Available online at www.sciencedirect.com
SCIENCE DIRECT®
Computers & Graphics 29 (2005) 871–881
COMPUTERS & GRAPHICS
www.elsevier.com/locate/cag

WAVE: Sound and music in an immersive environment

Leonel Valbom[a,b,*], Adérito Marcos[a,b]

[a]*Information Systems Department, School of Engineering, University of Minho, Azurém Campus, 4800-058 Guimarães, Portugal*
[b]*CCG/ZGDV –Computer Graphics Center, Azurém Campus, 4800–058 Guimarães, Portugal*

Abstract

This paper presents WAVE—a Virtual Audio Environment, which embraces the implementation of an immersive musical instrument model that uses three-dimensional (3D) sound techniques combined with visualisation and virtual reality technologies. This prototype environment aims to extend the idea of a musical instrument into a new musical/audio system, incorporating traditional musical concepts side by side with actual music concepts, in order to progress one step further in the music/sound composing and performing approaches.

The architecture of the system is based on low-cost hardware and open source software with affordable professional audio equipment to maintain an adequate sound quality. Also several applications of this virtual environment are discussed in the paper, including the way to satisfy at the same time composers, performers, music/audio students or even simple occasional users.

Keywords: Sound and music systems; Virtual reality; Interaction techniques; Performing arts

1. Introduction

In the last 10 years, there have been significant advances in the *technologies* related with Virtual Reality (VR) [1]. Some of them are becoming more robust, user-friendly and less expensive, applicable to many forms of daily activities, most of which were unforeseen some years ago and raising challenges for new ideas related to application and end-user scenarios [2].

One of the areas of research and development based on the VR technologies is related with electronic sound and music, especially considering the shaping of new instruments by means of their aural and visual (immersive) control.

One of the main principles of electronic musical instruments is to allow the conceptual separation of their control surface from the sound they generate [3]. This opens a window of possibilities to design and implement separate virtual control surfaces of almost unlimited size and of any type of shape, for each sound or set of sounds produced. VR plays a pivotal role here in boosting the design of new and effective control surfaces for musical instruments. This is accomplished based on VR's highly visual, immersive, aural, tri- and multi-dimensional interfacing potential as also its interaction plasticity.

In fact, with the actual processing power of home computers and the wide availability of existing surround-sound systems, it is possible nowadays to conceive and implement low-cost virtual environments that integrate models of musical instruments capable of responding to current demands in musical creation, sound localisation and performance. We have to face here the challenge of devising new innovative solutions

*Corresponding author. Information Systems Department, School of Engineering, University of Minho, Azurém Campus, 4800-058 Guimarães, Portugal. Tel.: +351 253 439 300; fax: +351 253 439 348.
E-mail address: lvalbom@ccg.pt (L. Valbom).

0097-8493/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cag.2005.09.004

that can bring together the art of music with digital and computer-based control of music/audio events and sound information, while contributing to a better understanding and awareness, as recognised in the entertainment industry, that sound is a vital aspect in the creation of ambience and emotion [4]. This comes along with new interaction paradigms, such as gesture based in immersive environments and three-dimensional (3D) visualisation, which follows the goal of bringing together both classical/traditional and contemporary musical activities.

In this paper, we present WAVE—a Virtual Audio Environment that aims to implement a set of integrated facilities for dealing with music and sound manipulation. The architecture of WAVE is designed to cope with different facets of music and sound such as performing, playing, creating and composing by generating new sounds or modifying existing musical and sound structures, while facilitating a wider access for the audiences. The main motivation behind the development of WAVE has been to mould and implement a new immersive musical instrument for users with different musical background, for multiple styles in musical education and entertainment situations, where VR links together full-body gesture input with 3D computer-based sound generation and computer graphics [5].

This paper is organised in four sections. Section 2 presents some related work, with special focus on the different attempts to create new instruments and performing artefacts that occurred during the 20th century as well as in recent years. Section 3 presents WAVE in terms of the principles and concepts behind its design and implementation. Some of the main requirements that will guide the design of a new instrument for immersive environments are defined. Then, the architecture, both as hardware and software modules, is described as well as its user interface, its main features and limitations. It is argued here, based on the developed prototype, how the concept of a musical instrument can be extended using low-cost technology in a VR environment. The prototype already developed is discussed in Section 4 and finally, in Section 5, some conclusions and a number of lines for future work are presented.

2. Related work

The development of new musical instruments has been a constant activity since ancient times. This activity has primarily involved artisans, carpenters, musicians or artists who have been looking for the best solutions in terms of materials, shape and musical accuracy for new as well as existing instruments. This resulted in a series of classical instruments, well known in the musical and artistic milieu of today, such as the piano or guitar, that have advanced through the past few centuries [6].

Starting in the second-half of the 19th and throughout the 20th century, we noticed a remarkable development of the technologies to support music in its several facets. This development can be divided into two main different areas, namely, sensors technology and sound/audio technology.

2.1. Sensors technology

The advent of electricity, analog and digital electronics as also computers has gradually speeded up the development and testing of new ways of dealing with sound and music. The history of building gesture interfaces based on sensors for real-time musical performance, for instance, started at the beginning of 20th century with electronic musical instruments like the Theremin (Fig. 1), the Ondes de Martenot (1928), the Pianorad (1926) and the Givelet [7].

The Theremin [8], in particular, used an innovative technique whereby the sound was initiated with the free movement of the interpreter's hands without any associated mechanical linkages. This increased tremendously the level of freedom for the performing movements, while endorsing the establishment of new lines of musical composition [9]. However, its main limitation was that it was a mono-timbral, monophonic device [10].

In the second half of the 20th century, a series of new means of expression and performance started to appear. Some representative examples of systems developed

Fig. 1. Theremin.