ABSTRACT
The Virtual Zournas, a digital Virtual Musical Instrument (VMI) developed under the project HERON, following a physical modeling approach, is presented, along with a classification scheme of real double-reed woodwind zournas and their characteristic acoustic analysis. Use-case scenarios of VMI zournas are also given regarding different user groups, including composers, performers, music teachers and musical instrument craftsmen. Aesthetical issues, limitations of the current version and thoughts on the anthropological and technological character of such tools are also discussed.

Categories and Subject Descriptors
H.5.5 [Sound and Music Computing]: Methodologies and techniques, modeling, systems.

General Terms
Design, Performance

Keywords
Virtual Musical Instruments, physical modeling, woodwinds, double reed, folk instruments, zournas, shawm.

1. INTRODUCTION
It is well known that musical instruments evolved throughout the history of the human civilization. If we look into the problematic of Dr. Eldredge [25], evolution, both biological and cultural, is strongly connected with the transmission of patterns of information. Since musical instruments enclose cultural material information, similar to species, their evolution could be studied in biological terms. Instruments follow the changes of their cultural environment and carry their “genetic past” in the same analogy with species and natural environment. Instruments evolve or become extinct trying to keep up with the ever-changing world. An abrupt rise or fall of an instrument could be connected with a cultural disruption in the same way that an ecological disruption led to the extinction of dinosaurs and the rise of mammals.

Perhaps it is possible to examine the evolution of musical instruments during the last 50 years through the aforementioned prism. Technology played a significant part in the formation of the ‘modern’ world. The effect of computers in everyday life was so drastic that could not leave culture intact. Musical instruments once again witnessed that effect. Terms like hyperinstruments and virtual musical instruments came up, proudly denoting a new era in the evolution of the orchestra.

Hyperinstruments are expanded musical instruments, varying from augmented conventional instruments [16] [24] to large scale musical systems [4]. Their novelty usually stands on the ground of original control interfaces and performance capabilities, as well as sound production and manipulation. As Anderson et al. states [2], their key aspect is flexibility, in terms of physical control, movement processing and music processing. The “hyperinstrument project” started in 1986 inside the realms of MIT media lab [12]. IRCAM and other research institutes also have remarkable applications to demonstrate in the same field [4].

A Virtual Musical Instrument (VMI) is another concept not so different than that of a hyperinstrument. The musical instrument is considered to belong not on the physical domain but in the virtual one. However, in most cases the interaction between the performer and the instrument still occurs in the physical domain, while the sound production is the one that occurs in the digital domain. Thus, a VMI is a complex instrument standing in between the real and the virtual world.

Some researchers focus on the sound synthesis aspect of a VMI [23] [20], others on the intuitive gestural controls and the innovative interaction schemes [9] [14] [15] and others on the visualization. Tenets and guidelines for designing VMIs are described in literature [8] [9]. In all these cases, physical modeling often comes up.

Physical models are based on mathematical models that can describe the physical acoustics of a real-world instrument. As Roads states [19]: “a physical model embodies the Newtonian ideal of a precise mathematical model of a complicated mechanicoacoustical process”.

On one hand, physical modeling provides a great methodology for describing the virtual analog of a conventional instrument. It allows real-time manipulation of sound parameters and straightforward control of the VMI in resemblance with the performance of the real instrument. On the other hand, physical modeling can
describe totally original musical structures, in terms of both performance and sound synthesis. It is possible to apply transformations between different fields like gestures, dance, image and sound, or to give a real-world projection to more abstract musical forms.

Have all musical instruments undergone such changes in their lifetime? One should examine changes inside a defined cultural context in order to answer such a question. In some cases, the cultural context has not changed dramatically during a certain time period, thus lacking the need for a change in the instruments as well. This is often the case with traditional or folk instruments. Inside a group where cultural habits tend to deny ‘modern’ interactions, folk instruments, together with music, dance and other forms of art, are not altered.

Hence another pack of questions may rise: is there a point in designing virtual folk musical instruments? Is it reasonable to extract an instrument from its natural environment and move it to the virtual plane? What uses could then be found and inside which new cultural sphere?

Such questions are examined in the present work under the prism of the characteristics of the applications that a virtual folk musical instrument may have. We study the case of the Virtual Zournas, a software application of a Greek folk musical instrument, based on physical modeling. In order to justify the uses scenarios of the virtual instrument, first we apply a piece of information on the zournas instrument. After presenting the Virtual Zournas, we comment on the scope of this application and possible use case scenarios, from the view of a composer, a performer, a teacher and an instrument manufacturer. Last, we discuss on the aesthetics of Virtual Zournas and its limitations.

2. THE ZOURNAS SHAWM

2.1 General Description

The zournas is a traditional Greek double-reed woodwind instrument. Its major parts are the embouchure and the bore (Fig.1). The embouchure is divided to the double reed, and to a conical metallic part which connects the double reed with the bore and forms the embouchure’s air stream. The bore conical, ending to a flared bell. The embouchure is connected to the bore through a cylindrical wooden part that can be removed from the main body of the instrument. The bore has seven tone-holes, on the upper side, one register hole on the opposite side, and in many cases, some air-holes spreading peripherally to the bell, which are not used during the performance but help the overall tuning of the zournas. There are no keys or other mechanical parts. The reed is usually made of cane or other cane-like plants. The bore is usually made of cherry, oak or apricot tree wood. [3][13][18][21]

Figure 1: The zournas.

2.2 Historical Issues

The zournas appeared in Ancient Greece under the name of oxyaulos, belonging to the family of the aulos woodwinds with the prefix oxy- noting the high pitched and strident timbre of this specific aulos. In fact hautbois, the French word for the oboe, is the French translation for oxyaulos.

While being known in Middle East, Central Asia and Egypt, it was spread in Europe through the Roman Empire and became the most popular double-reed woodwind during the Middle Ages under the generic name shawm, but with different names in every region. The medieval salmel had 7 tone-holes, and during the 16th and 17th century the bombard could be found in 7 different sizes. Until then, it was played by inserting the entire embouchure inside one’s mouth. In the 17th century, the high pitched bombard evolved into the hautbois, the oboe. A key mechanism was added and the performer played by touching her lips on the reed. The kronhort, the salmel, the racket, were all variations of the shawm.

The zournas was established with the rise of Islam, during the 7th century A.C. It was inserted inside the military bands and was spread at the conquered regions. Until today, it has been a common instrument in Islamic countries.

In Modern Greece, it was reintroduced during the Turkish Conquer, but was again related to its Ancient-Greek origins. Along with the daouli drum, it became the main music ensemble of Continental Greece (Fig.3). During the 19th and 20th century it had been gradually replaced by the clarinet. Nowadays, it has become extremely rare and has been connected with specific fests and cultural events.[3][13]

Figure 2: Depiction of a shawm in an Orthodox Christian Church icon.

Figure 3: The zournas and the daouli drum.
2.3 Technical Characteristics

Though the main features of the zournas are covered in 2.1, one should note the variety of shapes and sizes that are found throughout Greece. It should be made clear that in Greece the zournas is not mass produced by the industry and by following specific standards. Each manufacturer, who is usually a performer himself, makes the zournas following his own will and design plans. For that reason, each zournas is almost unique.

Three are the main shapes that are found in Greece and they are all named by their size or the region where they are most profound. These are: the short-sized zournas, found in Southern-Eastern Greece, also known as the Mesologitikos zournas, the medium-sized zournas, most widespread in Continental Greece and known as the Turkish zournas, and the long-sized zournas, found in Northern Greece and Thrace, also known as the Macedonitikos zournas.

In this study, geometrical measurements for 9 instruments were conducted, under the HERON project. Even though the sample is not large enough and appropriate for a statistical analysis, some results are shown in Figure 5. In the 3D graph of bore start diameter, bell diameter and length, the three kinds of zournas are easily classified. The medium-sized zournas seems to have the largest bell diameter, thus the largest flare.

2.4 Acoustical Analysis

Even though a complete acoustical analysis of the zournas escapes the scopes of the current work, some measured data are presented, in order to clarify issues on the use of the zournas and through these to pass towards the uses of the Virtual Zournas.

The first most characteristic feature of the zournas is its harsh, high-pitched timbre. It is also considered to be “very loud”, and is thus used only in open field, never in chamber. One should look on the harmonic distribution to find acoustical evidence on the aforementioned comments.

Figures 6a and 6b show representative spectra derived using PRAAT software for D#5 and G4 notes, played with a short and medium zournas respectively. In both cases, spectrum is reach in high frequency harmonics. Higher harmonics are the most prominent ones, rather than the fundamental. Same results were obtained for 9 different zournas analyzed for every note in their ambitus. The fact that the shape of the bore is conical and the bell has a flare explains these effects.
The presence of high frequency/high amplitude harmonics is responsible for the characteristic harsh timbre of the zournas. It can also give answers to the fact that the zournas is perceived as being loud. On one hand, a spectrum rich in high frequency/high amplitude harmonics corresponds to a signal with higher intensity than a signal that lacks these harmonics. On the other hand, since loudness is affected by frequency, a sound having high frequency harmonics between 2 KHz and 4 KHz are perceived as being louder [10].

2.5 The Cultural Background and Semiology of the Zournas

The zournas, as belonging to the aulos instrument family, carries the semiotics of the aulos and the great opposition between the aulos and the lyre. The myth of Apollo and Marsyas notes this duel. Marsyas the satyr, follower of Dionysus, skilful player of the aulos, challenged lyre-playing Apollo to a musical contest, where the winner would control the defeated in his will. The Muses, acting as judges, declared Apollo the winner. Apollo promptly flayed Marsyas for his hubris, his overwhelming pride against the god.

Apart from the warning against the sin of hubris, the myth reflects the cultural tensions the Ancient Greeks expressed in the opposition they often drew between the lyre and the aulos, between Apollo and Dionysus. The lyre, as its player Apollo, expresses reason, moderation, moral sanity and sophrosyne, versus the aulos and Dionysus that expresses madness, excess, ecstasy, moral insanity, lack of temperance and self-control.

It this way, the aulos accompanied a wide range of Greek activities, often related to Dionysus. It was present in fests, sacrifices, rituals, drama plays and even sports. The characteristic strident, high-pitched timbre of the zournas strongly supports such uses. Plato associates it with the ecstatic cults of Dionysus and the Koryphantes dancers. In his writings, Plato bans the aulos from his Republic but reintroduces it in “Laws”. He also uses the concept of methis and methexis used in Dionysian cults. The one that takes part in a Dionysian fest drinks wine and renounces any moral constrains (methis), becoming communicant to everything that happens, becoming one with the god himself (methexis). In the same way, Plato uses methexis to describe the state in which the individual is communicant to the idea, and experiences the abstract that materializes.[11]

In Modern Greece, the zournas is still related to remnants of Dionysian fests, such as the Triodium carnivals, or played in traditional marriage fests, still noting the bond-breaking and ecstatic character it used to have. It is also strongly connected to the culture of the Roma people in Greece. During the 19th and the early 20th century, most professional musicians where Roma since being a musician was not a well-reputable profession. Therefore, the Roma carried a great load of the Greek music tradition, while mixing it with theirs, and the zournas was part of it. Nowadays, the zournas becomes more and more rare, and the Roma are still the main carriers of its tradition. In this way, the zournas is also connected to the free and passionate nature that the Roma people express [3][13].

2.6 Choosing the Zournas for Modeling

Ethnomusicologists agree that it is of great importance for people to become familiar with folk music and instruments, especially in those cases where the later tend to become extinct. Even though there are hazards in drawing a folk instrument out of its natural cultural context and examining it under a new perspective, we find the zournas to be an instrument of great ethnomusicological interest and believe that such a study is useful for educative purposes.

Furthermore, the zournas offers scientific challenges as far as the acoustic analysis and the physical modeling are concerned. The double reed, the conical bore and the flared bell are all hotspot elements in the area of acoustics and are currently in research for western musical instruments like the oboe [1]. In this way, studying and modeling the zournas can give answers in open issues regarding the physics of double-reed woodwinds.

On the other hand the zournas, being a folk instrument, has also significant differences from western instruments. It should be made clear that in Greece there is not a mass industrial production of zournas. They are all handmade and usually the craftsmen are also the players, who build the zournas without following any specific standard but rather following previous successful tries. For that reason, every instrument is almost unique, even in terms of tuning, ambitus and producible pitches. Therefore, the development of a tool able to combine all different and custom forms of the zournas, in the virtual plane, seems for the writers both important and intriguing.

3. THE VIRTUAL ZOURNAS

3.1 General Description

Virtual Zournas developed using the KTISIVIOS framework developed under the HERON project, based on real-time sound synthesis by physical modeling and software components that represent the acoustical functional parts of the real-world instrument. More details regarding the framework, the design process, the application’s components and the physical model of the zournas can be found in [21].

Fig. 7 shows the GUI of the Virtual Zournas. Functions and control areas appear in Greek since the application was originally developed for Greek users. However, a new interface containing language options is currently in development. One can see three main sections. The upper, contains a 2D replica of the zournas that can be used for fingering selection. The middle section allows the user to change physical parameters of the instrument (geometrical, technical, execution). The lower section is dedicated to control, execution, and connectivity with external devices functions. There are also functions for opening and saving parameter files and a separate window pop-up for the use of the 3D zournas replica.

In order for the entire range of controls and functions of the Virtual Zournas to be made clear, we proceed with presenting basic use-case scenarios, which do not target to specific user groups.
3.2 Use-case Example Scenarios

3.2.1 Listening to Isolated Notes

By running Virtual Zournas for the first time, a default value set for the adjustable embouchure, bore and excitation parameters is loaded. To be more precise, these parameters are:

- Initial reed opening
- Reed width
- Diameter of the embouchure’s output
- Bore diameter
- Bore length
- Bell diameter
- Bell flare

The user can set the values for these parameters using the computer’s input devices. These values must belong into a specific for every parameter value range, since the models cannot produce sound for any given values. The appropriate range, along with a full instruction set, is provided to the user with the help function. If a given value is off range, a warning message appears.

After adjusting the values of the parameters, the user can hear the sound result from the Virtual Zournas he just defined. First, she sets a value for the blowing pressure, in the excitation section. Then, by clicking the “Blow” button sound is produced in real-time, and can be heard provided a usual computer sound system (soundcard, speaker) is present. The sound corresponds to that produced from a real-world zournas with properties defined by the parameters’ values and all tone-holes closed. Of course, it is possible that the values describe a zournas entirely unknown to the real world.

The user can save the parameter value set, in order to load it in later time without having to re-set the values from scratch. Values are saved locally as an XML formatted file. These files are defined as configuration files. Blowing pressure value is not saved, since it is considered to be an execution parameter.

3.2.2 Using the 3D Replica

By selecting the “3D visualization” menu, the 3D replica of zournas is activated. It is a highly detailed 3D VRML visual model of a real-world zournas (Fig.8). The user manipulates the model, turns it around, flips it over, and changes the point of view etc, using the computer’s mouse and the slide-bar “Move”.

Moreover, she modifies specific model’s features:

- Bore length
- Bore diameter
- Bell flare
- Bore material (only visual parameter)

The values of the parameters are shown in the lower part of the window. Apart from affecting the visual model, the values are also sent to the sound model’s components. In this way, the user “blows” again and listens to the sound produced from the zournas set up with the 3D interface.

3.2.3 Choosing Fingering

The 2D image of the zournas is located on the upper right part of the main GUI. The user selects a desirable finger by double-clicking over the tone-holes. Open holes appear black, while closed holes appear light brown (Fig. 9).

The fingering is confirmed by clicking on “Confirm Fingering” button and the Virtual Zournas is ready to be blown. The sound result matches that of zournas with the current parameter value set and the confirmed fingering. It is worth mentioning that a fingering cannot be saved and loaded in the way a parameter value set can.
3.2.4 Playing a Tune with the Virtual Zournas

After experimenting with sounds and fingerings, the user chooses to listen to a whole melody and not just isolated notes played. There are two ways to make Virtual Zournas carry a tune: by loading a MIDI file and by connecting external MIDI devices.

By clicking on “Load MIDI File”, the user browses and loads a MIDI file. MIDI messages are used by the sound production models, and the melody is played with the sound of zournas. The MIDI file must contain a monophonic melody, since the Virtual Zournas cannot produce more than one note simultaneously.

Perhaps the most interesting case is when the user connects an external MIDI device to control the Virtual Zournas and perform with it, in real-time. By selecting “Connect External Device”, a list of the computer’s MIDI devices connected to the user’s computer shows up and, if the external device is properly installed, it appears on it. By marking it and clicking “Start”, the user is ready to perform. Again, frequency and time MIDI messages are used for the sound production sequence. At the end of the performance, the connection is stopped by pressing the “Stop” button.

4. PERFORMABILITY

Performing music is perhaps the most apparent application that a virtual instrument owes to have. From this point of view, two groups should be most involved with the use of Virtual Zournas. On one hand, there are the composers who are interested in writing music for the Virtual Zournas. On the other hand, there are the performers who will play the written music or will play the role of the composer themselves, by improvising or interacting with the virtual instrument in any chosen way. In this section, the potential interest that a composer or a performer could find in the Virtual Zournas is being examined.

4.1 Composing for Virtual Zournas

Orchestration is an important issue in the art of composing. There are many different aspects to taken into consideration in order for a composer to decide how to orchestrate a piece written or how to write music for a specific instrument. Some aspects are more ‘technical’, like the features of the instrument (e.g. ambitus, timbre, playing techniques); others are more ‘aesthetical’, like the semiology of the instrument, its ‘symbolic dimension’, the ‘sonic stamp’ that the composer would like for the instrument to have, the cultural context that it reflects.

On the technical part, the Virtual Zournas offers a key feature characteristic in physical modeling sound production systems: multi-timbrality. By changing the values of the physical parameters, one can obtain different sound colours. Even though the model corresponds to a real-world zournas, and for that one would expect timbral changes analogous to the registers of the zournas, experimenting with parameter values and creating non-real-world instruments showed even greater spectral differences and unique sound colours for the producing sound.

Many composers and musicologists analyse in extent the importance of timbre not only as an orchestration parameter but as a music-space component like pitch or harmony [5]. For that, mapping the timbre-space of the Virtual Zournas in detail for different parameter values would be of great interest.

On the aesthetical part, the composer could be inspired by the semiology and the cultural background associated with the zournas in the real world and presented in 2.5. Myths and archetypal symbols are topics often handled in various music compositions, ranging from classical to contemporary and from programmatic to theatre and drama music, while folk music comes constantly on the foreground during the last century. The zournas, both real-world and virtual, combines these elements by carrying its archetypical symbolism through time, space and cultures, from ancient to modern, from East to West and from Dionysic carnivales to contemporary sound installations.

4.2 Performing with Virtual Zournas

As seen in the introduction, virtual or hyper instruments often apply the user with original performing schemas, allowing him to control the instrument in a unique way. Virtual Zournas does not include a sophisticated gestural or other control mechanism of its own, totally dedicated to performing issues. It relies on external MIDI devices (or files). In the current version, Virtual Zournas accepts MIDI messages of only pitch, duration, and velocity, making it a poor choice for a performer who wishes to make the most of it.

The first degree of improvement would be the modification of the application in a way to accept MIDI control messages that would control parameter values. In this way, the player would be able to change sound features (e.g. timbre) in a straightforward manner during her performance.

Of course, this could demand of a control device that would send such messages that affect only the specific model. So, the next level of improvement would be a control mechanism designed to work together with the specific physical model and alter as many model parameters as possible. Such devices are already in use with other virtual instruments, for example the Yamaha WX5 Wind Controller that works its best together with the Yamaha VL70m Physical Modeling Tone Generator, or devices designed by Perry Cook to control physical models and follow the SKINI protocol [7]. In a more advanced version, the 3D replica could also interact with the control device, something not possible at the moment.

In the same fashion, the physical model of the zournas should be improved, not only for bringing the virtual closer to the real but also for providing the performer with the maximum possible control over the instrument.

5. EDUCATIVE APPLICATIONS

Virtual instruments are not only developed for musical creation but for musical pedagogy as well. Applications such as virtual museums of musical instruments or virtual orchestras are often used in teaching [17]. The student obtains knowledge for instruments that may be unknown to her or just difficult to see and use the real ones. The Virtual Zournas delivers educative scopes in more than one way.
To begin with, as afore discussed, the zournas is not a widely known instrument for the Modern Greeks, even though it is a significant piece of the Greek musical culture. Moreover, since it has become rare, it is used only in special fests. Adding the fact that it comes in many different forms, it is hard for teachers to bring their student in contact with the instrument and its cultural context. In Greece, many people study folk music in special schools for them the need to become familiar with the wider music tradition is even more pronounced.

Virtual Zournas could help teachers to present the zournas to their students in cases where the real instrument is absent. It gives the user the possibility to listen to the sound of the zournas, and in fact, not just to a sampled zournas sound but to a dynamic sound that changes by changing the parameter values and closing finger-holes. Students can experiment with the parameters and spot the differences among different shaped and from different geographical regions, zournas.

Sound change by experimenting with the model parameters, could also point out issues regarding the physics of musical instruments, and woodwinds in specific; longer bore results to lower pitch, closing holes near the bell while keeping holes near the embouchure open results to same pitches, and one can find so many other examples that demonstrate the principles of sound productions in woodwinds.

Furthermore, the 3D replica takes this concept one step beyond. The student not only listens to the zournas but has the chance to see, rotate, move, and optically examine the instrument. Changing parameter values results not only to different sound but to different image as well, making the interaction with the student more complete.

6. VIRTUAL ZOURNAS AND CRAFTSMEN

Interviews conducted with 15 different zournas craftsmen verified our common experience that craftsmen in Greece do not follow a specific standard for making a zournas. For example, many of them answered that they make the tone-holes as far apart as to fit the fingers of the player. They often have to make many instruments until getting one that matches their expectation, especially in their early crafting days or when they use new materials, new equipment or try something new in general.

Even though they appear confident with their craftmanship and do find the use of a “tuning gismo” necessary anymore, they all agree that such a device would be useful in their early years or when they would like to experiment with a feature of the zournas. The Virtual Zournas could then serve as a complete virtual design studio for zournas.

Setting parameter values and listening to the virtual instrument absolves the craftsmen from the need of experimenting on real wood wasting time and effort. They are free to experiment on the virtual plane, adjusting dimensions and technical characteristics, tuning, tone-hole position and producible pitches, timbre, registers, and so many other features as many times as desired.

The current version of Virtual Zournas allows the variation of the specific morphological and technical characteristics presented in 3. For example, the material of the bore is not taken into account by the sound model, nor is it possible to place tone-holes in desirable positions on the bore, despite the fact that these features are very important for a craftsman. An improved physical model could include all necessary parameters in order for the Virtual Zournas to become a truly complete design studio.

7. AESTHETICAL ISSUES AND CONCLUSION

In the introduction of this work certain questions regarding the aesthetics of Virtual Zournas and its uses were set. After having examined some applications it is time to have a closer look upon these issues.

To begin with, as for the case of any synthesizer, a virtual instrument should not be the plain replica of a real-world instrument nor should be used only when the acoustic instrument is absent. The role of a virtual instrument is to offer innovative means of music creation or other original applications and not to imitate.

Furthermore, the fact that the Virtual Zournas refers to a folk instrument makes things a little more complicated. Perhaps it would be easy to claim that this or any other virtual folk instrument helps the protection and diffusion of cultural heritage. Well, that’s not entirely true.

For example, the educative role of such applications is important, but, on the other hand, a folk instrument ‘functions’ inside its natural cultural context. Using folk instruments in a contemporary manner automatically transforms the context and the anthropological background it carries.

The outline chosen for this work to be presented (real instrument description/applications, virtual instrument description/applications) is not casual but reflects the ideas of the writers on the aesthetics and the role that a virtual folk instrument should have. The study of the real instrument and its uses is important for designing and defining the virtual instrument, since the virtual is an evolved state of the real instrument. The applications of the virtual instrument could be linked to those of the real one, but should also be novel and unique, or else there would be no need for such an evolution to occur.

To sum up, it is a strong belief of the writers that the aesthetics of new artistic and cultural tools such as virtual musical folk instruments should be in great part defined by the applications these tools find and the manner in which they are used. That is the reason for presenting the Virtual Zournas through the prism of a wide range of applications.

The controversy between the ‘raw’ and the ‘cooked’ still goes on [6], but the alliance of technology and anthropology is not a new concept in interdisciplinary cultural studies and arts. Virtual folk instruments should find their room to develop inside a new cultural space, defining perhaps a new form of art by bridging the traditional and the modern through novel means of artistic expression.

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9. REFERENCES


