Gestural auditory and visual interactive platform
Baptiste Caramiaux, Sarah Fdili Alaoui, Tifanie Bouchara, Gaétan Parseihian, Marc Rébillat

To cite this version:
Baptiste Caramiaux, Sarah Fdili Alaoui, Tifanie Bouchara, Gaétan Parseihian, Marc Rébillat. Gestural auditory and visual interactive platform. 14th International Conference on Digital Audio Effects (DAFx-11), Sep 2011, Paris, France. pp.69. hal-00619308

HAL Id: hal-00619308
https://hal.science/hal-00619308
Submitted on 6 Sep 2011

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ABSTRACT

This paper introduces GA VIP, an interactive and immersive platform allowing for audio-visual virtual objects to be controlled in real-time by physical gestures and with a high degree of inter-modal coherency. The focus is particularly put on two scenarios exploring the interaction between a user and the audio, visual, and spatial synthesis of a virtual world. This platform can be seen as an extended virtual musical instrument that allows an interaction with three modalities: the audio, visual and spatial modality. Inter-modal coherency is thus of particular importance in this context. Possibilities and limitations offered by the two developed scenarios are discussed and future work presented.

1. INTRODUCTION

This paper introduces GA VIP (Gestural Auditory and Visual Interactive Platform), an interactive and immersive platform allowing for audio-graphical virtual objects to be controlled in real-time by physical gestures. GA VIP is based on a control unit driven by gesture processing monitoring the behaviour of the virtual objects. A global control of the virtual world ensures the inter-modal coherency of the proposed environment. The SMART-I² audio-graphical rendering engine achieves the spatialization of the virtual objects in a 3D audio-graphical scene [1]. The spatialization increases the coherence and thus the user’s feeling to be «present» in the visual scene [2]. Gesture processing allows for a wide range of natural interaction enhanced by the presence sensation [3].

GA VIP can be either considered as a sound installation, a platform of development for experimental protocol or an extended musical virtual instrument. By «extended», we mean that the created virtual musical instruments do not only allow an interaction with the audio modality, but an interaction with three modalities: audio, graphic and spatial. Declinations of GA VIP mainly depend on scenarios that are implemented. In this paper, focus is particularly put on two scenarios exploring the interaction between a user and the audio, graphic, and spatial synthesis of a virtual world where the interaction is thought in the sense of virtual musical instrument design. Previous works have dealt with the interaction between gesture and sound for the design of virtual musical instruments [4]. Early works have led to low interaction expressivity caused by a direct mapping between gesture parameters and sound synthesis engine parameters. Extensions have led to take into account more expressive interactions by considering higher level descriptors or mapping based on physical models [5]. Progressively, virtual musical instrument became more linked to the sound perception and immersion. This has led to consider the spatial diffusion of sounds produced by such instruments [6], thus changing the terminology from virtual musical instrument to sound installation in which interactions are multimodal [7]. In this paper, our contribution is to propose a platform that combines sound spatialization and audio-graphical systems. To enhance interaction, our platform aims to guarantee inter-modal coherency (see Sec. 2.2).

The paper is structured as follows. In the section 2.1 we present the concept of GA VIP (the general platform for designing new extended musical instruments). Section 2.2 describes a first scenario based on a simple interaction approach. To increase the degree of inter-modal coherency, a second scenario was developed based on a physical model. It is described in Section 2.3.
2.3. Architecture
In order to achieve interaction with consistent audio-graphical objects in a virtual 3D scene, we designed a general virtual space where the audio and graphical parts of each entity are governed by the same control unit. Concretely, one unique control model is mapped with both modalities (the sound synthesis and the graphical synthesis) and the virtual space (spatialization) according to three consistent intra-modal mapping strategies (see Fig. 1). This allows the immersed user to influence through his/her gesture the control model itself and, consequently, the audio-graphical objects behaviour and their position in the virtual space. The consequence of an action of the user is by nature multimodal (audio/graphical/spatial) and a careful design of the mapping strategies ensures, by construction, the preservation of a strong inter-modal coherency.

2.4. Audio-graphical spatial rendering
The SMART-I² (Spatial Multi-user Audio-graphical Real-Time Interactive Interface) \[1\] provides an immersive, real-time and consistent audio-graphical spatial rendering. The spatial sound rendering is achieved by means of Wave Field Synthesis (WFS) \[11\]. The WFS technology physically synthesizes the sound field corresponding to one or several virtual audio sources (up to 16 sources) in a large rendering area. The 3D graphical rendering is made using passive tracked stereoscopy. In the SMART-I² system, front-projection screens and loudspeakers are integrated together to form large multi-channel loudspeakers also called Large Multi-Actuator Panels (LaMAPs). The rendering screens consist of two LaMAPs (2 m × 2.6 m with each supporting 12 loudspeakers) forming a corner (see Fig. 2). Overall, the SMART-I² allows to generate 16 independent virtual objects. Each virtual object is a sound source and a graphical object. See \[12\] for more informations regarding audio-visual immersive systems using WFS.

Figure 1: Overview of the general architecture of the GAVIP

Figure 2: Front (left) and back (right) views of the SMART-I² audio-graphical rendering system. The left picture shows a participant using the early approach of interaction.

3. EARLY APPROACH
This approach was presented as a demo during the european meeting European VR-EVE 2010 that took place at the LIMSI-CNRS, Orsay, France.

3.1. Overview
In this first approach, each graphical object was a bubble and each sound source was a single sound sample taken from a given database (see Fig. 2). The challenging task was to control the set of 16 independent sound sources generated by the SMART-I². We chose to synthesize sounds of water drops. Two modes of interaction correspond to either a sequential or a single triggering of sound samples. Since a simple one-to-one mapping was impossible, we chose to have automatic controls of some of the sound parameters. We separated the sound controls (sample volume, sample playback speed, period between two successive sounds) from the spatial controls (voice number, distance, azimuth). Each of these parameters was controlled by a specific probability density function from which each parameter’s value was drawn. This allowed to control the parameters’ variations and to have less predictable behavior.

3.2. Gesture Control
The gesture control process is twofold. First, an Optitrack motion capture system composed of six circular cameras is used to track the user motion and adapts the graphic feedback to his/her spatial position. The calibration of the cameras is performed with the help of the Optitrack Rigid Bodies software. This software locates the markers dispatched on the user stereoscopic glasses and sends their 3D positions and orientation via a VRPN communication protocol.

Second the sound control is achieved by means of a WiiMote controller. Hence, the gyroscopes are used for driving azimuth and distances: the user can choose to be either closer or further from the sound sources and put the sources either on the right side or on the left side. Accelerometers are used for triggering control. We refer the reader to the previous section (Sec. 3.1) for the presentation of the two triggering modes. In the first mode (triggering mode), the user can use the controller to trigger percussive sound of water drop. In the second mode (sequential triggering), regular hits with the controller at a certain frequency trigger sequentially
played sounds with the same frequency. The frequency range allowed for synthesizing sound textures from separate water drops to heavy rains.

3.3. Limitations

The gesture control of audio-graphical objects proposed by this approach is straightforward. This enables a direct understanding of the general behavior by the user that can experience the scenario in a ludic way. However, this approach features several limitations. First, the global behavior is mostly controlled by probability density functions and the user’s degree of control is limited. Hence the user can not really consider the interface as a virtual musical instrument as its control in sound production and positioning in space is limited. Second, the audio and graphical elements have a basic discontinuous behavior that consists in appearing – disappearing which does not simulate sound texture.

4. CURRENT APPROACH

To overcome the limitations of the first scenario, focus has been put on the control aspects of the platform for two main reasons. First, we aim at providing a smoother control of sound synthesis and sound spatialization. Second, in our quest for inter-modal coherency, we were looking for a more coherent relationship between audio and graphical parts of the virtual entities.

4.1. Overview

We refer the reader to the general architecture of GAVIP depicted in Fig. 1. The control process in the early approach was based on accelerometer–gyroscope sensor data analysis and simply linked in Fig. 1. The control process in the early approach was based on W e refer the reader to the general architecture of GA VIP depicted.

4.2. Physical Model

Here we define a physical model governing the dynamic of abstract spherical particles in a 2D space. These particles are in a physical model of abstract masses linked together with springs governs their movements in this environment. Let us denote $\vec{a}_n(t)$ the acceleration of particle $n$ at $t$, each element $n$ has a mass $m_n$ and follows the Newton’s second law of motion defined by:

$$ m_n\vec{a}_n(t) = \sum_{k \neq n} \vec{F}_{k\rightarrow n}(t) + \vec{F}_{\text{centro-n}}(t) + \vec{F}_{\text{external}}(t) $$

Where at time $t$, $\sum_{k \neq n} \vec{F}_{k\rightarrow n}(t)$ is the sum of the forces applied from the other particles on the particle $n$, $\vec{F}_{\text{centro-n}}(t)$ is the force applied from the centre on the particle $n$, and $\vec{F}_{\text{external}}(t)$ are the external forces exerted on $n$. Within the framework of this physical model, the forces are defined as follows:

- $\vec{F}_{k\rightarrow n}(t)$ accounts for: the elastic force (characterized by a parameter $\alpha_k$), the viscous friction (characterized by $\mu_k$), the electrostatic attraction (characterized by the product of their electrostatic load $q_nq_k$).
- $\vec{F}_{\text{centro-n}}(t)$ accounts for: the elastic attraction (characterized by $K$) and the central viscous friction (characterized by $\eta$).
- $\vec{F}_{\text{external}}(t)$ accounts for: the global rotation (characterized by $\beta_n$) and a magnetic field that is linked to the electrostatic load of the particle $q_n$.

This physical model allows to generate the relative movements of masses from a given initial state. At each time step $t$, the physical model returns the particles’ index together with their Cartesian coordinates.

4.3. Sound Synthesis

The sound synthesis is based on the CataRT software developed by Diemo Schwarz at Ircam [13]. The software takes a set of sounds and segments them given a grain size (the default grain size is 242ms) and/or a segmentation algorithm (for instance based on onset detection). Since we work with sound textures with no onset, we choose to segment the input audio stream every 242ms. CataRT analyzes each grain by computing a set of audio descriptors. The resulting grain representation is a vector whose elements are the descriptors’ mean values. CataRT then visualizes those grains in a 2D space (also called descriptor space) where the dimensions are chosen by the user among the available descriptors, for instance the loudness along the $x$-axis and the spectral centroid along the $y$-axis. Depending on an input path on this 2D space, sound grains are selected: at each time step $t$, the selected grain (i.e., played) is the closest to the current position $x_t$, $y_t$ in the path in terms of a Mahalanobis distance. More precisely, this distance is computed between $x_t$, $y_t$ and the grain descriptors mean values that correspond to the 2D space axis (e.g., loudness and spectral centroid). Note that a path in the descriptor space can be given either by using a gesture interface such as a mouse or by an input sound described in the same descriptor space. The latter case is sometimes called mosaicing.

Here, the sound grains are selected by the abstract particles’ positions defined previously. To that end, we match both 2D representation used for the physical model and the sound corpus. Fig. 3 depicts the process. The sound corpus remains unchanged but the output of the physical model (which consists in each particle index and Cartesian coordinates) is scaled to fit the sound corpus dimensions. Hence we have two layers in the same Cartesian space (see the image at the middle of Fig. 3). An abstract particle position selects the closest grain (according to a certain neighborhood radius) at each time step. Concretely, our physical model is composed of 16 particles navigating in the sound corpus and selecting 16 grains (i.e., sound sources). Finally, this virtual plane is the sound field produced by the WFS.

4.4. Gesture control

The user’s head is still tracked using an Optitrack motion capture system that allows to adapt the graphic feedback to his/her spatial position. Then, the gesture control of the virtual environment and objects corresponds to the possibilities of action and influence that a participant will have on them. One of the main challenges is to offer the participant an important power of expression in his control of the environment and the virtual objects.

At this step, the mapping between gesture analysis outputs and physical model parameters is not implemented but the global con-

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**Proc. of the 14th Int. Conference on Digital Audio Effects (DAFx-11), Paris, France, September 19-23, 2011**

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5. CONCLUSION

In this paper, a platform for the conception and exploitation of immersive, interactive and multimodal scenario were presented. An effort has been made to define a modular architecture that allows for various interesting interaction designs with respect to the coherency between audio and graphical objects. Two concrete scenarios were presented. The first one made use of simple triggering and orientation interactions between gesture and audio synthesis and spatialization. The second scenario proposed a general physical model that governs the behavior of audio-graphical objects in the scene. Gestures analysis controls the physical model. This new approach offered better coherency between audio and visuals as well as a smoother gesture control of them.

Future works will consist in (1) completing the implementation of the gestural control of the physical model and (2) designing perceptual experiments to evaluate the platform.

6. ACKNOWLEDGMENTS

We are grateful to both LIMSI-CNRS and UMR STMS IRCAM-CNRS for the lending of equipment. We also would like to thank Matthieu Courgeon for his contribution and technical assistance on the 3D graphical programming.

7. REFERENCES


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