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The CORDIS Audio Haptic Real Time Platform for Musical Creation with Instrumental Interaction

James Leonard  
ICA, Grenoble INP, France  
leonard@imag.fr

Nicolas Castagné  
ICA, Grenoble INP, France  
castagne@imag.fr

Jean-Loup Florens  
ACROE, France  
florens@imag.fr

Claude Cadoz  
ACROE & ICA, Grenoble INP, France  
cadoz@imag.fr

ABSTRACT
In this paper, we describe recent work conducted at ACROE and the ICA laboratory of Grenoble INP on real time audio-haptic interaction with physical models for musical creation. These new developments enable the user to create complex mass-interaction physical models in a high level and user intuitive graphical environment. These models can then be simulated in real time, connected to a high fidelity haptic device, for rich audio-haptic musical interaction with ergotic coupling.

Keywords  

1. CONTEXT AND OBJECTIVES
Integrating haptic feedback into digital music instruments has become an increasingly popular activity in recent years. One of the main arguments is that haptic feedback can enhance the musician’s performance [1] and allows for a more intimate control over the sound produced. Moreover, the energetic exchange, or ergotic function of instrumental interaction, conveys meaning and is a key factor for expressiveness in the sound of a musical instrument [2]. The acoustic outcome of the physical interaction between a musician and an instrument is the result of a continuous and intimate exchange of energy between the two parties.

Haptic devices offer a unique platform for embodied cognition though the dynamic coupling of the user and a virtual entity [3]. Applied within the context of Computer Music, this brings forward a new perspective for interaction with virtual musical instruments [4].

A number of applications augment digital instruments with haptic mechanical models [5] to enhance playing “feel”. In some cases the haptic model also produces the sound, whereas in others it is correlated in a less direct form. When the haptic interaction is closely related to the production of sound, instruments such as the bowed string, which are usually difficult to play expressively via standard musical protocols such as MIDI, yield a convincing resemblance to their acoustic counterparts [6]. Indeed, the development of joined haptic / acoustical models in digital musical instruments can restore the ergotic function in an instrumental situation [7] [8].

This paper aims to present a modeling environment for mass-interaction audio / haptic models, and a simulation environment where the user can play these models in an instrumental fashion, using a haptic device fit for conveying the energetic coherence of the musical gesture’s ergotic nature.

This work builds upon two technological components that are presented in sections 2 and 3. Section 4 presents the work achieved for the CORDIS Audio Haptic Real Time Platform.

2. GENESIS MODELING ENVIRONMENT
GENESIS [9] is a physical modeling environment in which users can build elaborate mass-interaction models for musical creation (Fig. 1). The physical models are based on the CORDIS ANIMA [10] formalism. A small number of elementary modules, of two sorts, masses and interactions, can be assembled to form complex models. Being rooted at its lowest level on physical consistency, hence offering dynamics and subtle variations in the generated phenomena, GENESIS is an alternative to signal based top/down control, which is currently dominant in Computer Music.

Figure 1. GENESIS design activity and off-line simulation
GENESIS allows for microscopic sound construction as well as macroscopic physical structures for sound control, musical gesture metaphors, and compositional principles. Hence, GENESIS proposes the physical modeling paradigm not only as a tool for sound synthesis, but also as a full support for innovative musical creative processes, including musical composition. A single physical model can encompass, stand for, and generate an entire musical piece such as performed by Claude Cadoz in the artworks pico..TERA [11] and Gaia, composed of tens of thousands of physical interacting components. Figure 2 shows the simulation of such a large GENESIS model.
Figure 2. Simulation in GENESIS of a complex physical model by C. Cadoz, made of tens of thousands physical elements

Unfortunately, neither the modeling capabilities of GENESIS or its simulating capabilities are real-time and gesture interaction oriented. From the point of view of GENESIS, the work presented here goes toward the enlargement of its functionalities by integrating real time gestural interactions at the both modeling and the simulation stages.

3. HAPTIC REAL TIME WORKSTATION

The TGR (transducteur gestuel rétroactif) haptic device and the ERGON_X [12] simulation platform from ERGOS Technologies developed by ACROE form a high quality haptic simulation workstation. It combines very low latencies in terms of force feedback interaction with high morphological versatility in terms of workstation. It combines very low latencies in terms of force feedback interaction with high morphological versatility in terms of number of degrees of freedom and end-effectors organizations. The modular slice-based construction of the TGR allows for many degrees of freedom (one to sixteen) and can receive a number of mechanical end effectors, such as one-dimensional keys, 2D or 3D joysticks, 3D pliers, or string bows, allowing adapting to the versatile morphology of instrumental gestures. Figure 4 shows, as an example, the 12 key setup used in the present work.

The ERGON_X platform features the TGR and its electronics, and a “haptic board” [13] connected into a hosting computer. The haptic board function is implemented on a TORO DSP board from Innovative Integration, which hosts ADC/DAC converters and can calculate real time floating point operations. The real-time physical simulation runs fully on the haptic board, within a single-sample, synchronous, high frequency computational loop.

Both the haptic feedback and sound are produced from a single physical model based on the CORDIS-ANIMA formalism, computed on the DSP, at a high enough sample rate for audio restitution, typically 44,1kHz, in a single fully synchronous loop.

A wide number of physical real time simulations with haptic interactions [12] have been implemented on this platform, used in physics educative applications as well as in research on audo-haptic interactions and in virtual reality applications. Unfortunately, such a workstation does not yet benefit of modeling capabilities such as those developed in the GENESIS software. Hence, models were developed so far with a one-shot approach by researchers.

4. CORDIS AUDIO-HAPTIC REAL TIME PLATFORM

Bringing the GENESIS environment and the real time haptic simulation environment together proves challenging as their initial standpoints are quite opposed. Three main operations have been undertaken for the development of the first CORDIS Audio Haptic Real Time Platform.

4.1 A modular simulator

The GENESIS environment is primarily focused on physical modeling, with a modular system that gives the user the freedom to build any physical model he wishes. Simulation of the model is then calculated off-line. On the other hand, the real time applications are aimed at obtaining maximum efficiency for the simulation: they are programmed directly in C++ for the DSP, making use of algorithmic and code optimizations for each specific implemented model.

A new, modular, real time CORDIS-ANIMA physical simulation engine has been constructed for DSP applications. Thanks to data structure optimization, and tailoring of CORDIS-ANIMA algorithms for the specificities of the DSP architecture, it is model-independent while retaining similar performance results to model-specific, handwritten C++ code. The user is guaranteed full modeling freedom in GENESIS as well as optimal simulation efficiency in a real time situation.

4.2 Control of the correspondences between real and simulated worlds

We propose a number of processes in order to maintain the physical coherence of the whole interaction / simulation chain, and to provide the user with full and comprehensive control over the different quantitative elements that have to be considered, during the modeling process, in regards to the interaction between the simulation process and the real physical world across the haptic interface device.

The quality of the TGR’s dynamics, the synchronous temporal skeleton of the simulation and the complete control of the haptic device/simulation bidirectional chain make it possible to confer precisely known quantitative properties to this interactive simulation system. In particular, this concerns the various relationships between the parameters and physical quantities the user has to consider along the modeling process. This is particularly useful, not only for designing/playing virtual instruments or sound synthesis processes, but also for using the system as an experimental tool for audio or psycho-physic measurements.

Our process includes three steps:

- First, a calibration process allows maintaining the best possible precision for the position and force feedback data at each step of the device/simulation chain.
- Secondly, the user configures the relation between the set of parameters and variable quantities used in the GENESIS model, and those considered in the standard real world, evaluated with standard unit systems.
- The user can then refine the interaction with the simulated model in the real world, by adjusting the specific parameters of the haptic interface and simulation system:
  - The position/speed real/simulation conversion gain.
  - The force simulation/real conversion gain.
  - The sampling / simulation time step, usually set at a frequency of 44,1 kHz.

With these 3 steps, the user is able to map GENESIS physical models into the gestural world, and reciprocally - that is to adapt space and impedance [14] independently between gestural and simulated worlds for each TGR key, while guaranteeing quality energetic flow, which is crucial for the instrumental interaction.

4.3 The user-friendly software environment

We finally introduce a dedicated friendly graphical Human-Computer Interface for real time simulation of GENESIS models.

First, this environment mediates the concept of relations between the mechanical world and the simulation to the user, who can choose the convenient representation scales and set the parameters

1 http://acroe.imag.fr/ergos-technologies
that define the physical interaction between the simulated model and the mechanical world.

Secondly, it lets the user manage the various steps needed to go from the GENESIS model to the actual simulation. In this environment, any model created in GENESIS can be imported directly into the real time environment, where the TGR/Simulation interaction points and mechanical/simulation correspondences can be configured. The model is then interpreted and compiled into a real time DSP application. This offers an extensive modeling environment for creating haptic musical instruments (Fig. 3 and 4).

CONCLUSIONS

This paper presents recent work on audio-haptic interaction with physical models built in the GENESIS environment. The association of high performance haptic devices and an extensive modeling framework allows for complete dynamic coupling between the musician and his virtual instrument. This offers a unique tool for further exploring the influence of the ergonomic function in musical gestures, and the relevance of full instrumental audio-haptic interaction in musical creation processes with a digital and/or virtual music instrument. Through this work, we believe to have achieved a prototype of the first modeler/simulator for audio-haptic ergonomic interaction designed for musical creation (Fig.4).

REFERENCES

