Sound Navigation in PHASE Installation: Producing Music as Performing a Game Using Haptic Feedback

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Abstract. Sound Navigation consists in browsing through different sound objects and sound generators situated within a virtual world including virtual spatialized sound and visual scenes, to perform a musical trajectory and composition. In the PHASE Project installation, the 3D virtual world resembles the surface of a vinyl disk, magnified so that one can see the groove and move a "needle" (the "reading head") in it and out of it to read the disk. Another such "needle" (the "writing head") can "write" music in the groove. A part of the game is a pursuit between the writing head and the reading head handled by the player. Different musical devices have been implemented. Most of them have a haptic behavior. The scenario is fully related to the musical metaphor and aims to give equivalent pleasure to contemplative as well as to competitive players.

1 Context of the Project

PHASE (Plateforme Haptique d'Application Sonore pour l'Eveil musical) is a research project devoted to the study and the implementation of multi-modal systems for generation, handling and control of sound and music. Supported by the RIAM network, it was carried out by the CEA-LIST and Haption (for the haptic research and supply of the haptic device), Ondim (for the development of visual content and system integration(and Ircam (for the research and developments about sound, music and the metaphors of interaction). These developments were implemented in an interactive installation for the general public in the form of a musical game integrating various metaphors. CNAM-Cedric has been involved in the game scenario and its ergonomics. During the last three months of the project, a demonstration of some of the results of the PHASE project in the form of an interactive installation offering the public a musical game was presented and evaluated at the G. Pompidou museum in Paris. The aim of the game is to play music and to develop musical awareness. The pedagogical aspect was thus significant for children and for adults. This installation was an extraordinary success; many players of all age and different cultural backgrounds appreciated it very much, including blind people, which shows the validity of such a device and opens the way to many new possibilities of gestural music control.

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1.1 Project Purposes

The objectives of the PHASE project are to carry out interactive systems where haptic, sound and visual modalities cooperate. The integration of these three interaction channels offer completely innovative interaction capacities, comprising gesture with force and tactile feedback, 3D visualization, and sound spatialization.

The objectives are scientific, cultural and educational:

- To study the cognitive processes implied in musical exploration through the perception of sound, gesture precision, instinctive gestures and the visual modality,
- To try out new ways of interactivity (haptic interaction, spatialized sound and 3D visualization, in real time),
- To propose new sorts of musical gestures, and by extension, to enrich the methods of training of technical gestures in any field (industry, handicraft, education, etc.),
- To improve the characterization of sound and its relationship to music (exploration of the multidimensional space of timbre) and to offer a new kind of listening,
- To implement new methods of sound generation and to evaluate them with respect to a public of amateurs and professionals,
- To propose new forms of musical awareness for a large audience, specialized or not.

Finally, an additional objective was to test such a system, including its haptic arm, in real conditions for the general public and over a long duration in order to study and to measure and improve its robustness and reliability; and its interest for users.

2 Haptic Interface

2.1 Design Objectives

The haptic interface used in the project had to allow natural and intuitive manipulation and exploration of sound and music. Therefore, it must respect following design objectives:

- Performance criteria: The user must feel as if s/he is acting directly in the virtual environment. S/He must feel free in an unencumbered space (which requires a large and free workspace, low inertia and low friction) and feel crisp contacts against obstacles (which requires llarge force feedback, bandwidth and stiffness).
- Integration criteria: The input device must be compact enough to be easily integrated in a workstation or exhibition area.
- Maintainability criteria: It must be designed with commercially available components as far as possible in order to minimize cost and simplify maintenance. Consequently, a Virtuose 3D 15-25 haptic interface has been deigned by French society Haption [14]. It is thus well adapted to our specific needs. It offers a rugged and validated basis well adapted to the PHASE project specific needs. Since the installation was conceived to be used by the general public over a long duration, particular care was paid to its safety, its robustness

and its reliability. Moreover, to allow for an elbow-supported manipulation as previously specified, an ergonomic desk was designed and manufactured at CEA- LIST. It enables a precise and comfortable use without fatigue. It also allows an immediate understanding of the workspace of the arm, thus making the handling intuitive.

3 Gesture, Music and Metaphors

In the Phase project, gesture is the entrance point of the considered multi-modal systems. In view of gesture interaction, playing a traditional instrument is the first idea, which comes when thinking of playing music, but there are many others ways such as controlling music, for example conducting or mixing. A series of studies were thus carried out to measure the relevance and the properties of some gestures in the specific context of musical control.

Fig. 1. Modified Virtuose 3D 15-25 integration

More generally, we searched which freedom could be left to the player to express himself/herself in a given musical space, in order to produce music at a satisfactory expressive level. One can, for example, have access to rate, rhythm, timbre, tonality, etc. Various modes of gestural and musical playing have thus been studied. The aim for the user is to play and control music. The user's gesture is carried out in the real space (containing his hand). Various feedbacks (haptic, sound and visual) influence his gesture. For example, to help the user to play a musical instrument, which requires long practice before precise control is reached, haptic feedback can be used as a guide like sliding on a string. Note that a scenario of the course as in the installation's game can also facilitate training. Unlike vision and hearing, the haptic feedback loop is direct since gesture and force feedback are localized in the hand of the user. Among other important necessities, coherence of the various modalities must also be guaranteed between the real and virtual world. This is achieved by using a metaphor which defines the link between the real

world where the hand acts, and the virtual music world, where the avatar acts. According to the context, one can define various metaphors, which lead to different implementations, more or less close to reality. Several types of metaphors were tested. Some of them will be detailed in section 5.

3.1 Playing Music

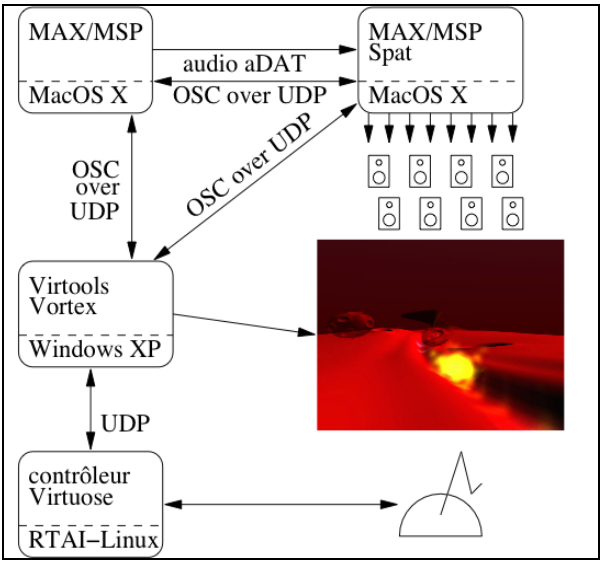

Fig. 2. Architecture

One of the innovative aspects of the PHASE project is the aim of generating, handling and controlling sound and music. Different ways of using gesture for playing music have been studied. On one side, the player can, for example, have access to rhythm, timbre, tonality, etc., and on the other side different gestures can be used for this control. Different modes of playing (from a gestural and musical point of view) have been identified: positioning oneself in the music, browsing the music, conducting the music, playing the music (like with an instrument, etc.). There are also different kinds of music that can be played and re-played. We use the term replay meaning that the music is already recorded or programmed, to be precise, the player does not exactly compose it nor interpret it, as he or she is did not study the score before. Replaying strategies can be either very simple and passive or very active and creative. As explained in the previous section, well-known music and temporal musical structures can easily be identified even when they are quite affected by a transformation, and the control of a temporal position is easy. However, music is otherwise fixed and not adjustable in such a scheme. On the contrary, specific music pieces can be composed so as to be modified by players. Furthermore, music processes or generators can be designed and programmed in order to produce a specific kind of music in order to interact with players in the particular way needed for the application.

Different musical interactive tools have thus been realized, that allow users to:

_ Manipulate musical phrases, specifically created and easy to transform.

_ Change musical parameters in play time or/and real time, for creating different variations.

_ Generate a continuous staccato flow, omnipresent and typify of an object or a character, enabling numerous programmed and interactive variations very near to real time. Some work on recorded or generated sound material has also been realized

in the project using, for instance, granular synthesis which offers a privileged access to time control. It allows the system to re-play the music in different ways and to separate pitch transposition from time position and speed control. For example, one can control directly the temporal development with gestures. One can also control a tempo, or acceleration and deceleration. Manipulating short time musical structures modifying time window in loops or on a stream. Another approach consists in constructing a virtual physical world and listening to it in different ways. It is then tempting to exploit the measures that come from the physic engine directly, particularly with the so-called physical model synthesis. Finally, the musical link between different physical and sound objects needs to be defined and developed. Writing and playing such sounds and music, using dynamic controls remains a challenging task.

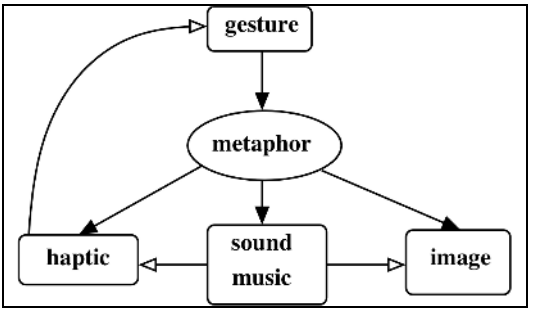

Fig. 3. Interaction metaphor

3.2 Sound Navigation

The trajectory and interaction of the user in a simulated world articulates music events and phrases. This is called *Sound Navigation*. *Sound Navigation* consists in browsing through different sound sources placed in a specialized sound scene to compose a musical form from the mix produced by movements and interaction with these sources. It is an artistic transposition of our sound experience in the physical world.

The user or player can freely choose between a simple visit, play with sound behaviours or perform a personal expressive path.

The choice of a musical implementation of each sound actor related to its interaction metaphor, is determined by the musical functions attributed in the composition. As the player can choose to trigger different sound behaviours in its own choice order, the horizontal construction is determined by the environment interaction setup. For example, two sounding objects in different places cannot be hit at the same time, and there is a speed limit between hitting the two objects successively depending on the distance and the possible velocity of the controller. Sound navigation applies to musical situations where the spatial metaphor offers non-conventional musical paradigms. These situations have a strong spatial organisation and therefore should not be confused with image illustration, for they are not images and do not illustrate anything other than themselves.

3.3 Gesture and Haptic Feedback

On account of the complexity of the whole system, a recording and mapping abstract module has been realized in order to disconect gesture control from various implementations, allowing to switch from a controller to another. This allows testing

musical or sound behaviours and interactive gestures without the haptic arm itself, which necessitates technically complex realizations. For example, a graphic tablet or a simple mouse has been used for quicker experiments. One obviously needs the complete device for final adjustments, but the abstract module permits to validate concepts and implementations under simulation. Naturally, the absence of force-feedback, the changes of the controller body and it's set of parameters must be taken into account in such a simulation.

In addition, it is possible to record gestures, to re-play them (in order to test, regulate and to validate dynamic sound behaviours) or analyze them offline, with or without the haptic arm. Thanks to the assistance of Frederic Bevilacqua, a study was carried out to compare a graphic tablet (Wacom Intuos A4 and aerographer) and a force-feedback arm (Virtuose 6D from Haption, www.haption.com). The goal was to identify significant parameters in the context of real-time sound and music generation. In addition, this study was used to evaluate the limitations of the graphic tablet against the haptic arm within the context of our metaphors.

4 Scenario

While in the large majority of cases, the music of video games is put at the service of visual, a part of our research was devoted to the use of the three modalities for the processes of musical awareness: how to design a device to sensitize general public with new listening and musical creativity modes?

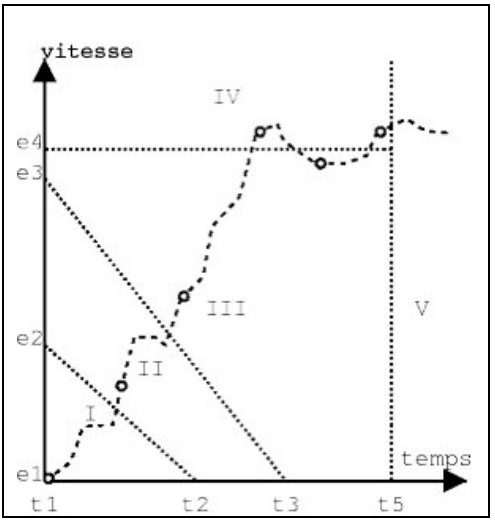

Fig. 4. Gameplay schematics

To answer this question, a simple scenario has been conceived with a very intuitive beginning [16], [17]. It is based on the metaphor of a writing head and a playing head in a vinyl disc groove. This metaphor thus involves three main actors, the two heads and the human player, and allows for a significant amount of possibilities of interaction.

Liliana Vega and Thomas Gaudy did the game design itself, under the direction of Stephan Natkin from CNAM-Cedric. One of the main issues of a game shown to any public in a museum, including musician and not, children and adults, experienced players and art amateurs, was to allow different kind of playing. We considered gamers as competitive players and others as contemplative ones. As evaluating music production quality is quite a tough achievement for a computer, we decided to evaluate the player using two simple parameters: time and speed. Every player will go through level I to III and at the end of the time to level V but only excellent player will reach level IV. Game scenario and music.

Level 1 : The machine (the writing head WH) traces a curve corresponding to a musical phrase. The player must reproduce it holding his avatar (the reading head RH). If he succeeds, a new phrase curve is produced more difficult and progressively linking becomes continuous.

Level 2 : The imitation becomes a chase and the ground starts rolling. The player can also wander around experimenting sound and musical interactions.

Level 3 : Once the player has reached the writing head the scenery changes, the landscape becomes more accidental and more obstacles and traps come out to slow down the player. Each of these obstacles produce sound when interacting.

Level 4 : When the player's avatar reaches the writing head, they stay magnetized and move together in a duo, until too much opposite force tears off their link. Only good players can reach this level and are trying to stay in it as long as they possible because it is very fast and the music becomes virtuoso and dramatic.

Level : 5 is the end. All forces disappear, everything slips until the end/start position of the game is reached again.

Unfortunately only levels II and III where implemented and it was not possible to implement levels I, IV and V and theses parts of the scenario require a future opportunity to be realized.

The musical aspect of the metaphors corresponding to the scenario will be detailed in section 5.

In PHASE, music and player actions are strongly attached together through the gameplay. In other words the score is the game itself or its rules and the interpretation comes out of the player's involvement in the action. The musical result is then deeply dependent on the scenario and on the physical/visual world.

The mode of competitive play is involving for the player but is not imposed. At any time, it is possible to stop the RH, leave the groove and to play with sounding objects or zones of interaction, which are always sounding, even during the race. This helps immersion and sound and musical awareness for the player, by the richness of the sonorities and the proposed interaction. When the player stops, the WH waits for him/her in silence and starts again as soon as the player comes back into the groove. There is no real accurate "scoring" of the player's performance, but the progression of the player is evaluated in order to adjust the behaviour of the system: a player having difficulties to play and a contemplative one are different, but in both cases the system slows down, thus facilitating the usage of the system for everyone.

4.1 Scenario Implementation

One of the main clues was to be able to test the gameplay and to adjust the scenario while testing. In this aim, Xavier Boissarie has created a Virtools scenario editor, which allowed us to assemble groove bricks and build sequences and to precisely position the obstacles. We wished we could dispose of a meta tool for elaborating, defining, modelling and testing such interactive scenario, instead of trying to link bits of systems together. Liliana Vega (CNAM Cedric) has made some pre-figuration of such tool. At the end, different parts of the scenario are divided between each functional elements of the system.

5 Musical Creation in the Installation

5.1 Metaphors

In the PHASE installation, we have mainly developed 3 interaction metaphors: the obstacles, the zones and the music groove. The three of them can play all together or separately. We decided that they should have a good sound behaviour independently and a complementary orchestral function when they play together. Moreover, their sound behaviour has not only esthetical functions but also informative functions, such as saying whether the player's avatar is touching the groove's bottom, or the ground, informing the player that a new obstacle is coming soon when visually hidden, indicating excessive pressure on an object, etc.

5.2 Obstacles: Direct Interaction

Direct interaction resembles ‘sonification’. The physical model is taken as a starting point to produce a significant immersion for the player, since the modalities are then close to those usually perceived in reality. In this case, physical objects are also sound sources. The interaction between the user and these objects is similar to the play of a musical instrument.

Obstacles are objects in the game space with various shapes. They are separated into two types: fixed and mobile obstacles. They have several sound behaviours: Approach, hit, press, scrub and bounce.

5.3 Zones : Divertimento Variations

Zones are musical playing spaces on the sides and inside the curves of the groove. They are represented by long grass moving when touched. They allow a musical real time control on an animated dynamic sound process according to the position inside the zone, the speed of input in the zone, the pressure and the velocity of movement.

5.4 Music Groove: Main Clue

The writing head (WH), represented by a bright spot of light, runs in the groove at a certain distance behind the player. It is flashing synchronously with music. One hears and sees the writing head (WH), which generates and plays music according to the player's actions and the position in the scenario.

The writing head plays the music and writes it into the groove in the form of a visual and haptic trace made of colour traces corresponding to notes.

The player holds its avatar, the reading head (RH), which is represented by another spot of light pursuing the writing head (WH) when placed inside the groove. The reading head replays the music after a delay which is a function of the distance between the writing and the reading heads. It flashes synchronously with the music events read from the trace. The RH pursues the WH.

The trace links the RH and the WH together. The WH writes the trace in the groove, which scrolls when the RH is inside it, like a needle in a vinyl disc groove. Thus, the movement of the RH is relative to the trace and the player controls

indirectly the speed of the re-played music. To follow or even catch up the WH, the player must follow the music as exactly as possible along the trace.

The choice of this metaphor is justified for several reasons:

_ An analogy with the real world: one can think of a vinyl disc the groove of which is engraved by the WH and re-played by a needle held in one's hand (the latter situation does not happen in the real world)
_ A well-known game mode: a race between to vehicles (here the WH and the RH ; an improbable situation)
_ A musical principle of re-play, close to the canon or the counterpoint (here quite a strange canon)
_ Facility of gesture : the groove serves as a guide for the player.

6 Music and Public Reception

While visitors using the installation in free access at the G. Pompidou museum were playing music, or skimming through R. Cahen's composition, their performance was recorded on a CD that was given to them at the end of their session (5 to 20 minutes). The installation was an extraordinary success. The number of visitors is estimated at approximately 20.000, including children, adults, musicians, composers, teachers, etc. The reaction of the public was constantly enthusiastic, underlining the interest, the innovation and the pedagogical aspect. The realization of this interactive installation for the general public in the form of a musical game integrating various metaphors shows the value of such a device.

7 Conclusion

The PHASE project was dedicated to research and experiments on the use of gesture control with haptic, visual and sound feedback, with the aim of playing music. Hardware, software and methodological tools were designed, in order to allow for the development and the realization of metaphors having a musical purpose. These developments are now available and usable. They were integrated in a installation used in an open public area with a great success.

One essential characteristic of the installation is the scenario. The metaphor of the vinyl disk has proved to be easily understandable by the public. Manipulating the reading head by mean of the haptic arm is very intuitive. The pursuit is a familiar situation which is related to a musical process. All these properties allow the user to be both in a game situation and playing music. This is one of the main results of the research work, since keeping the interest of the users and gamers to a musical creation activity was one of the most difficult challenges at the start of the project.

In the scenario, the gameplay is nearly transparent in the sense that the user does not need to be conscious of the different levels he/she is going through. It does not require any preliminary training.

Haptic game design reveals itself to be able to contribute significantly to music expression. Considering an haptic play area as an imaginative navigation score seems to considerably enhance the game experience.

Such research projects, linking scientists, engineers and artists, as the ones the RIAM promotes, appear at early states of development, to be a good way to improve technology and new forms of expression.

It opens the way to many possibilities of gesture music control, original fields in music composition, interpretation and game design. A DVD has been realized (in French) which presents the project and the installation.

References

[1] A. Hunt, M. Wanderley, R. Kirk, "Toward a Model for Instrumental Mapping in Expert Musical Interaction", Proceedings of the International Computer Music Conference (ICMC), Beijing, China, October 1999

[2] R. Cahen, "Générativité et interactivité en musique et en art électroacoustique", 2000, http://perso.wanadoo.fr/roland.cahen/Textes/CoursSON.html/MusiqueInteractive.htm

[3] M. Wanderley, "Interaction Musicien-Instrument : application au contrôle gestuel de la synthèse sonore", Ph.D. diss. (in French), University of Paris-6, 2001.

[4] C. Cadoz, M. M. Wanderley. Gesture - Music. In M.M. Wanderley and M. Battier, editors, Trends in Gestural Control of Music, Ircam - Centre Pompidou, 2000, pp. 71-94.

[5] P. M. Fitts, "The information capacity of the human motor system in controlling the amplitude of the movement", Journal of Experimental Psychology, 47, 1954, pp. 381–391.

[6] J. Accot, S. Zhai, "Beyond fitts' law: Models for trajectory-based hci tasks", In ACM/SIGCHI: Conference on Human Factors in Computing Systems (CHI), 1997.

[7] T.H. Massie, J.K. Salisbury, "The PHANToM haptic interface: a device for probing virtual objects", Proceedings of the ASME Winter Annual Meeting, Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, Chicago, November 1994.

[8] K. Young Woo, B.D. Jin, D.S. Kwon, "A 6-DOF force reflecting hand controller using the fivebar parallel mechanism", Proceedings of the 1998 IEEE International Conference on Robotics and Automation, Louvain, Belgium, May 1998, pp. 1597-1602.

[9] R. Baumann, R. Clavel, "Haptic interface for virtual reality based minimally invasive surgery simulation", Proceedings of the 1998 IEEE International Conference on Robotics and Automation, Louvain, Belgium, May 1998, pp. 381-386.

[10] D.A. McAffee, P. Fiorini, "Hand Controller Design Requirements and Performance Issues inTelerobotics", ICAR 91, Robots in Unstructured Environments, Pisa, Italy, June 1991, pp. 186-192.

[11] G.W. Köhler, "Typenbuch der Manipulatoren - Manipulator Type Book", Thiemig Taschenbücher, Verlag Karl Thiemig, München, 1981.

[12] G. Burdea, P. Coiffet, "La réalité virtuelle" (in French), Hermès Publishing, Paris, 1993.

[13] F. Gosselin, "Développement d'outils d'aide à la conception d'organes de commande pour la téléopération à retour d'effort", Ph.D. diss. (in French), University of Poitiers, June 2000.