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Projet d'Étude et de Recherche

Three-dimensional musical instrument

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Introduction

A three-dimensional musical instrument might sound quite abstract for the bystander. One can think of it as a musical instrument taking place in the virtual reality or augmented reality domain. While an exact definition might be hard to settle because every instrument will be different in core features to others, a general definition might be an instrument which can have either :

- A visual representation in a three-dimensional space
- Interactions in a three-dimensional space

The two points are generally shared, however it is harder to display the instrument in 3D than to interact with it.

The display can have two goals : [BHDC10]

- Giving visual cues to the spectators of the musician's actions.
- Helping the musician to perform.

One of the main focuses of this exposé will be to assess the different display techniques suitables to a 3D instrument, and the other will explain how it can improve existing 3D instruments.

The last part of this report will be about the choices we had to make in order to setup our own 3D musical instrument.

Chapter 1

3D musical instruments and 3D displays for performance

1.1 Subject presentation

3D Musical instruments
At the **SCRIME**[1] and **LABRI!**[2], three-dimensional musical instruments have been implemented within the context of research in interactive virtual reality and music computing.

The **Drile** [BDCH+10] is a 3D musical instrument which allows manipulation of the structure of a song using live looping, in an immersive virtual reality scene.

The **Aerial Percussion** is a 3D musical instrument which generates sounds using the position in space of sensors which are put at the end of drumsticks. Virtual 3D shapes like cubes, cylinders, are positionned around the instrument and the musician. According to the position, the orientation, and the speed of the sensors, sounds are generated.

Required work
We were asked to implement a prototype of a 3D render and display device, for musical performance. It is necessary to take into account the constraints inherent to a musical performance environment, as well as the constraints of the instruments.

Here are some constraints for the performance :

- The musician has to be in front of the audience.
- The musician requires visual cues inherent to the utilisation of the instrument, and the audience must see the instrument to understand the gestures and actions of the musician.

To enact this implementation, a precise explanation of the nature of the 3D musical instruments is required.

Plan for this section
We will first make a short presentation of 3D musical instruments, present and will then define the concepts of immersivity and interactivity.

[1] Studio de Création et de Recherche en Informatique et Musique Électroacoustique
[2] **LABRI!**

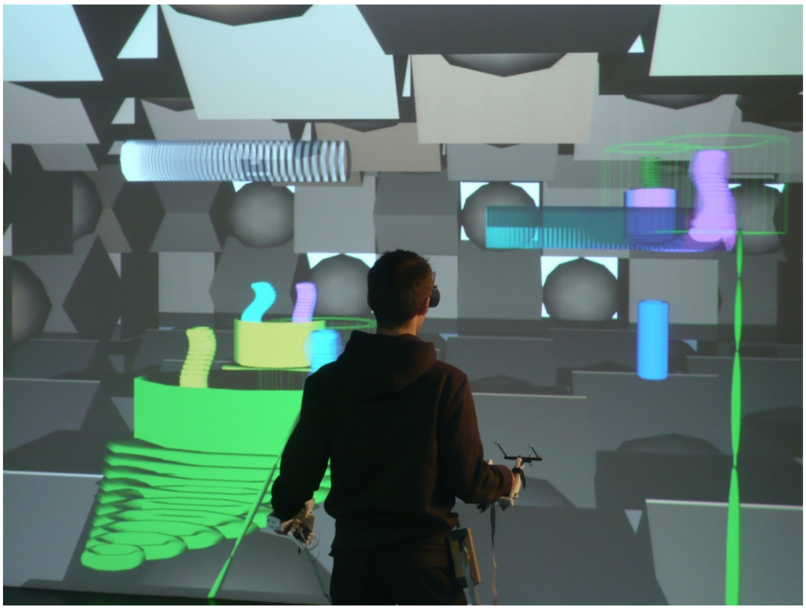

Figure 1.1: Picture of a musician using DRILE

1.2 What is a 3D musical instrument?

TODO a reformuler : bof le wikipédia

A 3D musical instrument, or an immersive virtual musical instrument, represents sound processes and their parameters as 3D entities of a virtual reality so that they can be perceived not only through auditory feedback but also visually in 3D and possibly through touch as well as haptic feedback, using 3D interface metaphors consisting of interaction techniques such as navigation, selection and manipulation.

Example for the Drile

For instance, the picture 1.1 shows a musician with special glasses, as well as joysticks with force-feedback haptic sensors (Piivert [BHDC10]). The user handles 3D shapes in a 3D environement to influence the music generation. A specific part of this report will be dedicated to a precise study of the **Drile**.

1.3 Immersion

Definition
Immersion is a psychologic state where the subject stops about taking care of its own physical state. The immersion is quite important in virtual reality. For instance, for the Aerial Percussion, it would come down to the state the performer is when he stops thinking consciously of the disposition of the shapes he interacts with. The musician will then be immersed in the virtual 3D environment which consists in the shapes disposition.

Hence, to immerse an user, multiple parameters are accessible to the 3D instrument designer. They are mostly linked to the senses of the human body. In our project, we will mainly focus on vision, and more precisely on 3D display devices.

Interactivity & reactivity
Interactivity is an important aspect of the immersion capacities of a musical system. The user is more likely to get an immersive feeling in a virtual world, if the world instantly reacts to his actions and gestures [BD95]. This leads us to an important part of the 3D musical instrument : the interface, the controls that the performer requires to operate the instrument.

1.4 Control

In order to understand and define what is the control of a 3D musical instrument, it is necessary to think of the instrument in two different ways :

1. First of all, it is a musical instrument, which implies multiples constraints :
   - It has to be adapted to the human body shape so that the musican can manipulate it.
   - It has to be precise enough for the performer to be able to learn how to play the instrument.
2. But it is also an interactive immersive system, which means that it requires :
   - A lot of interactivity.
   - The usage of senses for a feedback : for instance, immersive visual and haptic feedback (as well as auditive, since it is a musical instrument).

Musical instrument gestures
In order to conceive a 3D musical instrument, it is necessary to understand the movements that the musician does while playing. For instance, the Cadoz gesture segmentation [Cad99] is an attempt to differentiate different families of gestures while playing.

Cadoz defines three kinds of gestures that all come to play when playing music:

- Selection gestures : The musician selects a component of the instrument that he will play on. For instance, for stringed musical instruments, where the same tone can be achieved on different strings, but with a different timber, it is the choice of the string on which the note will be played.
- Modification gestures : It is an action that modifies the physical state of the instrument. For instance, it would be the case of the guitar player who presses its hand on the guitar strings against the wood.

- Excitation gestures : These actions are the ones generating the actual sound of the instrument, by making the air vibe. On a guitar, it would be picking a string, and on a violin, it would be moving the bow against a string. This gesture is the one the artist can put expression inside : for instance, a violonist can press his bow softly or hardly, in order to change the nuance.

Control and immersion

In order to correctly play an instrument, the user requires some kind of manipulation comfort : it must not be painful or too tiring to play. Hence the requirement for immersion : being immersed means that the user does not need to put effort into playing the 3D musical instrument, he becomes part of it. An easy way to improve immersion is to make the environment react to the performer's movements.

This can be achieved by using head tracking, with a **Kinect** for instance, or a **HMD**[1], a **CAVE**[2] or other virtual reality devices and methods like Fishtank VR [RCVD97]. This allows to adapt the scene's projection to the movements of the head of the user : for instance, if he turns his head to the right, the display will adapt by showing him what he would see if it was real.

Haptic feedback buttons also increase the consciousness of the user's actions, which implies an increased precision.

Florent Berthaut thought about most of these problematics while conceiving **Piivert** [BHDC10], the control interface to the **Drile**.

[1] Head-mounted Display

[2] CAVE Automatic Virtual Environment

Chapter 2

Three-dimensional displays

2.1 Definition of a 3D display

While it is commonplace to hear about 3D display in television or smartphone advertisement nowadays, the distinction between 2D and 3D might be more difficult to settle.

2.1.1 The problem

If we take the simple definition : a 3D display is a display that can show 3D images, it is really ambiguous, because of what is supposed to be "3D". For instance, for years, video games have been advertising 3D engines and spectacular 3D graphics, even without what we now call 3D displays.

Hence, we have to qualify what is 3D and what is not.

2.1.2 Parameters

In the litterature ([Oko76], [PS12]), the main idea is to relate to the human brain and body capabilities. For instance, a big part of the "3D" feel is due to the fact of having two eyes that looks in the same direction, but from a slightly different angle, but it is not all.

The visual cues of 3D vision are separated in two families:

- Physiological cues. They will relate to the capabilities of the human body.
- Psychological cues. They will relate to the information inference capabilities of the human brain.

2.1.3 Presentation of common visual cues

Psychological cues
Occlusion
Linear perspective
Atmospheric perspective
Shading

Figure 2.1: Psychological cues

2.2 Classification of the 3D displays

One of the main problem while trying to find a proper display for a given application is to choose a relevant classification for the displays, that allows a choice with criterions relevant to the application.

2.2.1 Criterions

There was a lack of proper nomenclature in the literature for a long time [PS12]. However, some attemps have been made to find relevant criterions that would be general enough to cover the current display techniques, but also the ones that are not yet thought of.

Different classifications

The first classification was in [Oko76], and it was really based upon the different kinds of displays :

- Lens-sheet three dimensional pictures.
- Projection-type three dimensional displays.
- Holography.

However, it did not hold well against the emergence of new techniques, like volumetric displays for instance.

««« < HEAD Other classifications would limit themselves to only a subset of 3D displays. ======= Other classifications [?] would limit themselves to only a subset of 3D displays.

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Hence the need for a classification that would not base itself on the different technologies, but on criterions that would be inherent to the idea of display and human vision.

Chosen classification

In [PS12], the main idea is to classify the displays according to two axes :

- The display depth (flat or deep).
- The number of points of view from which the image can be seen (duoscopic, multiscopic, or omniscopic).

2.3 In-depth presentation of some 3D display methods

Pepper's Ghost

Glasses

Head-mounted displays

Hologram

Autostereoscopic screen

Chapter 3

Presentation of 3D musical instruments

3.1 History of the 3D musical instruments

De nombreux instruments de musiques immersifs se concentrent sur la navigation dans un environnements 3D virtuelle. Tout d'abord le projet Phase [RLC+05] explore la génération, la prise en main et le controle de son ou de musique à l'aide d'un capteur haptique et d'une représentation visuelle pouvant guidée l'utilisateur. Un second projet, Plumage [JAC+07], est une interface pour le contrôle interactif de la composition audio spatialisées. Des plumes dispersées dans une scène 3D représente des grains sonores, générent du son lorsque des têtes de lectures les parcours. Les têtes de lectures sont contrôlées directement par l'utilisateur. Néanmoins ces deux projets ne permettent pas de manipuler directement la structure de la synthèse sonore, mais seulement de la manipuler.

Une autre gamme d'instrument 3D se concentre sur une unique synthèse sonore. Dans ce cas nous pouvons trouver par exemple le *Virtual Xylophone*, le *Virutal Membrane* ou encore la *Virtual Air Guitar* [MPLKT05]. Un autre exemple d'interaction 3D avec une synthèse sonore unique est celle de Mike Wozniewski [WSC06]. Son application permet a un utilisateur de naviguer dans une scène 3D comportant à certain point précis des générations de son. L'utilisateur entend les sons en fonction de sa position et de son orientation dans la scène 3D.
La percussion aérienne est un intstrument 3D que nous pourrions mettre dans cette classe d'instrument.

Le DRILE propose une nouvelle utilisation de la 3D. Le DRILE utilise l'interaction 3D pour pouvoir manipuler plus aisément la structure même d'une musique.
Le DRILE et la percussion aérienne ont été conçu pour la performance musicale.

3.2 The DRILE

3.2.1 livelooping

3.3 Aerial Percussion

Chapter 4

Realisation

4.1 Required work

Apart from the research work, the application of our research to two musical instruments (the DRILE and the Aerial Percussion) is required.

The goal of our work is to enact a live show with these two instruments, that allows for both the performer and the spectators to see the musical instrument in three dimensions.

4.1.1 Finding a display

The first task is to find a suitable display method that would allow :

- The performer to interact with the instrument
- The spectators to see the performer as if he was part of the 3D scene
- If possible, a stereoscopic feel.

4.1.2 Implementing suitable renderings

There is already some existing work for the rendering engine of the DRILE, however there is nothing for the aerial percussion.

We have to make renders from two different viewpoints : one for the performer, antoher for the spectators.

4.1.3 Customisation

If we have time left, we are to add some customisations to the aerial percussion rendering, in order to make it look like a real show, with special effects, flares, particles, textures...

4.2 Implementation

We will describe here the multiple choices that have been made during this project, and the reason behind these choices, as well as the result of our implementation.

4.2.1 Chosen display techniques

There are multiple factors to take into account :

1. The availability of the technology.
2. The potential price of the required materials.
3. The time to setup the display.
4. The scaling for a medium-sized audience.
5. The compatibility with the double requirement : a view for the performer, and another for the spectators.

   We are now going to study these requirements point by point.

Availability

This is the main problem : many of the display devices presented in 2 have only been the subject of research and not of a real implementation sold by a company (e.g. holograms). Also, the development state of some technologies might not be sufficient for what we are striving for (e.g. autostereoscopic displays which are only present in very small screens like smartphones).

Price

Some technologies might be irrelevant only because of the amount of money needed to get a working implementation. For instance, an active 84" 3D HDTV generally costs more than ten thousand dollars, which is unsuitable to this project.

Setup time

Some methods might require a very long time to setup. While we don't have a required maximum time to setup the show, we should try to keep it as low as possible. For instance, the Pepper's Ghost technique is quite long to setup, because there is a lot of massive hardware, videoprojectors, screens, to setup.

Scaling

Since this is for a show, we need a system that will allow everybody in the room to enjoy the performance. The estimate is at about 40 persons : we need a display that provides big enough viewing angles and is big enough for everybody to be able to enjoy it. A square display with a side of two meters would be ideal to enable complete immersion.

Double-view requirement

This is one of the hardest requirements, because it can easily double the quantity of required hardware. For instance, if we were to use 3D TVs, we would need one TV for the viewers and one for the performer.

4.2.2 DRILE Implementation

Technologies used

Pictures

4.2.3 Aerial Percussion implementation

Technologies used

Displaying the data

Truc sur les angles

Pictures

Conclusion

Glossary

atmospheric perspective the impression of depth given by the refraction of the air. For instance, we can say that mountains are far because they appear more blue than close mountains.. 8

display something that can convert data as a byte stream into light, in order to be perceived by an human eye. 8

linear perspective the way our visual perception of objects are affected by their position and dimension. 8

live looping A REMPLIR. 4

occlusion when an object is hidden by another.. 8

- L'article [HDFP11]
- L'article [PS12]
- L'article [MPWL13]
- L'article [KHY+12]
- L'article [Cad99]
- L'article [BHDC10]
- Le livre [Oko76]
- L'article [RLC+05]
- L'article [JAC+07]
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