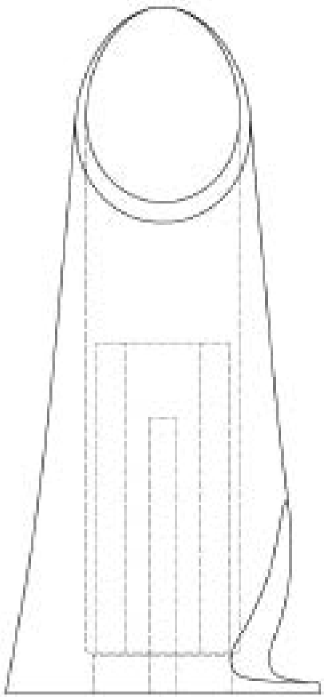

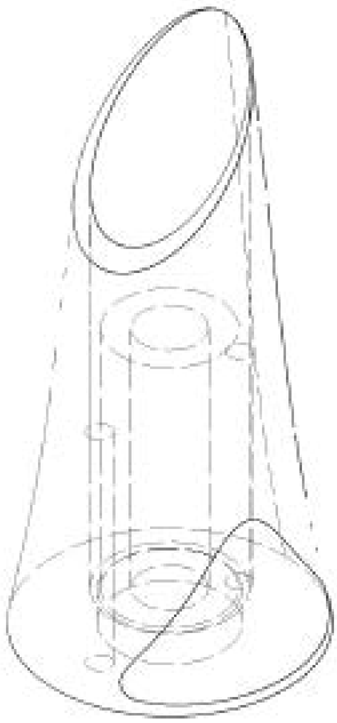

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