WoodMusICK (WOODen MUSical Instrument Conservation and Knowledge) FP1302 COST Action aims to combine forces and to foster research on wooden musical instruments in order to preserve and develop the dissemination of knowledge on musical instruments in Europe through interdisciplinary research. This program involves curators and conservators on the one side, wood scientists, chemists and acousticians on the other side, and finally, researchers in organology and making of instruments.

The main objective of this COST Action is to improve the conservation of our wooden musical instruments heritage by increasing interaction and synergy between wood scientists and other professionals (including instrument makers) applying wood science, curator, organologists and makers towards the study, conservation and restoration of wooden instrument collections of artistic or historic interest, and to offer a novel and reliable, independent and global knowledge on these collections.

This Conference aims to enhance the cooperation among makers, museums, scholars, and scientists to increase the basic and general knowledge of how wooden musical instruments work, and also how working together can improve this knowledge.
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Rethinking the Possibilities of a Notched Flute: The Case of Quena

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Abstract

The quena is a notched flute from South America. Notched flutes share the same excitation mechanism but differ in several aspects such as the number of holes, the geometry of the notch and the size and shape of the tube. Today the quena is an instrument widely played in Latin America both in rural and urban contexts, where it gradually adapted to tonal music. It is in the latter context that we propose to revise the design of the bamboo quena from an acoustic perspective, optimizing the position of the toneholes and modifying the geometry of the bore in order to obtain a flexible and adequate instrument not only to play tonal music but also to adapt to the chromatic needs of contemporary music. The analysis is based on a linear model of the acoustical propagation inside the instrument, which is numerically simulated and optimized in order to obtain a new design of the instrument addressing some of the limitations found in the original cylindrical quenas.

1. Introduction

The Grove Music Online describes notched flutes as ‘an end-blown flute (open or stopped) with a V- or U-shaped notch cut or burnt into its upper rim to facilitate tone production’ [1]. Notched flutes are played widely and can be found in Africa, East Asia, the Pacific Islands and Central and South America. One of the most well known notched flutes is the Japanese shakuhachi. It is made traditionally out of bamboo and its most common form has four finger holes and one thumbhole. Variants of the notched flutes are found in China, Korea, Vietnam and Taiwan. The quena (or kena) is a South American notched flute. Like the other flutes, it is an ancient instrument, with a history of over 2000 years [2]. The instrument is mainly found in Peru, Bolivia, northern Chile and northern Argentina and is less frequent in Ecuador, Venezuela, Columbia and the Guyanas. It can be made out of cane, wood or reed and most instruments have six finger holes and one thumb hole [3].

2. Musical and cultural contexts

All these different flutes are used in specific musical and cultural contexts. Notched flutes were played in Peru as far back as the Chavin era (900-200 BCE). The traditional repertoire of the quena is closely associated to the dry winter season and is still played in Aymara communities on the Bolivian altiplano [2]. The instruments (kena-kena), used in these rural communities, are between 50 and 70 cm long, have six finger holes and are played as part of an ensemble. However, quenas were not solely confined to a rural environment. Solo playing developed within an urban setting, consolidated around the mid-twentieth century, when Andean music benefitted from a huge rise in popularity thanks to a cosmopolitan pan-Andean music genre created in Paris, where many
Argentinean, Chilean and Bolivian groups recorded and gained popularity in the 1960s [4]. This led to the modification of the instrument in order to cater to artistic needs such as adjusting to a more tempered scale and playing with other instruments. Today, the standardized urban instrument is generally made out a single piece of cane, wood or even plastic and features six finger holes and a thumb hole at the back [2]. Some modern models are also in two parts, with a joint between the head and the body (Garcia, interview 30 May 2016, Paris).

In Chile, the *quena* and the *charango* were used extensively in left-wing Nueva Canción groups, identifying themselves with a pan-Andean revolutionary movement [5]. These instruments were so closely associated with this political movement that they were strongly discouraged after the 1973 military coup, overthrowing Allende’s democratically elected government [6] (Wang, interview 5 July 2016, Paris). Despite this, traditional instruments were soon openly played by local musicians. One of these groups, Barroco Andino, was formed immediately after the coup and performed a Western Art Music repertoire initially conceived for different instruments (Wang, interview 5 July 2016, Paris). This led the musicians to push their instruments beyond their limits as they started experimenting in order to meet the demands of the music, leading them to an idealised “well-tempered *quena*” (de la Cuadra, interview, 8 February 2016, Paris). The decontextualization of the instrument from its folk and traditional repertoires triggered a movement that led to further modifications. More recently, for example, flautist and Ensamble Antara leader, Alejandro Lavanderos, contacted Paris-based flute maker Jean-Yves Roosen to create a chromatic instrument that would allow composers and musicians to go beyond the instrument’s current limits.

3. Influence of the musician on a flute-type instrument

Changes in repertoire imposed by musical, political or cultural change lead musicians and instrument makers to modify their instruments in order to cater to specific musical needs [7], [8]. If we reverse the position and propose an instrument with slight modifications, how will this impact the musician and his/her musical practice? As the one of the main driving questions of this study we wish to understand if the musician welcome change or if it will be problematic and whether a modified instrument will lead to the performance (and composition) of a different repertoire or if the musician will change the performance of his/her current repertoire.

Although the instrument is a separate object to the musician, both are intricately linked. Indeed, an experienced musician will be able to control his/her instrument in such a way that his/her technique will override many technical or structural issues that an instrument may have [9]. The structure of the instrument will influence how the musician controls the instrument but will not impede the musician’s production of a precisely targeted emission. We could theorize this in the following figure:

Although understanding the musician’s control over the instrument is not the goal of our study, it is an important aspect of our research in order to understand how the physical parameters of the instrument affect him/her.
4. Technical knowledge

In the last decades the knowledge of the physics of flute-like instruments has improved and a new research field, the musician’s control over his instrument, has shown to be both attractive and promising [9], [10], [11]. These improvements, together with the possibilities of accurate acoustic impedance measurements and the availability of materializing technologies such as 3D printers and CNC lathes, set up favorable conditions to study and revise the design of musical instruments. Analytical models of non-trivial geometries for instruments from the flute family are too complex to implement. Alternatively, the transmission matrix approach [12] provides a powerful tool to simulate and predict the linear passive acoustic behavior of flutes.

5. Revising the instrument

When conceiving a flute, there are several parameters that the builder can modify in order to obtain a desired intonation (tuning). The most important include the position, size and height of the toneholes, the bore’s internal geometry and the shape of the embouchure.

In a previous study [13] we observed that the bore geometry could be crucial in determining the inharmonicity between the first and second register of the instrument. In order to describe more precisely the tuning of the first two registers for every note from a given bore geometry, we simulated several internal bore shapes, cutting the passive end at places where it would produce a tempered scale if the resonator was an ideal cylinder. That is, in places where the length of the \(n^{\text{th}}\) chromatic note is given by: \(L/2^{(n/12)}\), where \(L\) is the length of the bore. For every truncated bore we simulate its acoustic impedance and measure its inharmonicity. Figure 2 shows the simulated response of a set of bores whose internal diameters are displayed on the upper side of the figure with their corresponding inharmonicity below:
We observe that the inharmonicity differs greatly among the three geometries and also varies considerably from note to note with differences that can span over a range of over 80 cents. Several bore geometries were simulated in the same way, providing a dictionary of bore shapes with their associated inharmonicities.

Once the geometry of the bore is chosen, the toneholes provide the means to tune the first register and fine-tune the second register. In order to identify how much inharmonicity can be controlled by adjusting the size and height of the toneholes, figure 3 shows a simulation of a 37cm cylindrical bore with one tonehole whose center is positioned at 34.96cm from the embouchure end, that is the length where an interval of a tone would be produced if the bore was truncated.
We notice that toneholes with equivalent inharmonicity can be obtained by correctly choosing a combination of tonehole height and diameter.

The variation of inharmonicity that can be induced by such holes is smaller than 5 cents, which shows that the inharmonicity induced by the bore’s internal geometry dominates over that of the toneholes.

With these parameters in mind, two instruments were simulated. The first features an intonation profile emulating the impedance measurements of real instruments (Figure 4, right); the second features a profile calculated to produce a tempered scale with a smooth evolution in the control over the two registers (Figure 5, right).

Figures 5 and 6 (left) show the bore profile and the size and position of the toneholes calculated to match the desired intonation.

In order to address our initial question, posed part 3, we are now in the process of printing both instrument simulations with a 3D printer.

6. Perspectives
Our next step is to measure through motion capture, video, sound and interviews how the musician adapts to the instruments. We are aware of personal differences between musicians and we are currently establishing an experimental protocol including two musicians and their reactions to both instruments within a musical context.

References
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