THE VIRTUAL ELECTRONIC POEM (VEP) PROJECT

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ABSTRACT

This paper outlines a demonstration of the reconstruction of the Poème électronique experience using virtual reality and binaural audio techniques. Here we discuss the genesis of the project, the search for original material, discovery of clues for the reconstruction of several sections of the artwork and the creation of the VR/binaural installation within the context of an interactive exhibition.

1. INTRODUCTION

The Poème électronique was an unique experience, originating from the request from Philips to Le Corbusier to design the company’s pavilion at the Brussels 1958 World’s Fair. The whole project was initiated and directed by Le Corbusier, who also selected the images for the audiovisual show, while the organized sound was composed by Edgar Varèse and the stunning surfaces of the building were designed by Iannis Xenakis. The result was the very first multimedia project to create a complete sound and vision experience using a totally immersive environment, since the space of the Pavilion hosted the audio and the visual materials as integral parts of the architectural design (Figure 1). Unfortunately, this visionary synthesis was ahead of its time, and the concept was never repeated or even attempted again: the Pavilion, the incredible number of visitors (2 million) notwithstanding, was demolished a few months after its inauguration, at the end of the Exposition. The destruction of the Pavilion turns the Poème électronique into a lost masterpiece and a represents a serious blow to the cultural world. Today, we are left with only fragments of the various components, such as photographs and drafts of the architecture, the projected video from the Philips archives and the recordings of Varèse’s and Xenakis’s music. Nowadays, technological advances in virtual reality and binaural audio make a recreation of the Poème électronique possible in the spirit of a Gesamtkunstwerk. This paper describes a project that demonstrates the application of a form of experimental archaeology to the recreation of the Poème électronique for a virtual environment.

Figure 1. The Philips pavilion at the Brussels World Fair in 1958 (from [7]).

There have been several attempts to reconstruct (at least in part) the Poème électronique experience. There are at least three commercial stereo versions of Varese’s music, and the Concertgebouw in Brugge, Belgium, hosts a 14 channel version as a permanent installation (realized by Kees Tazelaar). The audio and visual aspects have also been reproduced on DVD, in theatres and for live installations [3]. There are current attempts to rebuild the pavilion physically (http://www.alice-eindhoven.nl).

The novelty of the VEP project (http://www.edu.vrmmp.it/vep) lies in the reconstruction of the Poème experience through an immersive application that combines virtual reality (VR) and binaural audio. Although there have been other computer graphics reconstructions of the pavilion and the multimedia show, VEP is the first attempt to provide a complete contemporary perspective on the Poème experience, both visually with a head-mounted stereoscopic display that immerses the wearer in the darkness of the pavilion, and aurally with binaural audio through headphones creating a 3D audio experience of the sound material travelling over the 400-loudspeaker sound routes.

2. THE POÈME ÉLECTRONIQUE

The history of the Poème électronique is well known (see, e.g., [6] and [7]). Louis Kalff, artistic director at Philips, did not want to demonstrate commercial products, but the pavilion had to impress visitors with the use of the Philips technology. Le Corbusier accepted
the idea and proposed the realization of an electronic poem inside a building without obvious facades. The poem would be a synthesis of sound, light, colour and rhythm. For the music he insisted on the participation of Edgar Varèse. After a few meetings, Kalff and Le Corbusier agreed on the duration of the poem: ten minutes, with a two-minute interval and eight effective minutes of show. Because of the succession of performances during the day, the entrance and exit of the pavilion needed to be separated, while the pavilion was a kind of stomach that digested visitors who would leave the show transformed. The architecture of the pavilion had to include two almost vertical walls—oriented to inhibit reverberation—for the projection of the visuals. These requirements were translated into curved surfaces with a varying radius.

### 2.1. Architecture of the pavilion

Iannis Xenakis, who at the time was working in Le Corbusier’s studio in Paris, conceived a totally self-supporting pavilion, where the walls were ruled surfaces (that is, curved surfaces ruled by straight segments) and the stomach contour was formed by the points where the curved surfaces intersected the horizontal plane. The ruled surfaces were hyperbolic paraboloids, and the stomach was formed by a number of hyperbolic intersections between the hyperbolic paraboloids and the ground (see Figure 2 - left).

![Figure 2. The hyperbolic paraboloids intersecting the "stomach" (screenshot from Alias Maya with superimposed plan from Philips technical review); directrices (A, B) and generatrices for the generation of hyperbolic paraboloids.](image)

The 3D model of the pavilion was constructed using the same tool that Xenakis himself used: a pair of rods connected by elastic wires. In fact, ruled surfaces can be built by twisting a pair of straight lines called directrices (A, B) and generatrices for the generation of hyperbolic paraboloids.

A closely related issue is the positioning of loudspeakers on the inner surfaces. Most of the bibliographic sources are contradictory: the loudspeakers were probably distributed along 10 routes (according to a sketch by Xenakis in [6]), and number between 300 and 450. Original images, which could provide clues to the correct positions, are few. Consequently, we have started by studying Xenakis’s original sketches. From this source we have deduced an approximate number of speakers and a hypothetical placement on the surfaces of the pavilion. Subsequently, by using a 3D authoring tool, we have ranged the speakers across the surfaces and then matched ten original photos against the 3D model. Despite some inaccuracies due to approximations of unknown focal properties of camera lenses, we have deduced a satisfactory positioning for about half the speakers. The remainder have had to be guessed by taking into account the density and the patterns in the known parts of the building. As a result, we have been able to identify locations for 380 loudspeakers.

### 2.2. Audio design

The audio part of the Poème is traditionally considered the most important, having had major influences on contemporary music. In order to reconstruct an immersive experience of the original show we needed access to the individual sounds that comprise the Poème and then arrange their spatialization. This aspect of the philological reconstruction is rather intricate.

Following a digitization prepared by Kees Tazelaar from Varèse’s original production tapes (stored in the archives of the Institute of Sonology in The Hague) we have been able to rebuild the three tracks that fed the spatialization equipment. The allocation of audio tracks to speakers was controlled by a separate tape that is now lost. However, there is one portion (30 seconds) of the control score extant, from which some of the style of operation can be determined (in [9]). We know that the speakers were grouped either in clusters or in sound routes, along which the sound could be made to appear to travel in one direction. The task of the audio reconstruction has been to create a set of 380 sound files corresponding to the sound routed to each speaker. We have chosen to implement the sound routes and clusters as Csound instruments and then try some experiments.

The problem of spatializing the Poème composition has taken into account some aspects of the Varèsian poetics on space, as stated in some lectures (see [8]) and in [2]. For example, it is worth mentioning the Varèsian idea that “sound masses” should not be blended, but form zones that would be differentiated by various timbres and intensities. So, the Poème really seems the effective realization of Varèse’s dream.

The preparatory phases of spatializing the audio with binaural techniques have been to simulate the shape of the interior (from the 3D model created for the VR rendering) and to model the acoustic properties of the inner surfaces and the characteristics of the Philips speakers using common room acoustics modelling and simulation software [1]. By a combination of mirror imaging and ray tracing methods, room impulse responses for all speakers and one listener position have been rendered for use in the auralization process of the “raw” audio material. The characteristics of the human hearing-system are incorporated by a set of HRTFs from a dummy head created by C. Moldrezyk (TU Berlin).

For the auralization task we have taken two approaches: (i) binaural impulse responses, where a
directional room impulse response for a given source loudspeaker (or a subset of speakers) is combined with the HRTF-set for a particular rotation of the listener’s head by convolution; (ii) B-Format impulse responses, i.e. a B-Format or first order Ambisonic™ room impulse response for a specific listener and loudspeaker position with the technique described in [4],[5]. Ambisonic B-Format is also directly supported in Csound through new opcodes for encoding and decoding (e.g. spat3dt).

Finally, a relatively simple issue is the rendering of Xenakis’s interval music Concrete PH. The title can be seen as a homage to the hyperbolic paraboloids (PH is the French acronym) in terms of concrete music (burning charcoal), as well as a reference to surfaces made of concrete or to the initial letters of Philips. Currently, this piece is available from the INA-GRM institute in Paris. According to the few contemporary records, it was played at low volume through the speaker clusters at the entrance and exit of the pavilion during the change of audience. In the VEP reconstruction, Concrete PH marks the prologue and epilogue of the Poème reproduction.

2.3. Images and light ambiances

Even if the visual element of the Poème did not follow the fortune of the audio material from Varèse and Xenakis, it is still fascinating and complex in its projection and realization. There were five visual elements: (i) “Ambiances”, light effects filling the whole pavilion and dividing it into different chromatic zones; (ii) “Volumes”, two objects, a female mannequin and a geometric object made of metallic tubes, suspended in the air and giving a fluorescent effect; (iii) “Écrans”, two “screens”, that is the two interior projection surfaces for the film (the film itself was mainly black and white stills, but the ambiances tinted them); (iv) “Tritrous”, coloured spots, sometimes filled with photographic images, projected around the écrans; (v) other projected elements (a red sun, a white moon, clouds) and glittering bulbs (representing stars). All this material was synchronized through a score (“minutage”), with a row for each of the 480 seconds of the show and one visual element per column.

As with other elements of the Poème, the scarce and sometimes inconsistent technical documentation has made the reconstruction of the visual element quite a complex task. The reconstruction focuses on two aspects: (i) the original set-up of the installation, provided by Kalff [9] and Petit [6], with inconsistencies resolved by referring to the photographic material in [7], sourced primarily from the Philips Company Archives and the Getty Center; (ii) the control score of the performance designed by Le Corbusier and written up by Petit. (Figure 3).

The material for visualization is reconstructed from written and diagrammatic sources (e.g. [6, 7, 9]) and photographic information. The steps of the reconstruction are: (i) collection of the original materials (écran in video format from Philips archives\(^1\), content of tritrous, exact colours of the ambiances, types of projectors in order to provide a better approximation of colour nuances and the types of materials that made up the surfaces inside the pavilion); (ii) placement of projectors and other devices on the 3D model in terms of textural elements simulating projections; (iii) tuning of a prototypical installation; (iv) validation of the final result by a committee of experts drawn from various areas.

![Figure 3](image3.jpg)

**Figure 3.** Visual elements: one page of the control score and one snapshot of the show (from Getty Center and [8], respectively).

3. VEP EXHIBIT INSTALLATION

The philological reconstruction of the material is not sufficient to determine a presentation in terms of a VR installation. What happens at the moment one dons the helmet and headphones? Is it possible to move and how? How might exterior of the building appear?

From the very beginning of the project it has been clear that the presentation of such a complex and multifaceted project must observe human-machine interaction principles and capture features of the Poème itself. Furthermore, we have realized that the Virtual Electronic Poem (VEP) project could go beyond its raison d’être of reproducing the Poème experience and lay the basis for a framework for contemporary artists to develop new projects for the pavilion and its audiovisual equipment or indeed completely new audiovisual spaces.

The VEP scenario is in the nature of edutainment, preparing the visitor for a fruitful experience of the Poème. The whole application starts in a museum exhibit, where four sections can be accessed through panels: (i) the Poème “son et lumière”, (ii) the architecture of the pavilion, (iii) the fair and its times, (iv) the making of the VEP project.

The simplified schema in Figure 4 represents the architecture of the VEP application. A controlling application (in Java) interprets the user inputs (head movements, direction of navigation, ...) and directs the application by retrieving data from a control score (which includes the control score of the Poème). This main application controls the two (independent)

\(^1\) Reportedly, there is a copy on film at the Dutch Film Academy, but we do not have access to it at the time of writing.
engines, that provide the visual 3D stereoscopic and binaural audio rendering for the user. The latter takes account of the impulse response of the pavilion given the speaker positions, the geometry of the pavilion and the listener position, the association between sound sources and sound materials and HRTF. The 3D rendering engine takes account of the models of the objects and the textures of the surfaces, including the visual show (écran, ambiances, tritrous, ...) represented as textural elements.

The system drivers process real-time data from user actions coming from a head-tracker, a standard PC keyboard, and analogue controllers. A data pre-processing stage discards meaningless data arising from communication noise (like ripples in head-tracker data sent even when the user’s head does not move intentionally). Real-time user data are interpreted to yield a higher semantic level. For example, the system detects whether the user is staring at some particular object, or acts as if s/he wants to approach some object. The behaviour logic analyzes the user’s behaviour in order to determine how the virtual experience might proceed (a rule-based system describes the behaviour of an interactive 3D virtual experience). The 3D engine interface defines a common low-level interface allowing a decoupling of the framework from a particular engine. Moreover, it makes possible the simultaneous use of several engines.

The VEP installation is also accessible on the WWW through an interactive 3D-based application where the audio is converted from binaural to stereo, 3D object quality is reduced and navigation is by mouse and keyboard. The virtual tour via WWW includes: the EP mode, in which the Poème électronique is displayed with the option of looking around; the discovery mode, in which the user can look around and discover the architecture; and the edu mode, in which multimodal educational information concerning the history of the Poème électronique is presented along with some original photographic material.

4. CONCLUSION

This paper has presented the VEP project, a reconstruction of the Poème électronique experience with virtual reality and binaural audio techniques. The project has addressed issues both in researching the technical details of the original artwork and in software design for devising the appropriate solutions in building a coherent scenario for the virtual reality application. We believe that the immersive environment developed in VEP can make the remarkable aspects of the Poème experience accessible again after almost 50 years.

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6. REFERENCES