Ergotic Sounds
A new way to improve Playability, Believability and Presence of Digital Musical Instruments

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Abstract

We explore here is how "ergotic gestural-sound situation", i.e. the situation in which the instrumental gesture and the produced sound are intimately energetically linked, is a way to guaranty the playability, the believability and the presence of the musical digital instrument. The chosen experimental situation is the evaluation of a musical pattern on a bowed string performance that consists in maintaining the continuity of the sound when changing the bow direction. We present some surprising results, thanks to the hiqh quality real time "cello-like" haptic simulation, implemented on the ERGOS haptic technology.

1. Ergotic sounds

In the musical performance situation, two types of relation between the human gestures and the produced sound are usually distinguished:

• Non-instrumental musical practices, like the musical conductor situation, or the control of synthetic sounds parameters by mapping techniques [1][2].

• The instrumental musical experience, as when an instrumentalist is playing a physical instrument.

In non-instrumental practices, there is no energetic relationship between the human gestures and the sound so-controlled. Conversely, in the instrumental musical experience, the performer and the played object are physically dynamically coupled during the playing [3]. The produced sound engraves the physical energy exchanged between the performer and the physical musical instrument. It is what we call "ergotic sounds" to relate about an « ergotic relation to the sound » according to the typology of relations between human and environment proposed by C. Cadoz [4][5].

As emphazised by O'Modhrain et al. [6], we assume that the instrumental musical experience is an emblematic case of enaction, exhibiting the main features of the enactive theory of cognition:

• The world without representation [7]: the representation of the instrumental situation is only the situation itself.

• Cognitive categories (as here for example "musicality) do not pre-exist: they are emerging from the interaction with the environment, i.e. from the instrumental situation itself.

• Enactive knowledge acquired during the experiment is robust: the learning of the task (here is the performance) and the cognitive category (here is the musicality), that are emerging during the performance itself leads to a robust know-how.

The role of the energetic exchange between the instrumentalist and her instrument is well recognized when playing mechanical musical instruments. We may assume that the ergotic relation to the sound is an important feature for the playability of the musical instrument, that have to be re-introduced in digital musical instruments to improve their playability, their believability, the feeling of their sensory presence and of their presence in hand.

However, it is not easy to experiment such assumption in real mechanical situation and digital musical instruments can be very new experimental set-up to understand what it happens during an ergotic instrumental situation.

In the following, we describe the simulator we designed to catch the main feature of ergotic musical situation, and a first set of results obtained from a pilot experiment performed with 10 subjects.

2. The Virtual Cello-like Platform

2.1. The Physical model of the bowed string

Current implementations of interactive sounds are usually based on the mapping concept. Indeed, in the mapping concept, there is no energetic consistency between the process that produces the sound and the process that maps the gestural data acquired through sensors to the parameters of the sound synthesis process. The data flow between both is unidirectional, from the gesture to the sound.

When extended with force feedback interaction, as done in [6][1][8][9], the gesture side is improved by a local physical model that produces the force sent to the hand, but there is no longer retroactive interaction from the vibrating string to the manipulation part. Even though we may assume that the vibration of the string is not felt by hand, it is known in acoustics that the interaction from the string to the bow at the acoustical frequency plays an important role in the bowing.

A virtual bowed string model, that respects the bilateral physical interaction along all the instrumental chain, between the hand and the bow and between the bow and the vibrating structure, has been implemented in [10]. It is composed of two sets of interactions (Figure 1):

- two bilateral interactions between the bow and the vibrating string: (1) the buffer interaction for the transversal motion representing the collision and the pressure between the bow and the string and (2) the friction interaction for the lateral motion.
- A bilateral interaction between the bow and the hand via a 2D force feedback device returning the pressure and the friction forces from the bow to the hand.

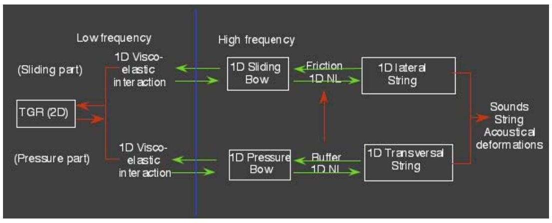

Figure 1.Ergotic Physical model of the bowed string

This model guaranties the "ergoticity of the situation" as it is the case in real mechanical instrumental playing; there is no break in the rendering of the energetic consistency between the hand and the hear.

2.2. The high quality ERGOS Experimental Platform

The technical platform has to implement a real time simulation of the previous model with a sufficient quality to be sure that the main features existing in the real situation could be caught.

Florens and his co-workers [10][11][12] developed the most reactive implementation based on a synchronous computer architecture and a high fidelity haptic ERGOS technology. In this implementation, the previous bowed-string model has been implemented with a two overlapped frequency loops: 3 KHz for the hand-bow loop and 44 KHz for the bow-string loop. An impressive quality of the sounds has been reached, encouraging to go further in the understanding of the sensitivity of the string by the hand, by asking the question: Is the gestural sensitivity of the vibrating string, although filtered by the bow and by the mechanical human body, important, and for what? Such question has never been experimented neither in real life situation nor in virtual reality based situation, although the "feeling" of the vibration of the string in the fingers is often noticed by instrumentalists.

To elicit the role of the "ergoticity" in the playing – i.e. the role of the energetic link between hands and sounds, one way is to implement an experimental virtual reality platform able to render the feeling of the vibrating string within the hand. Consequently all the part of the physical previous model must be implemented at the frame rate of the sound, i.e. at 44 KHz (Figure 2).

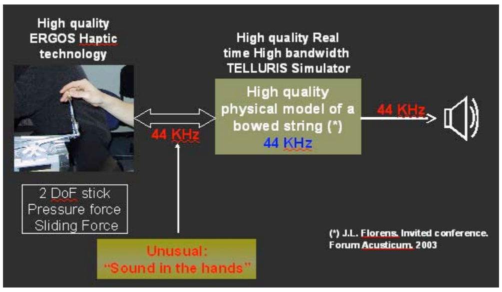

Figure 2. Functional diagram of the high quality 44 KHz experimental ERGOS platform

To do that, the entire model has been implemented on a DSP board directly connected to the force feedback ERGOS device by high reactive DA/AD converters and the sound is directly picked onto the DSP board.

The reactivity between input action and force feedback as well as between input action and sound are both of 1/44000 ms, and totally synchronous at that rate.

2.3. The experimental protocol

We select a feature that is considered as difficult to perform and to learn in real practices. It consists in maintaining the continuity of the sound when changing the bow direction.

This feature is subjectively well - identifiable by the performer and by the audience.

But it is also objectively observable on the signals as shown in the snapshot on Figure 3. When changing the direction of the bow by maintaining the continuity of the sound, the bowing movement is inverted (3), but the phase of the string vibration is not changed.

Performer and audience are invited to point out when the goal is reached and the moment when the subjective success occurs.

The experiment has been performed 10 subjects: 25 to 55 years old, 4 females and 6 males, 6 non professional musicians (3 totally novices and 3 with a slight instrumentalist expertise) and 4 musicians. One of them is a native blind people. The audience is composed of the previous subjects and 10 others persons, most of them being not aware of the activity of the laboratory.

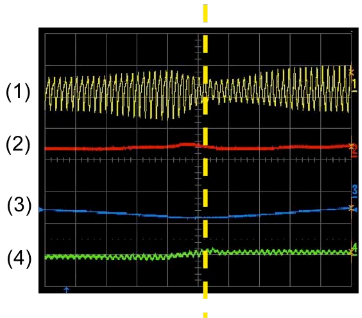

Figure 3. Signals corresponding the bow direction changing. (1) Acoustical vibration of the string, (2) pressure force of the bow on the string, (3) Displacement of the bow, (4) Sliding force of the bow

The subjects play freely the duration they want.

Subjects are confronted to four types of gestural feedbacks: (a): no friction; (b): slight friction, i.e. lighter than in the real case; (c) normal friction, i.e. closer to the real case, (d) exaggerated friction, very higher than in the real case.

Success is observed on objective signals and by asking the performer and the audience.

3. Results

3.2.1. Occurrences of the success of the task

The main observations are the following:

• With Slight or Normal Friction: Most of the people reach several times the goal after a very short time of trial (no more than 15 minutes), even if they estimate they are bad or non expert. The occurrence of success is greater than in real case.

• With Exaggerated friction: A very few number of people reach the goal. The best scores are obtained by the blind people. For all of them, the playing is difficult and non satisfying.

• With Null friction: A very few number of people reach the goal. The best scores are performed by the blind people. All the scores are better than with exaggerated friction. However, most people estimate that they can reach better after more learning.

We may conclude that adequate well-tuned ergotic relation to the sound is important to reach this goal.

3.2.2. Cognitive styles

A very first observation was that the ways of exploration depend on a priori cognitive styles. During the first minutes of playing, some people are caught by non dynamic features such as spatial features (geometrical properties as curvatures) or musical features (timbre or pitch). But progressively, and quite quickly (less than 15 minutes), all are attracted by the dynamic of the playing and started to explore it with new non predetermined ways: changing the force, the accelerations, the velocities, the trajectories, etc.

3.2.3. Modes of Playing and dynamic adaptation

A very obvious observation is made by all the persons of the audience and confirmed when examining the video movies: there is a continuous adaptation of gestures to find the best way of manipulation to reach the goal. Some examples are:

• Exploration of various modes of grasping and postures: With fingers, hand palm, deployed arm, strong full hand grasping, etc.

• a wide exploration of dynamic strategies: bow direction changing by soft round turning, road turns, Möbius-style movement, elliptic trajectories, modulating the cinematic of the gestures, acceleration/decceleration near the point of changing, relaxing the pressure before or after the turn point, etc. (see photographs on Figure 4).

Figure 4. Exploration of different ways of playing to reach the goal.

3.2.4. Continuous Dynamic Learning

Despite the morphological non - similarity with a real instrument (the displacement of the bow is of about some centimeters!), all the people learn very fast how to perform the playing. After less than 15 minutes, all the people were at ease with the instrument, improving very quickly the quality of their gestures.

Very quickly also, they start free exploration of a wide range of dynamic strategies to reach the goal. They declared that imagined a priori strategies are not correct. They learn on the fly "to be within the situation" and so doing they find very original strategy to reach the goal such as: *"Relax and let the bow act by itself just before the turn"* (Quotation of most of the people)

The best were the blind people for whom it is confirmed that she is a fine expert in haptic - audio strategies and, surprisingly, people that never manipulate real instruments or that do not have non predetermined cognitive styles.

3.2.5. Playability, creativity and Presence

For all the performers, "Exaggerated friction" is non affordant. For example, persons starting with this case do not understand the task itself. However, we observe that this non-affordance stimulates the discovery of new efficient ways of manipulation and of playing, leading to create new type of gestures and sounds. Affordance and creativity seems different concepts that can be sometimes and perhaps contradictory.

Obviously, the normal friction is the most playable and pleasant for all the performers. It increases to duration of playing stimulating creativity but within a more conventional attitude with less original exploration.

But above all, the unexpected result we are particularly proud, that is very new and very promising, relies on the spontaneous remark made by all the performers happily surprised by the "strong presence of the string in hand". Thanks to the 44Khz audio-haptic simulation, a strong and unanimous of "*The string Presence*", "*the string in the fingers*", "*the string is really here*", etc. Something of new appears, comparing with our first high quality implementation of ergotic sounds in which the haptic parts were running at 3KHz only. This could explain the strength and the predominance of the sound in the identification of the object by a co-reinforcement of the haptic and audio feedbacks in the sense that the acoustical vibration of the string and the "feeling of the string in hand by the haptic feeling of its vibration" convinces reliability of the indubitable presence of "that instrument".

4. Conclusions

The experiments presented here were motivated by an assumption that is well-accepted in the mechanical musical situation but quite impossible to evaluate without a specific virtual instrumental playing implementation: examine if ergotic audio-haptic situation - i.e. a situation in which the physicality of the interaction is maintained within the whole instrumental chain between the hand and the hear, the gesture and the sound - plays a core role in performing complex and subtle musical cues. The first set of performed experiments presented here are promising. Adapted and well-tuned ergotic sounds situation enhances instrumental learning and playability. It allows the performer to dynamically adapt her manipulation "on the fly" for the success of the goal. It supports very fast instrumental learning through very quickly acquired exploration strategy of manipulation. But above all, the most unexpected and promising result relies on the spontaneous remark made by all the performers happily surprised by the "strong presence of the string in hand", triggering a strong feeling of presence of the string, thanks to the never realized 44Khz audio-haptic simulation, implementing really what we called at the beginning of the research "ergotic sounds".

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