MindFluctuations: POETIC, AESTHETIC AND TECHNICAL CONSIDERATIONS OF A DANCE SPECTACLE EXPLORING NEURAL CONNECTIONS

MindFluctuations: CONSIDERACIONES POÉTICAS, ESTÉTICAS E TÉCNICAS DE UN ESPECTÁCULO DE BAILE EXPLORANDO CONEXIONES NEURONALES

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ABSTRACT:

In this era of co-evolution of humans and computers we are witnessing a lot of fear that humanity will lose control and autonomy. This is a possibility. Another is the development of symbiotic systems among man and machines. To accomplish this goal is necessary to research ways to apply some key concepts able to have a catalyst effect over such ideas. In discussing this possibility through the case study of the spectacle **MindFluctuations,** an experimental artwork exploring neural connections, we are looking for ways to develop them discussing this particular case study from its conception to its realization. It also establishes a process of reflection on the design, development and production of this dance spectacle. This artwork uses a customized application, **NumericVariations**, to explore the quoted neural connections for spectacles, performances and site specific installations. Its approach was made possible by recent neuroscience research, and the development of a Brain Computer Interface (BCI) integrated with a virtual reality framework, both allowing an experimental interactive virtual reality artwork to emerge. A neural helmet, connected to the computer and entwined with mathematical procedures, propitiated a symbiosis of humans with computers.

KEYWORDS: Computer Art, Algorithmic Art, Virtual Reality, Brain Computer Interface BCI, Java3D

ABSTRACT IN SPANISH:

En esta era de co-evolución de los seres humanos y las computadoras estamos presenciando mucho miedo de que la humanidad pierda el control y la autonomía. Esta es una posibilidad. Otro es el desarrollo de sistemas simbióticos entre el hombre y las máquinas. Para lograr este objetivo es necesario investigar formas de aplicar algunos conceptos clave capaces de tener un efecto catalizador sobre tales ideas. Al discutir esta posibilidad a través del estudio de caso del espectáculo **MindFluctuations**, una obra experimental que explora las conexiones neuronales, estamos buscando formas de desarrollarlas discutiendo este caso particular desde su concepción hasta su realización. También establece un proceso de reflexión sobre el diseño, desarrollo y producción de este espectáculo de danza. Esta obra de arte utiliza una aplicación personalizada, **NumericVariations**, para explorar las conexiones neurales citadas para espectáculos, actuaciones e instalaciones específicas del sitio. Su enfoque fue posible gracias a la reciente investigación en neurociencia y al desarrollo de una Interfaz de Computadora Cerebral (BCI) integrada con un marco de realidad virtual, que permitió que surgiera una obra experimental de realidad virtual interactiva. Un casco neural, conectado a la computadora y entrelazado con procedimientos matemáticos, propició una simbiosis de seres humanos con computadoras.

KEYWORDS IN SPANISH: Arte informático, Arte algorítmico, Realidad virtual, Interfaz informática de cerebro BCI, Java3D

INTRODUCTION

In this era of co-evolution of humans and computers we are witnessing a lot of fear that humanity will lose control and autonomy. This is a possibility. Another is the development of symbiotic systems among men and machines. “Symbiosis is a state found in Nature in which two or more organisms act in complementary ways to achieve survival. (…). From my point of view, it is fascinating the possibility of deeply interacting with machines, to be turned inside out by seeing my own mind fluctuations translated into something through the action of a computer. By externalizing a few emotional states and thought processes, facing the fluctuations of one´s own mind it will maybe be possible to glimpse at this mysterious, unfathomable process we call 'thought' [1]. I do not believe machines will substitute humans, but, since they are built mirroring humans' own decision and reasoning processes [2], they have had, more and more, a complementary role in human lives. This complementary role I have called symbiosis” [3], (pp3). But, it is not the goal of this article to focus on symbiosis. Here it is only necessary to point to its importance as a key concept for the spectacle set up since it is able to have a catalyst effect over the spectacle’s development.

In discussing this possibility through the case study of the spectacle **MindFluctuations** we are looking for ways to understand what Roy Ascott defines as the confluence of dry computational systems with wet biological ones. This particular case study is discussed from its conception to its realization. This spectacle was quite complex and involved several professionals such as musicians, choreographers, dancers, light designer, stage manager, sculptor, programmers and scientists from various fields, among others.

Computer Art has existed for more than 60 years but there is still a lot of resistance within the art world to appraise it as an art form. In the meantime, there is an

increasing number of artists who are using customized software and hardware developed for artistic goals opening a large field of possibilities for artworks produced through computer coding. “Usually such artworks are evaluated with past criteria, criteria that deny their main characteristics, which are to be what they never were before. Therefore, such artworks have to be approached with different evaluation methods. There are many differences between computer artworks and other means of creating art. There are convergences and divergences which are not at the focus here. The present approach does not intend to enhance one kind of art by depreciating the other” [4] (p 186), but rather understand the singular aspects that characterize a spectacle, an installation or a performance using real time virtual reality technology [5].

It is important to note that “similar to traditional artworks, computer artworks are poetic and aesthetic creations of human minds evoking emotions, sensations and a labyrinth of representations and, sometimes, ambiguities and paradoxes. These subjective sets intensify mental connections allowing the human sensory apparatus to be entwined with mathematics. They establish different relationships causing different readings. Therefore, numerical relations and functions are woven with sensory experiences and the results are not always predictable” [4] (p 186).

The spectacle **MindFluctuations** has been designed in conjunction with the American choreographer Maida Withers and premiered in March 19th, 2015 in Washington, DC, and will happen in the future in site specific installations and performances. To achieve neural connections with poetic and aesthetic expressions this artwork looked for ways to use neural data and other related procedures able to be translated by numbers [8].

In this spectacle the dancers wore two neural helmets to capture data related to their emotional states. After these states were scanned and input, they were interpreted by computer and influenced virtual scenarios that were projected over a screen on the backstage. The resultant scenarios are artificially alive systems allowing the dancers to “symbiotically interfere in the algorithmic nature of artificial 'seeds'” [6] (p. 169). Composers and musicians John Driscoll and Steve Hilmy performed the musics live in a sound environment created with robotic instruments and electronic music.

Many conceptual, aesthetic and poetic aspects of other similar works to this one, has been extensively discussed elsewhere [6], [14], [16], [17], [18], [19], [20]. Here, the aim is to describe how the **MindFluctuations’** design and development have established the necessary ground for the production to unfold. It also highlights the poetic and aesthetic aspects that are necessary to develop and perform an interactive artwork such as this. This discussion happens in the section ‘The poetic and aesthetic approaches within **MindFluctuations**’.

MindFluctuations employs the customized virtual reality software **NumericVariations** to explore neural connections for spectacles, performances and site specific installations [6] [7]. It employed a neural headset and developed a Brain Computer Interface, BCI, to achieve its aim. In **MindFluctuations** the dancers experimenting with these settings and environments faced a major challenge. Their understanding of the emerging configurations and of their different ways to perceive and respond to these virtual realms, allowed them to constantly re invent their own ways to perceive the environment where they were immersed exploring their own sensory system, their own aesthesis, from the Greek, 'Aisthēsía'. The performers

Ederson Lopes and Mirtes Calheiros, working with another similar software, **EpicurusGarden** [23], have stated, several times, that such awareness arose, constantly, in their minds, during interaction with similar virtual worlds. Aspects of this software and its brain computer interface, BCI, are presented in section “The application **NumericVariations”**.

Within these realms emerge affective fields whose sensory stimuli establish a complex network of data and relationships. They create many possible configurations that may or may not have been foreseen by the artist-programmer [8]. Since computer languages were not designed for artistic expression, sometimes it is necessary to subvert their use. Such innovative and original attempts, exploring the immanent potentialities of computer languages allow the emergence of new poetic and aesthetic solutions [9] [10].

Within the virtual realities there are autonomous agents that respond to the emotions of the dancers. These scenarios are a set of 11 virtual domains showing processes inherent of an evolutionary dream journey. These domains are virtual realities inspired in nature. Meanwhile, they happen from much simpler processes than the ones existing in the natural world; they are similar to the waves of sea, the clouds meandering on the sky, or the snowflakes: always the same and never the same. In these virtual domains 'trees' grow, emotions inseminate particles that spread through space, virtual flocks of preys and predators fly around – the latter either acting as cannibals or chasing each other and dancing when they meet –, the virtual camera slides and glides within the virtual space, balls collide and roll in virtual platforms. All these processes, these varied set of changes, are influenced by the dancers emotions and take place in a specific way in each presentation. Although the general scenarios’ configurations are repeated the end result is unique in each presentation

and can never happen again in exactly the same way. They show processes of becoming while they happen. Something that is metaphorically similar to living things and that are, simultaneously, a visual representation of a pure mathematical universe.

Finally, at the conclusion a few reflections are presented. They establish and coalesce the process of creating, developing and producing the spectacle.

METHODOLOGY

This article aims to show the professional development of an interactive computer artwork and its application in the scenic area presenting the spectacle **MindFluctuations** as a case study. It reflects upon the poetic, aesthetic and technical aspects involved in its set up and the resolution of many of the problems arisen during its production. It applies a methodology of successive approximations to the desired goals [21]. In it, art, architecture and design, created with the aid of computational devices, dialogue with the choreography, the music, and the scenic space. The transdisciplinary intersection of these fields has enabled the development of the investigation so that they could form a fundamental set of strategies and actions, enabling the production of the spectacle and its complementary products.

RESULTS AND DISCUSSION

Due to the complexity of the spectacle set up the questions related with its poetic, aesthetic and technical approaches are focused here in two different sections. At the former we inquire what is necessary to develop in order to perform interactive computer art with fullness and strength. How can one do it? How to express something so that what is being done brings the audience to feel and sense poetically

that situation? How to articulate what is done so that the computer technology works and introduce itself without hiding and disrupting the poetic and aesthetic goals of the work? How can one intertwine a complex set of relations to create something meaningful? At the later, in order to perform interactive computer art with fullness and strength, one also has to ask: How do the devices work? How to convert the various formats involved when working with the digital and the analog fields? What are the strategies needed so one can choose the best result within a large field of possibilities? How to deal with interference and degradation of the signals in technological mixed environments? We looked for such reflections while searching for answers to these questions.

It is desirable to point to the marked differences between working with videos in databases and live interaction happening in real time in virtual reality set ups. An aphorism sums up the possible field that presents to the computational artist programming such virtual realities and the choreographers working with them: “If a picture is worth a thousand words an interactive simulation, a virtual reality, is worth thousands of millions of them” [6] (p. 170). Snapshots taken of these virtual worlds during interactions show only some views of these micro-universes. These snapshots are nothing more than glimpses of them. Videos show the diversity and dynamics of these virtual realities, however they are only moments of an interaction that was captured, frozen in a linear timeline. Examples can be found at the videos on youTube, Vimeo and the author’s site: http://taniafraga.art.br; https://vimeo.com/taniafraga; and https://www.youtube.com, /user/taniafraga1.

One must understand that applications or software that create virtual realities have within them 3D objects, agents or virtual ‘beings’ (alive processes) that inhabit these spaces. It's very different from a video that captures the interaction and presents it linearly, always repeating the same sequence previously captured. The computer

artworks addressed here are immanently different of a video, since what it is presenting are processes in its becoming, in its coming into being [23], [24], [25], [26], [27], [28].

As stated earlier, these micro universes allow real time variations of many autonomous processes that follow a set of rules but that manifest themselves in singular modes at each presentation; they are similar scenarios to others previously shown; but they are never exactly the same for each presentation of the work, either in site specific installations, or in shows and performances. The same 'seed' is presented at various times and creates a result which is singular. This result carries the potential to never happen again in the same way. That's because they are similar to the processes that happen in life and in nature, although they are much simpler than those; they are processes which, as said before, are both a visual and audible representation of a fluid mathematical universe.

The poetic and aesthetic approaches within **MindFluctuations**:

Firstly, “the term 'artistic research' will be briefly presented here, owed to the importance of its poetic and aesthetic goals. Artistic research for the present approach means an ‘art that understands itself as research, in that scientific processes or conclusions become the instrument of art and are used in the artworks’” [11]. Such instrument is related to the artwork poetics. Poetics is an adopted word, borrowed from the literary domain and transferred into the field of contemporary art. Here it is used with semiotic freedom” [4] (p 187) to explore many relations emerged during the spectacle conception, design, development and production. In brief, the word poetics is used here mainly to describe how results are produced and which tools are used to overlay meaning over a set of virtual signs. Perhaps the Greek word 'techne', which is the etymological source for the word technology, could also be

applied for the development of techniques for virtual poetics, but such use could become confused. For the present approach, is enough to say that such techniques emerged of doubts related with the actual construct of the sciences and the models of artistic research which are within close proximity of the scientific territory. On the other side, the aesthetic qualities of the artwork are related with the qualities of expression and the sense perceptions [12]. Its expressive and sensory fields are entwined within the artwork and, for example, is hard to separate, for a theoretical analysis, how parameters for interaction are chosen and how the neural data are transformed. Objective and subjective choices are interlaced.

For this approach many other questions were formulated. For example: How to maximize expression, aesthetic and poetic qualities in order to create something meaningful, using data from sets of neurons into works of art? How the biological and electronic brains may work together?

We point to that “the virtual domains are compositions of colors, movements and shapes carefully selected rather than aimless mixtures of whatever is randomly available. In this artwork, shimmering colors, forms, lights and cameras in movements, metaphorically express the unending changes of life. Space and time create almost unbounded numeric variations” [4] (p 187), a perplexity the author has never totally grasped. They condense, out of the author’s mind, in entwined geometries, shifting structures creating delicate wave patterns over wire frame constructions, suggesting living things [22] (p.180), [23], [24], [25], [26], [27], [28], [4] (p187), see “Figure 01”. “Flickering lights are combined with darkness; colors and shapes, space and time are woven together as a tapestry: the burning heat of the reds; the unfathomable depths of the indigo and navy blues; the ranges of dark grays

and blacks; all establishing contrasts with bright bold tropical colors. There are hidden 'seeds' waiting for the users' emotions to trigger growth behaviors; there are flight behavioral patterns allowing some agents to persecute or flee; there are changing relations among the velocities, the positions and the gravities, distinguishing, for example, determined realm or even the camera movement flying through it; and many, many others functions, characterizing the agents' behaviors, which are woven through numeric threads" [4] (p187-188). By the other side, "from a poetic and aesthetic viewpoints lightness, weightlessness, fluidity, clarity, simplicity and visceral human-machine symbiosis are vectors pointing to the solutions I have intended to reach" [3], (pp7).

The geometric transformations used were related to time and space variables, the numeric variations, synthesized in the application's title. They were studied and chosen within a wide range of possible choices. The pictures used in texture mapping, in gif format, resulted of images carefully photographed, chosen and reworked, see "Figure 02". The behavior of virtual agents entwined with the human emotions of the dancers creates results that are not literal. The shapes and colors were defined in ranges so that, even when affected by random factors, they maintain their proportions, hues, saturation and values within harmonic sets and, therefore, their visual qualities are not lost during interactions. In the meantime, it was possible to look for the weaving of intertwined nets in which the virtual and the human were united to present these metaphorical realities. Consequently, it is appropriate to call them symbiotic relationships [6] (p. 179), [22] (p.26).

Also, there is no desire to control what the audience will feel while leading them toward a metaphorical journey. A journey with different meanings open to

interpretation for the diverse eyes of different beholders. The whole set of 11 virtual realms were created with the intention of going from a beginning until an end. Any beginning; any ending; but an end that is not a final one but, maybe, another beginning. Its abstract set up can be understood either as a journey pointing to the amazing development of the brain or towards the evolution of life. The journey begins with 'TheEgg' as a symbol with its clear connotations and denotations as ovule and finishes with 'Panspermia' [13], meaning the seeding of the Universe with ideas or life. They allow the public to have as much freedom as possible for their own interpretation of the journey [4] (p. 188).

The French thinker Edmund Couchot has classified the kinds of computer interactions as exogenous and endogenous [15]. Exogenous interaction is the paradigmatic approach of the question and answer, of which we are accustomed to handle when working with computers. On the other hand, endogenous interactions are the ones that happen between autonomous processes (agents) that act without any human control.

As an I had a visceral desire to find ways to research symbiotic processes among computers and humans. These would aim to explore modes of actions between humans and machines. The potential of the computers would be explored to expand human aspects. Human sensitivities would be utilized to affect machine processes. Thus, I arrived at the idea to implement artworks using human emotions to influence autonomous agents behaviors, either being them physical robots or virtual ones. Therefore, it would be possible to experiment how human emotions would affect autonomous processes. This should happen in such a way that virtual agents would have to be influenced when perceiving and acting on their own robotic or virtual environments, or both.

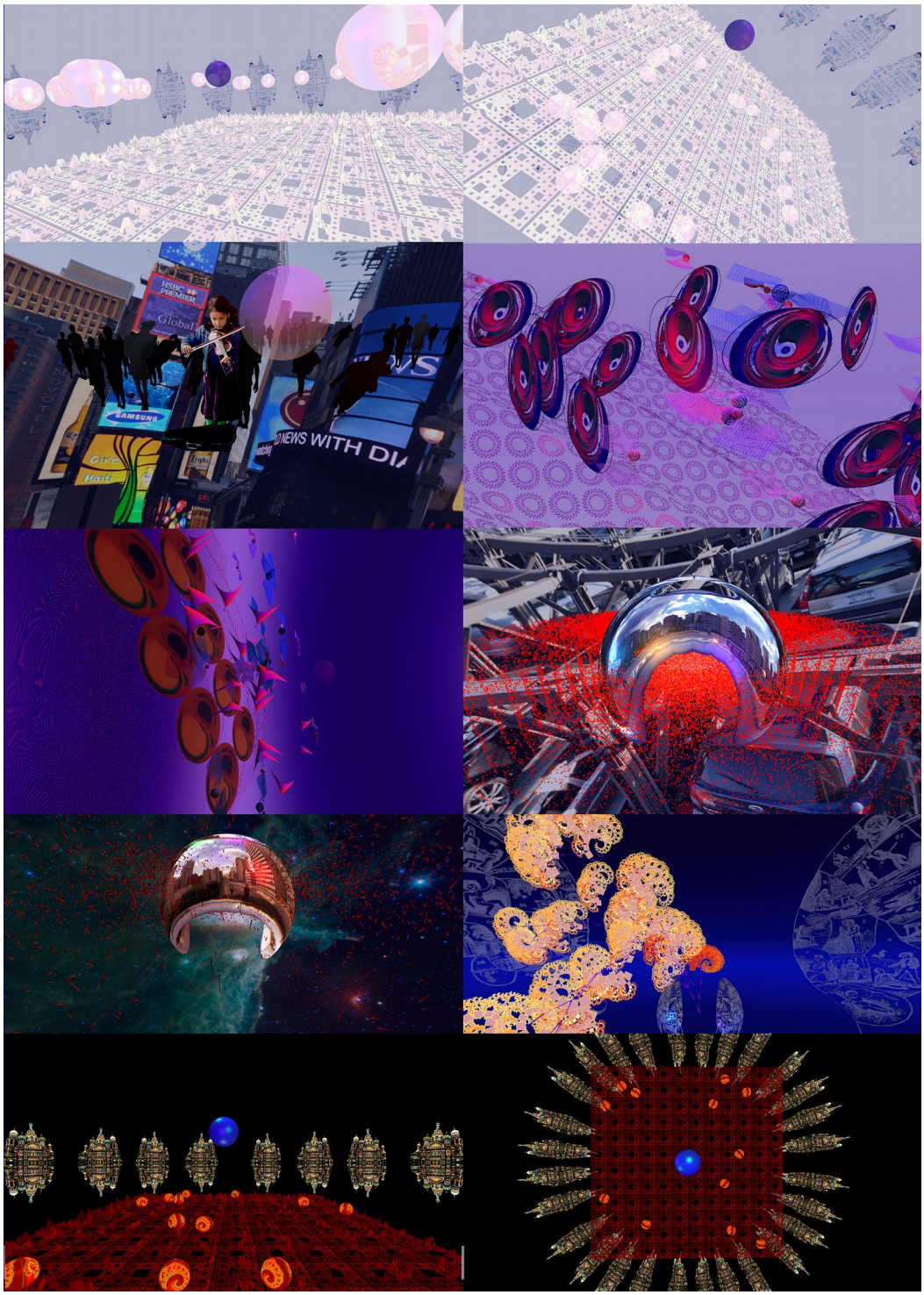

Figure 01: snapshots of a few virtual worlds

Figure 2: Photos of virtual worlds backgrounds (left) and its transformations for Java3D (right) with the end results in the middle

Looking for concepts that could express this kind of interaction the concept of exoendogenous interactivity was created [14]. What is this? After the computer digitize the user's input data in an exogenous way these data will be used by autonomous, endogenous, processes within the virtual domains affecting, as said above, the way in which the agents perceive their own virtual environments and, therefore, could determine their own behavior. In the future this approach will be used to extend these solutions to another artwork – **NumericTessitures** a work in progress [16] – in which users will be mixed with virtual and robotic agents. It has been assumed that this kind of research might allow the emergence of meaningful processes arising in a kind of very interesting human-machine symbiosis.

It was reasoned that since the human body acts by outputting the brain's electrical impulses, these impulses could be used to interfere in the virtual agents' behaviors. Summarily, one may say that human behaviors may be conscious instructions or unconscious results of sensory and emotional mind fluctuations. Someone helpless to control their own unconscious impulses may have them read and translated to numbers. These states are owed to the action of neural fields captured and scanned through non-intrusive devices, such as the Emotiv neuroheadset [29], which is connected to the human mind. When translated into numbers such data may be used by electric-mechanical systems. Wherefore, the present art experiment was conceived. In it these stimuli could affect the autonomous agents existing within the virtual realms. Some of the images resulting of such an experiment are shown in “Figures 01, 05 and 06” and in a few videos [26], [27], [28].

A project such as **MindFluctuations** requires the use of algorithms that involve intensive calculations for its real-time processing [30]. In decades past such projects would necessitate supercomputers for its realization. Today it is possible to carry them with personal computers and this article aims to provide an overview of the technical strategies found to bring such a project to the general public.

In the 90s of the last century, one minute of animation, – 1800 frames – could take weeks for processing. These animations could only be presented in videos. In the following decades these animations, sounds and precomputed images began to be stored in databases. The contents of these databases can be accessed constantly and be presented in interactive ways. Such procedures often create the illusion that animations, sounds and images are being processed in real time. This situation is still employed and causes numerous misconceptions as there is a lack of knowledge by the public of the processes that are happening on stage. Presentations using video databases are quite different from what takes place in real time on stage using virtual reality technology, because what is happening in this last case, as stated many times before, come about as processes of becoming.

For **MindFluctuations**, after the general structure of the customized software **NumericVariations** was created, it was necessary to continue its development with the choreographer. Therefore, in February 2014, after the basic structure and the algorithms used in the software were running satisfactorily the choreographer Maida Withers traveled to São Paulo for a 15 days residency that allowed her to experiment with the application interface. From the beginning a set of virtual realities were planned as a journey with 11 virtual worlds outlining a beta version of the application. Based on this draft, a joint development process took place which lasted about a year. It required the development of modes of investigations and trials to enable their achievement. There was need for improvement and constant adaptation while

creating new versions of the application which were sent to Maida Withers, in the USA, for testing by dancers and musicians. Two site specific installations in exhibitions were mounted with them, see “Figure 03”. These exhibitions took place, both in 2014. One happened in Santa Maria, at the Contemporary Art Symposium, where it was possible for the public to use the neural helmet to interact with the virtual worlds. The other happened in Brasilia, at the exhibition EmMeio # 6, at the Museum of the Republic, both in Brazil. In this last exhibition a video of the neural activity was used to affect the virtual worlds.

To illustrate the joint development of this project extracts of some correspondences with Maida Withers, exchanged via email, and Skype conversations, are presented below:

“I (Tania) am finishing the tests for the new version. It is as you (Maida) asked me. I will put it in Dropbox as soon as I finish the tests thus you may work with them.

There are big changes in many of the worlds due to the emotional state values I am using. For example, the camera in the 'Musician in LA' and the 'Beginning' may become very crazy if the dancer is in a state of calmness and will work more harmoniously if they are excited. In 'Blackness' and 'Whiteness' the balls go berserk for the same state, and in 'Whiteness' they even may fly. In the bots worlds it is hard to perceive the changes with the bots although the cannibals may become fierce and all the pink bots may be eaten and only the blue ones will survive and stay on the scene. With the fractal growing trees they also grow or contract depending on the emotional state of the dancer. If this state fluctuates a lot some chaotic phenomena may occur due to the type of number I used (float). In 'BrainEruption' (the cars) and 'Panspermia' there are explosions of particles each time the dancer is excited. I tested the application in two exhibitions here and it is working very well.

If you are not seeing these effects it is because the window that reads the data over the Emotiv software is not properly set. (…) This window MUST be over the end of

the window of the affective suite of the neuroheadset at Emotiv control panel. This small window reads the position of the orange line and pass values to the worlds. I used such values as parameters for changing the agents´s behaviors. I am sending a video with my brain wave activity that has exactly the same size of this small window. By using the video instead of the Emotiv Control Panel we may simulate the brain activity without using the helmet. If you put the small translucent window over this video (re size its window and use the smallest possible size for it) it will be as if someone is interacting with the worlds. This will also be our plan B just in case we have any loss of the connection of the helmet during the spectacle. (…) Also the viewpoints have much more time now, in between 4 and 13 seconds (we can have any necessary amount of time we want and I will program them when you have decided the time for each section). The walk through (initial view point animation) is much better if it happens slowly but you must have to wait until it finishes before to take any other action. Therefore the computer will be crazy trying to run too many threads at once. (…) I think it is very important for you to work out the differences with the dancers' emotions.

The computers set up needs to be:

1. Two identical computers with two video cards each running in parallel, each one with the virtual world on the stage projector and the Emotiv software in the offstage monitor. The small translucent window will go directly over the affective state window at the Emotiv software. The translucent window may be dragged but it is also easily put in place through numbers at any location inside the monitor screen. It will go to the exact point we want it to go. But since this value will change in different computers we must give the correct coordinates (numbers) in a text file and set it up by the final week before the spectacle. (...) If necessary, to facilitate the set up for the person working offstage, a video splitter may duplicate the projector’s signal to another monitor in front of this person.

2. For example, computer 1 is running 'TheEgg' (world 0) with one dancer using the

helmet 1. Computer 2 is being prepared. The ball to connect to world 1, 'Blackness', is in waiting on the screen and the dancer using the other helmet, helmet 2, is prepared in computer 2 and is also in waiting. At time *T*, a cue is given and the technical person offstage clicks the ball. World 1, 'Blackness', begins, the dancer enters the stage and the computers are switched, spectacle goes on. Computer 1 now has the ball to run world 2, 'Beginning'. The first dancer wearing helmet 1 comes to the computer set, puts saline solution on all the connectors, verifies if all is connected and working well. And so and so.....(…)

The purpose to have 2 outputs for each computer is that I need to extend the desktop up to 2 sources (minimum), 1 monitor and 1 projector. The projector shows the real time Java3D application while the monitor runs the Emotiv software and read the dancer´s emotions, which will then be sent to the computer to be processed. Therefore the outputs are: one to connect the projector, the other to connect the monitor. In general they are SVGA and DVI and, if so, probably it will be necessary 2 connectors to convert them to HDMI. This may happen since everything now is HDMI. The video card needs to be compatible at least with OpenGL2.'

The application **NumericVariations:**

The first result of the art research applied in **MindFluctuations** was achieved by the construction of robotic artwork **Caracolomobile** [3]. This robot was built with an award from the Brazilian Cultural Institute Itau, in 2010. Following this approach the customized application **NumericVariations**, was created. It inquired about: What virtual realities are? How may someone describe them? Which are the differences among a virtual reality artwork and any other interactive computer application? Looking for answers one may say that a virtual reality, realm, domain or world, is a real time simulation of a 3D environment with geometrical, topological and physical

characteristics similar to the physical world. Although all simulations can share such characteristics, the artworks are conceived to develop singular and specific ones.

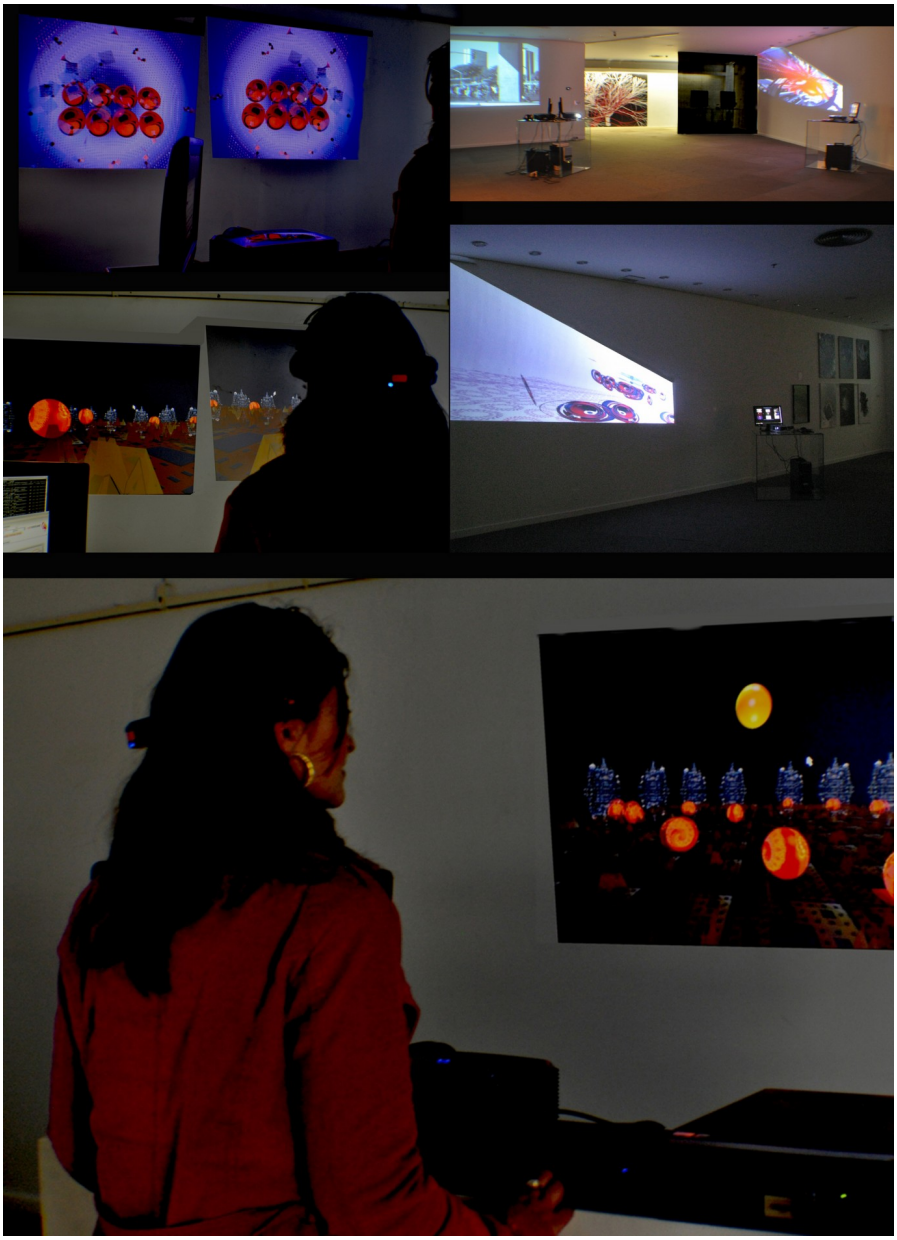

Figure 03: exhibition in Santa Maria and at the Museum of the Republic, in Brasilia, 2014

Within the application the computer mediate dozens of processes linked together through thousands of lines of code. **NumericVariations** application is written in Java using the API Java3D™. It took three years for it to be programmed. It has a repertoire of around 280 Java classes with approximate 70,000 lines of code. It uses algorithms for collision detection and avoidance, for organization and growth of fractal trees, for elevation of fractal terrains, for particles, for behaviors related to collective flocks (with prey and predator behaviors, and of proximity, separation and alignment parameters for flights), among others [30]. In them the user's emotional data, interfere with the behavior of endogenous virtual agents. As said before, **NumericVariations** portrays a set of 11 virtual domains. There are whole arrays of sub systems such as packages for: geometries, autonomous, artificial intelligence and artificial life behaviors, animations, materials, lights (illuminations), camera movements, interactions, navigation, utilities, input and output controls, mathematical functions, scene graph creations, and images for textures and animations, among others, see a fer virtual worlds in “Figure 01”.

The use of neural data added a few more unknowns to this situation. To use them for exhibitions and performances, it is important to understand their working conditions. In response to them the artist-programmer must have, at one's fingertips, some strategies to deal with possible delays and signal losses that may occur during the data transfer between the computer and the helmet readings. While the dancers using the helmet are feeling something such as excitement or frustration, some sets of neurons within their brain will fire, creating variations within the electric gradients of neurons' fields. “The neuroheaset captures the variations of these electrical impulses and the helmet interprets them sending them to the computer. These electrical impulses are then translated as numerical data. These data are programmed to

interfere with the behaviors of the autonomous agents within the virtual environments" [7] (p 193).

For anyone waiting to have a literal type of interaction, with input and output data changing in real time, the whole experience happening at the stage may be frustrating once what is happening is a mixture of exogenous and endogenous processes [14]. The result may be different in scientific environments, with computers that are outstanding machines and where the whole environment is totally controlled. In my experience this has never happened until now in the many art exhibitions I have curated or participated [8], [9] and also, from an artistic perspective, it is not desirable. "Depending of the computer specification, the data traffic may produce lags, which have to be considered by the artist-programmer, in which case they will not affect negatively the audience´s fruition even if they are affected by a network of processes, either stochastic or neural" [7] (p 193).

It is interesting to inform the public that they will not have literal interaction. Since literal interaction is becoming well known by the public people usually looks for it without being aware of other much more interesting alternatives. For the artists participating in such experiments, the mixed endogenous and exogenous interactions are much more challenging since in these kind of experimentation lies the vitality and more thought-provoking ways to conceptualize innovative computer artworks. As said before, I have called this type of mixed interaction as exoendogenous interactions [14]. If the resulting mixed interactions become too literal they could be exchanged for much simpler exogenous types of interaction, in which cases such a use of neural data could be characterized as nothing more than an approach aiming to demand attentions instead of developing a set of much more interesting research inquiries.

For each virtual object or autonomous agents' behaviors within a virtual domain it is necessary to define algorithms. The algorithms used were implemented in Java3D by Andrew Davidson [30]. They were adapted and transformed for the achievement of the project´s goals. “They need to be added to other properties, such as: colors, shapes, proportions, textures, illumination, movements, accelerations, velocities and gravities, camera location, paths and related movements, among many others attributes. Redundant procedures must be studied and backups prepared since faults, losses, and noises may happen during the data transit among computers and devices” [7] (p 193).

To create an artwork all these characteristics must be planned. How to elaborate the way they entwine must be chosen. These characteristics must always ensure the best aesthetic and poetic contents throughout the whole artwork. Faults must be changed into improvements. In general, artworks are focused on perceptions and sensory relations even if these are not easily unveiled. It does not matter if they are subjected to realistic renderings or other more abstract and dashing ones.

Therefore, lights, illumination, colors, materials, proportions, and any similar artistic characteristics must always be carefully chosen. If photographs are used they must have the best possible resolution allowing them to be shown in big projections screens. If and when pixelations occur, the images must be designed in order to maintain the quality of the whole.

An interface is a boundary between two things. The software **NumericVariations** allows the establishment of an interface between the human brain of the dancers and the computer. This application establishes a flexible membrane, not permanent, not invasive, between the biological and the electronic brains. It is rather different of a prosthetic device, which would aid one to overcome, for example, a disability. Also it is rather different from the scientific goal to understand the workings of biological or electromechanical brains. The present research, as an art-research [9], aims to achieve poetic and aesthetic possibilities resultant of the experimentation with this type of application. It has no focus on the operational aspects either of both kind of brains or of any possible practical applications. It is not a procedure helping to make machines more intelligent, affective or sensitive. It is not a research to understand how biological brains work. It is not either a software aiming to achieve the development of algorithms. It is an artwork for fruition, for expression of poetic and aesthetic qualities, for experimentation with perceptions and sensations [31] (p.182).

As said before a similar approach was made possible by the creation of the robotic artwork **Caracolomobile** (which had a neural interface) [3], by recent neuroscience research [32], [33], by artificial intelligence research [2], [31], and a Brain Computer Interface (BCI) [14], [34], [35] integrated with a virtual reality software made possible by the use of a framework that has been in development since 2003. These factors have established the basis for the creation of this experimental and interactive artwork and the achieved solutions have allowed the emergence of a symbiosis [22] (p. 26) where the users' emotional states, such as excitements and frustrations, affect the virtual realms within the computer creating slightly different configurations at each presentation of the artwork. These final outcomes take into account that audience will perceive activities owed to human mental states' fluctuations, something inconceivable in the recent past.

Figure 04: The computing environment above and the neuroheadsets (with Maida Withers, Anthony Gongora and Alicia Days)

In order to achieve the artwork's main goal and to answer the questions outlined during its conception it was necessary to understand the possibilities available in the market. Also, it was important to achieve an agreement about the logistical difficulties someone has to face when creating custom software to be presented in spectacles, exhibitions and performances. Therefore, firstly, there was the need to find a sufficiently complex device that would allow data to be reliable and that were simple enough to permit their manipulation and use by non-technical users, such as dancers or public. Secondly, there was the certainty that the most important feature of such artworks would be their aesthetic and poetic qualities. Thus, after experimenting with other commercial devices available [36], the Emotiv neuroheadset was chosen [29], see "Figure 04".

This headset was regarded as the most appropriate for the purposes sought. It offers a non-invasive system of neural monitor readings and made possible the use the affective states of the dancers who wore it. Among the many possible affective states it was chosen the ones ranging from excitement to calm/frustration and vice-versa. The helmets were connected to the computers via devices (dongle) bluetooth. Interferences with other radio signals occurred and the positioning of dongles on the scene demanded special attention.

What does this device allow? It permits to read facial expressions, emotional states and a few cognitive data related to movements. After researching possible results of the use of such data we concluded that the most interesting and challenging approach for the aforementioned artwork would be to use the helmet's affective suite.

The next step was to find how and which of the achieved data would affect the virtual realms, allowing expressive and not literal poetic results.

The autonomous agents inhabiting the virtual realms were planned as sets of design principles that enable them to provide appropriate behaviors within a given virtual environment. They are small systems which can be regarded as relatively intelligent. An agent is any process that may be viewed as able to perceiving its environment through sensors (virtual or physical) and then acting upon them [2]. They are relatively simple sets of instructions programmed to produce complex and unpredicted behaviors. Although very simple these sets of instructions organized as software may exceed the capabilities of their programmers. The Deep Blue chess playing computer developed by IBM, in 1997, and Stanley, the robotic car created at Stanford University that won the DARPA Grand Challenge, in 2005, are just two examples showing the progression of the development of autonomous processes using computers.

For **MindFluctuations**, from a point of view related to the hardware, a system of two identical computers was chosen to run the application **NumericVariations**. Each computer had two graphics cards and two monitors, see “Figure 04”. These computers ran consecutive virtual worlds. The monitor connected to the projector, showed the virtual world that was being affected by neural activity of the dancer performing on stage. The software for the helmet and a prerecorded video of neural activity ran on another monitor. The video was used as an alternative plan when the loss of the helmet signal happened. During the spectacle this monitor was operated by the author as well as the second computer that was being prepared, simultaneously, to run the following virtual world. Two data switchers connected the two computers and enabled to exchange them at the end of each section. Another

switch used for the video projector system on stage allowed, sometimes, the transition between two consecutive virtual worlds to happen with a fade.

Taking into account the problems that could arise during the spectacle two versions of the application were created: one using two computers, and the other using only one computer in case one of the two computers needed to be rebooted during the presentation. Both versions were installed on both computers. Because the whole system would be offstage and due to the total newness of this type of presentation a short video explaining the operation of the system was created and was placed on the Internet and passed on a TV in the theater foyer before the beginning of the spectacle [27]. The music happened live and musicians, their instruments and devices were located in the orchestra pit in front of the stage. To simplify the activities that took place offstage, after the time of each section was defined, automated viewpoint animations were created (walk troughs) for each virtual world. These animations initiated about 20 seconds after the beginning of the world and ended about 30 seconds before its end. The initial time was due to the need for flexibility for changing computers and the transition that was performed by the switcher device for the video projector. The final time was needed so that one could manually make the change of views depending of the development of each virtual world. For example, if the 'trees' grew too much, a point of view that moved away from them was chosen; if they shrank an approaching view was chosen, presenting them always in their entirety. Auxiliary scene personnel were trained to help dancers to exchange helmets when so designated by the choreography. Each helmet has 16 sensors that need to be in contact with the user' scalp. They also need to be kept moist with saline solution to ensure the establishment of a good electrical connection.

CONCLUSION

Semiotic universes fighting against stereotypes and the dulling of our capabilities constitute an intriguing art research approach. The profile of the artists who will explore such domains is of the artist-researcher, that is, one who delights in unknown exploratory adventures and the challenges of diving into other knowledge areas. The type of experimental artwork emerging from this context demands an intensive work of partnership, cooperation and collaboration with scientists and technical developers. The emergence and proliferation of garage laboratories begin to deploy and probably will boost such partnerships. The exercise of freedom, possible through the development of Computer Art, enriches this process and has a latent potential to uncover new and exciting niches of experimental research to be explored.

Another consideration that comes to mind is the philosophical problem arising from Goedel's theorem of incompleteness, adding a very interesting problem to the spectacle set up, owing to the logical conclusion that no system can alone explain itself. Accordingly, perhaps, we will never understand the whole unfathomable potential that the biological brain's system poses to us. But by being optimistic it is possible to point to the furthering of changes owing to the sharing of knowledge that the free software and hardware communities are providing. This is provoking the emergence of an improvement causing transformations in society. The role of computer artists in this process is becoming relevant. Artists, experimenting with sensory and semiotic characteristics, may integrate them with other inherent aspects of computer languages creating unexpected results. In this context one wonders: Which systems of organization resulting from these new sensory expressive gatherings could be developed? What new morphologies could be studied?

I am convinced that Computer Art courses need to be created. Beyond traditional disciplines to train artists it is necessary to introduce the study of mathematics, physics, and topics of computer science and robotics. This logical universe is generally averse to artists, and may be quite difficult, but not impossible, to embed such subjects in a curricula. Throughout the last 60 years, many computer artists, such as myself, often, with very low budgets, are developing creative strategies to design works and projects anchored in visual, gestural, auditory and tactile languages, integrating them with mathematics. The unfathomable field of possibilities open to artists a melting pot for thought exercises constituting a great reward for our endeavours.

Summing up, it is possible to speculate on the growing capacity of the cognitive, affective and human sensory systems for developing potential symbiosis with machines [3] (pp: 438, 494-495). Maybe it is unlikely that someday we might understand and relate with all factors inherent to the complexity of the phenomena involved within human neural affective and cognitive systems. But, while we are here on this planet, our task is to try, forever.

Figure 05: **MindFluctuations**: Maida Withers, Washington, DC, 2015

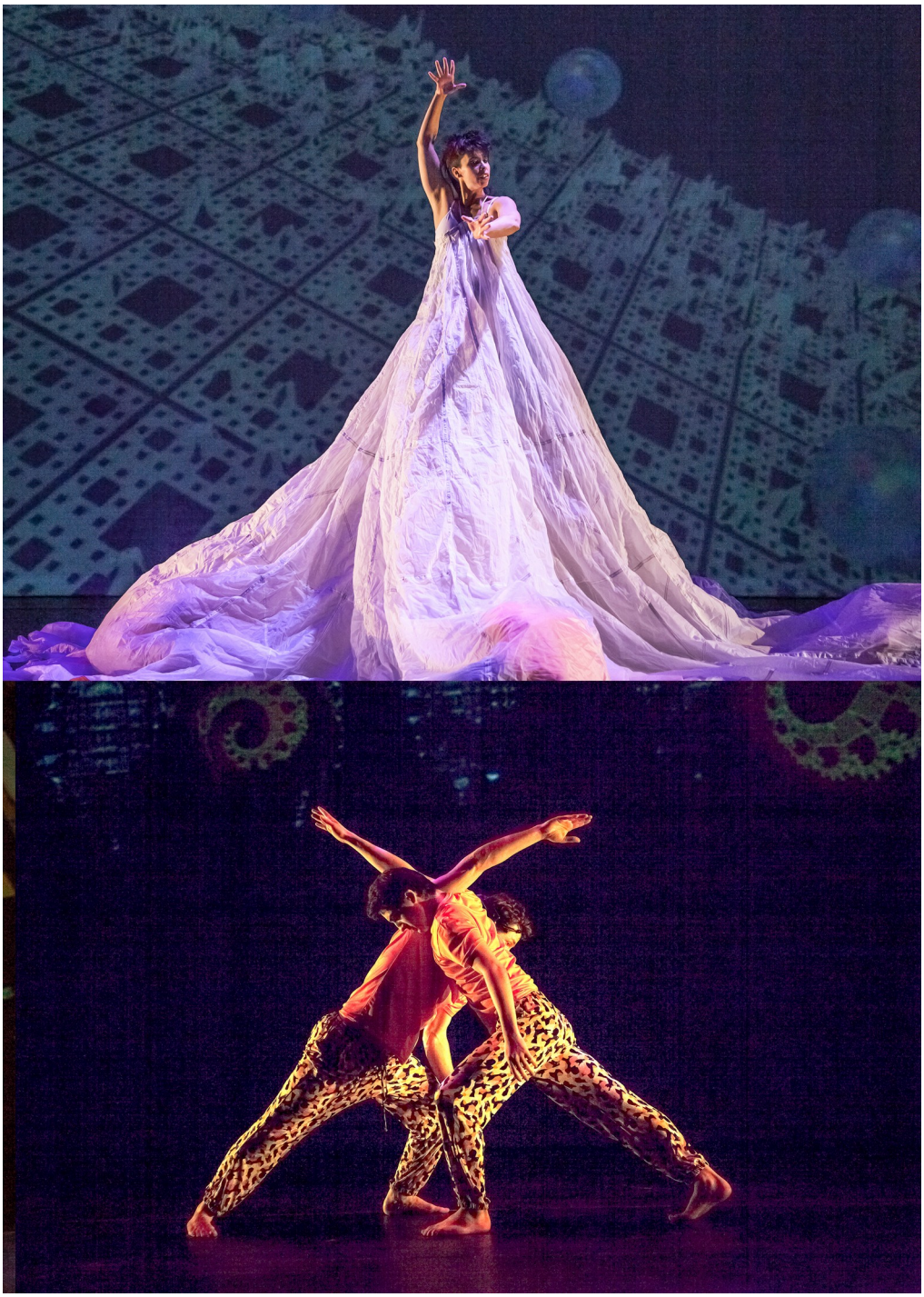

Figure 06: **MindFluctuations**: Felicia Avalos, Matthew Thornton and Ian Ceccarelli, Washington, DC, 2015

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