

# Polyphony and Technology in Interdisciplinary Composition

Paulo C. Chagas

Department of Music – University of California, Riverside  
900 University Ave. ARTS 138, Riverside, CA 92507, USA

paulo.chagas@ucr.edu

**Abstract.** *This paper discusses the relation between polyphony and technology from the perspective of two of my interdisciplinary compositions: “Circular Roots” (2004) – interactive performance for violin, electroacoustic sounds, video and image processing – and “Canções dos Olhos (Augenlieder)” (2005) – intermedia sound cycle for soprano, dance, video and electroacoustic sounds. It provides theoretic insights on musical gesture, interactivity, and the visibility and invisibility of the body in composition. The concept of interdisciplinary composition is also explored in relation to polyphonic subjectivity and technology. There is a need to develop a phenomenology of gestures and a systemic approach of interactivity in order to clarify the changing contexts of artistic creation involving digital technology.*

**Resumo.** *Este artigo discute a relação entre polifonia e tecnologia do ponto de vista de duas de minhas composições interdisciplinares: “Circular Roots” (2004) – performance interativa para violino, sons eletroacústicos, vídeo e processamento de imagem – e “Canções dos Olhos (Augenlieder)” (2005) – ciclo de canções intermídia para soprano, dança, vídeo e sons eletroacústicos. O artigo desenvolve noções teóricas sobre o gesto musical, interatividade e visibilidade e invisibilidade do corpo na composição. Aborda também o conceito de composição interdisciplinar em relação à subjetividade polifônica. O autor defende a necessidade de desenvolver uma fenomenologia de gestos e uma abordagem sistêmica de interatividade a fim de elucidar as transformações dos contextos de criação artística envolvendo tecnologia digital.*

**Keywords:** polyphony, technology, gesture, interactivity, visibility and invisibility, digital arts, autopoiesis.

## 1. Polyphony, polyphonic subjectivity, and technology

The notion of polyphony implies the perception of multiple and simultaneous sound events organized in a system of relationships producing a temporal processing of *meaning*. As I pointed in a former essay, polyphony is a “specific mode of operation of auditory perception, which distinguishes multiple and independent events and creates a musical difference between sound an environment” (Chagas 2005). This point of view



emphasizes polyphony as an experience of embodiment, which is triggered by sound phenomena. However, experiences of embodiment involving perception of simultaneous events are not restrained to the realm of sound. Rather they involve the structural coupling of different domains of experience that contribute to create the notion of temporality. The neurobiologist Francisco Varela describes time-consciousness as the articulation of different levels of temporality. According to Varela's enactive point of view, "any mental act is characterized by the concurrent participation of several functionally distinct and topographically distributed regions of the brain and their sensorimotor embodiment" (1999: 272).

The constructivist and psychoanalytic philosophy of Deleuze and Guattari closely relates polyphony to the ideas of *plurality* and *heterogeneity*. In his last book, *Chaosmose* (1992), Guattari develops the notion of "polyphonic subjectivity", which transverses the material and virtual universes of capitalistic society and operates by means of "technological machines of information and communication" (1992: 15). Guattari proposes a polyphonic analysis of subjectivity based on the "ethic-aesthetic paradigm" that is conceived as an alternative to scientific and philosophical models. He defines the polyphonic and heterogenic complexes of subjectivity as "machinic assemblages". His notion of "machinic" embraces both technological and abstract machines, such as social bodies, scientific discourses, cultural formations, desires, collective behaviors, and so forth. This "machinic" also extends the cybernetic concept of autopoiesis proposed by Maturana and Varela (1980) to the social domain, but through a different perspective than Luhmann's theory of social systems (Luhmann 1984; 1997). Instead of focusing on operationally closed systems, Guattari's "machinic" emphasizes the relations of alterity between collective entities. As subjectivity is not restricted to human consciousness but is also embodied in technology, the machinic assemblages of technical machines and human beings become an autopoietic character. The "machines of subjectivity" shape the autopoiesis of the post-human society in which human beings interact with technology.

Polyphonic composition conveys the idea of music consisting on multiple parts played by instruments and/or voices. *Interdisciplinary composition* extends musical polyphony to the dimension of the subjectivity that is related to and shaped by our artistic experience with technology. It embraces both the multiplicity of elements, layers and contexts, and the multiple kinds of interactions that are generated in the relationship between human and not-human bodies. In this sense, the idea of interdisciplinary composition emerges in the convergence of two tendencies: (1) the *process of differentiation* of the art system in which forms become media for the development of new forms and domains of experience (Luhmann 2000), and (2) the *autopoietic dimension of the machinic*, i.e. the experimental field of the arts dealing with the technological apparatus.

As pointed by Luhmann, art has the capability of integrating "the most heterogeneous modes of operation into an autopoietic functional nexus" (2000: 178). Using a variety of material as a basis (visual, textual and sound elements), the art system has therefore the capacity of integrating new elements produced by the technology. Electroacoustic music, for example, combines virtually all kinds of sounds, including electronic and concrete sounds, noise, sound of language, and vocal and instrumental music. Technology recycles the previous sound material and creates new meanings. The aesthetics of the "machinic" explores the parameters and functions of

machines, such as automation, interface, feedback and control of processes that can be connected with or independent from the human body. The creative process involving the interaction between human and technological processes brings awareness of the changing “relation of human subjectivity to its environment” (Hayles 1999: 290).

In the following sections, I will describe some aspects of the works *Circular Roots* and *Canções dos Olhos (Augenlieder)*. Both pieces reflect on the transformation of human existence in a heterogeneous environment and the interaction between human and technology in the artistic process. They represent different approaches of interdisciplinary composition concerning the connections between sound, image and body and the strategies for exploring the relationship between polyphony and technology.

## 2. *Circular Roots*: visible and invisible gesture

*Circular Roots* (2004) is an interdisciplinary sound and image composition for violin, electroacoustic sounds, video, and real time image processing. It uses gestural control by the violin player to process digital images projected on a screen. The violinist synchronizes his/her performance with the pre-produced electroacoustic sounds that are projected in the room as surround 5.1; there are no live-electronics and no live-processing of the violin sound itself. The piece was commissioned by the Centre de Recherches et Formation Musicales de Wallonie (CRFMW) and premiered at the Festival Ars Musica in Brussels (March 16, 2004). The work was developed in close collaboration with Luiz Carlos Joels, a Brazilian environment engineer and video artist, the violinist Izumi Okubo, and computer scientist Patrick Delges, who created the interactive design and image processing.

A variety of literary, visual, musical and sound materials formed the basis of my composition, including:

(1) The short story *Circular Ruins* by Jorge Luis Borges (1970). It tells the story of a man who came to the ruins of a temple, which had been devoured by ancient fires. He is possessed by the idea of dreaming a man, who should exist as a real person. The Fire helps him to accomplish his task and his son is born as a person that all creatures, except the Fire itself and the dreamer, would believe to be a man of flesh and blood. But later the man understood that he as well was an illusion, that someone else was dreaming him.

(2) Video images by Luiz Carlos Joels documenting the destruction of the Brazilian Amazon rain forest and the transformation of the natural environment. The video shows footage of the life in the Amazon region, such as the manufacture of manioc flour by “caboclos” (habitants of the countryside), a purification ritual held by a Brazilian Indian, and boats anchored in the harbor of Manaus (capital of the Amazon state).

(3) Recording of the virtuosic passage of the violin 1 part of Beethoven’s string quartet op. 74, first movement, measures 221-246.

(4) Samples of my voice (whispers, laughs, screams, etc.) and concrete sounds recorded on the site of the former coal mine of Göttelborn, Germany.

*Circular Roots* generates polyphony by exploring the relation between instrumental gestures – produced by the human body manipulating the gestural



controller – and technological gestures – generated by the computer interface and the mapping strategies adopted by the composition. Sensors are attached to the violin bow and the body of the violinist capturing instrumental gestures, which are used to control image processing. The sensor data is interpreted as dynamic gestures that express the changing of some quality over time. The systematic use of feedback and recursivity for sound and image shaping emphasizes the *gesture of circularity* as the main idea of the composition.

*Circular Roots* shows how the use of technology contributes to the emergence of new interdisciplinary artistic situations. The starting point of my investigation is the role of gesture in musical understanding. According to Wittgenstein (1958; 1980; 2001) and Cavell (2000), gestures can be defined as expressions of instances and directions of projection of understanding (including musical and artistic understanding). Wittgenstein argues that when somebody tries to understand and explain a musical phrase, “sometimes the simplest explanation is a gesture” (1980: 69e). Gesture makes visible the interiority of musical understanding. But he also doubts that the understanding of a gesture can function as an explanation of musical understanding, for that gestures – as musical elements – can be re-interpreted in different contexts. [1]

In his phenomenology of gestures, Flusser (1994) gives an original insight on the gesture of listening, which he considers as a matrix of musical gestures. The gesture of listening is not a movement but a particular position of the body. The representation of this posture can be traced on the medieval iconography of Mary’s conception. Mary conceives by listening. According to Flusser, listening to music “is the gesture of fertilization through the word (logos)” (1994: 151). This point of view is not new. As pointed by Eco (1997), there is no medieval author that does not refer to the transcendental property of music to convey the meaning of a invisible (divine) order, making visible things that are beyond our comprehension. This idea is also related to the theme of a “polyphonic order of the universe”, which is the paradigm of medieval beauty (1997: 39). The transformation from invisible to visible accomplished by music is a process of embodiment. Therefore, the gesture of listening to music expresses the transformation of both “body in music and music in body” (Flusser 1994: 155). It is a gesture of a musical embodiment that puts the body in vibration and makes it function as a receptor and transmitter of information. Further, Flusser affirms the gesture of listening expresses the possibility of overcoming the “separation between man and world” (1994: 158). In this sense, music acts as interface in both existential and biological domains.

But the question here is how to approach musical gestures in the context of electronic and digital media and interfaces. Although the study of gestures became a focus of computer music research, performance and composition (see for example Wanderley and Depalle 2004; Miranda and Wanderley 2006), there is still a need to develop a more substantial and less mechanical theory of gestures and digital music instruments. I claim that is necessary to overcome the limitation of the structuralistic conception of gestures, which establishes a separation between information and meaning, and move towards cognitive and phenomenological approaches of gestures as a process involving “multiple levels of interconnected, sensorimotor activity” (Varela, Thompson and Rosh 1991: 206).

Such a phenomenological approach has to take in account the interplay between different kinds of gestures in musical performance. Traditional musical sounds are produced by analog gestures – vocal and instrumental. Vocal gestures are the closest related to the body, although this relationship can create all sorts of transgressions of the “natural” characteristics of the body. Instrumental sounds require a synchronized action between bodies and objects: the sound symbolizes the projection of a physical, muscular and intellectual effort of the vibrating object. Instrumental gestures make this projection visible.

Gestures in electroacoustic music are shaped both by traditional sonic model – such as vocal, instrumental and concrete sounds – and technological apparatuses. However, the meaning of the electroacoustic gesture is not conveyed by an external reference – for example analogies to known sounds – but is closed related to the apparatus that produces it. In these sense, electroacoustic music create gestures that are decoded as expressions of *programs*. Programs, according to Flusser (2000) are abstractions of concepts (scientific knowledge), which are ritualized in the post-historical society as “models.” They replace the “myths” of the historical society based on alphanumeric codes. Programs stand for the communication that is made available by the technical apparatuses (computers, cameras, synthesizers, iPods, etc). Apparatuses are intelligent tools that change the meaning of the world. Musicians use them to enhance the musical possibilities through automation, simulation, sound synthesis, sound processing, information processing, etc.

In *Circular Roots*, the research of the musical gesture is anchored in the broader research on interactivity that explores sensor technology on musical performance. The violinist uses two sensors in the performance: an accelerometer attached to her bow and a flexometer attached to her skin in the inside angle of the elbow articulation. The accelerometer gives two values measuring the changing of the speed of the bow in both the X axis (horizontal) and the Y axis (vertical). As the bow is drawn across the string of a violin, the string vibrates back and forth smoothly in a saw-tooth-like motion. The displacement of the bow has to be as continuous as possible in order to produce a “sonorous”, high quality vibration. The changes of velocity (speed) occur basically when the bow moves in the opposite direction in the X axis or when it moves toward a different string in the Y axis. But acceleration and retardation of bow velocity can also be related to the changing of specific sound qualities, such as loudness. The transition between loud and soft sounds requires both a changing of bow pressure and motion. The flexometer measures the gestures of expansion and contraction of the right arm, which holds the bow, at the elbow articulation. In opposition to the accelerometer, this sensor gives a much smoother curve of values over time because the violinist tries to keep the arm movement as continuous as possible in both directions.

The sensors capture all gestures produced by the violinist during the performance, including those that are not immediately translated into sound. An example of one gesture would be moving the arm to put the bow at the right position before starting a strong attack. This gesture and many others are a significant aspect of the performance and play a crucial role in musical understanding. Sensor data acquired by the gestures are mapped to the visual effects, which transform the video. MAX/Jitter (cycling74.com) software is used for image processing. The audiovisual interactive composition explores the patterns emerging from the combination of different layers of gestures relating the body to sound, music and visual information.



Thus, *Circular Roots* develops a process of coding and decoding gestures in the three levels of the composition:

(1) In the music for solo violin by applying fractals transformations to the Beethoven excerpt. I used the library Chaos by Mikhail Malt (1994) on the Patchwork programming environment. The fractals expand the harmonic, periodic progression of Beethoven's music.

(2) In the electronic music by creating an environment of concrete sounds without any reference to the musical and visual elements.

(3) In video composition by processing the images through the mapping of the gestures of the performance to the visual effects. Image processing algorithms include positive and negative feedback, delay, zoom, superposition of two layers of images, etc.

### **3. *Canções dos Olhos (Augenlieder)*: visible and invisible body, interactivity**

The visibility and invisibility of the body and the interactivity on artistic creation are the central issues of *Canções dos Olhos (Augenlieder)*, a composition for soprano, electronic music (surround 5.1), dance and digital image created in collaboration with the choreographer and media artist Johannes Birringer and the dancer Veronica Endo. The work exists in two versions: (1) the live performance version for soprano, dancer, electronic music and video projection; (2) the DVD version featuring the electronic music and the video dance. [2]

*Canções dos Olhos (Augenlieder)* was developed in a period of only two weeks (July 18-30, 2005) in the "Interaktionslabor", an international workshop founded and directed by Birringer in 2003 on the site of the former coal mine of Göttelborn, Saarland, Germany. The mining activity was suspended in the late 1990s and threw the region into a crisis of chronic unemployment. Several traces of the past remained more or less intact in the mine landscape. You can still see the imposing wind tower, which measures 74,2 meter and is the highest in Europe, the huge machinery spreading among several facilities, the large network of belt systems that served to transport the coal through the several processing unities, the heavy and dirty machinery rusting inside and outside, the workrooms, labs, hallways and other spaces still filled with equipment belonging to the miners – tools, reports, newspapers, calendars, pinup girls, photos, etc. Traces and inscriptions of this history appear in the architecture and physical environment. There are signs of human presence, as if the workers had left the place in a hurry fleeing from a sudden catastrophe. The abandoned and jeopardized infrastructure of the mine outlasts as a memory of the vanishing industrial society.

After the collapse of the mining economy, the local government set up an initiative for recycling the industrial landscape. The project called "future cité", aims to create a post-industrial living environment by attracting high-tech companies to the site of the former mine. Organized as a network of individuals and machines producing and exchanging information, this new environment represents the dream of a telematic society as expressed by Flusser (1985). The Interaktionslabor emerged inside this dream as a self-organizing "laboratory for interactive media, sound, design, digital video, telecommunications and performance" (Birringer 2005, 2005a). Since 2003, Birringer has promoted an annual summer workshop inviting groups of artists, scientists, and engineers from different parts of the world. Participants live for two weeks in the region (since 2005 at the site of the mine) and work on individual and collaborative projects in

which digital media and interactive performance are coupled with specific qualities of the physical environment. Originally, the events and works produced in the Interaktionslabor hoped to provide the structures – the medium/form relations in the sense of Luhmann (2000) – for observing the conversion of the post-industrial society into the utopia of the information society. As this process started to take place, as seen in a new photovoltaic plant which occupies a large space of the former mine, the dynamic of the Interaktionslabor has shifted its focal point. The sounds, images and other digital objects collected in the environment become less visible and sustainability emerges as a focus of the research and artistic projects.

*Canções dos Olhos (Augenlieder)* is inspired by the novel *Blindness* (1995; original title: *Ensaio sobre a Cegueira*) by the Portuguese author and Nobel Prize winner José Saramago. In this story, Saramago has created a contemporary city where everyone loses their sight. Blindness spreads rapidly like an epidemic and provokes social collapse. Life is reduced to the basic instinct of survival; despair prevails. The author's literary metaphor of blindness points to the vulnerability of a society on the edge of chaos with no guarantees of stability. I had previously explored Saramago's novel in a former project for the Interaktionslabor 2004 – *Blind City* – a model for an interactive opera-installation that “focused on the haptic and the auditory, seeking to displace proprioception from vision, [to] make us ‘see’ without seeing” (Birringer 2005a).

When I conceived *Canções dos Olhos (Augenlieder)* for the Interaktionslabor 2005, I revised Saramago's narrative, focusing on the operational distinction between visibility and invisibility. Inspired by Schubert's *Winterreise*, I imagined a cycle of “intermedia songs” that explored the relations between sound, image and dance in the unique environment of the mine. [3] The song cycle focuses on the *Blindness*' main character, the doctor's wife – performed by the dancer – the only person that apparently can see in the virtual city where everyone else has gone blind. Her story is not told as a linear narration, but as an invisible layer of fiction that “actively probes the spaces between the different media” (Higgins 2002: 91).

The music of *Canções dos Olhos (Augenlieder)* was composed in the Max/MSP programming environment using basically two different kinds of samples: (1) recording of a solo soprano voice singing four songs using excerpted passages from Saramago's *Blindness*; (2) recording of my voice reading a cycle of five poems that I wrote for the chamber music composition *Canções dos Olhos* (2004, for mezzo-soprano, cello and piano). The sample material is processed through granular synthesis, using the Max/MSP external objects and abstractions developed by Nathan Wolek (2002). They offer a large variety of control of grain parameters and can be easily integrated in the patch structure of Max/MSP. Granular synthesis plays a significant role in the composition and shapes the overall texture of the electronic music.

The piece has five sections organized as sub-patches of Max/MSP. Each sub-patch contains a certain number of controls (between 8-16) for manipulating in real time the parameters of granular synthesis and also other secondary effects. I used a hardware MIDI-controller (Behringer BDF2000) and assigned the controls to faders and knobs. In the live-performance version of the *Canções dos Olhos (Augenlieder)*, the electronic music is produced in real time and the voice of the soprano can be also processed with Max/MSP, although this possibility was not explored when the work premiered on July



30, 2005 in Göttelborn. The DVD presents a version of the electronic music mixed with the recorded voice of the soprano.

The aesthetics of *Canções dos Olhos* (*Augenlieder*) reflects on *interactivity* and *collaboration* as distinguishing features of the interdisciplinary artwork involving technology. As I said, the idea of “intermedia song”, which undergoes the conception of the piece, proposes an interdisciplinary form characterized by the connection between different domains of perception and experience – electronic music, digital image, body. The questions here are: (1) how it is possible to observe the unity of the interdisciplinary form; (2) which role interactivity plays in this process? As pointed by Luhmann (2000: 54-101), the observing operation that realizes the unity of the artwork is a distinction and indication that generates differences in both levels of first- and second-order observations. First-order observation distinguishes and indicates the arrangements of materials and elements assembled by the artwork itself; in other words, it observes *what* is the artwork. Second-order observation refers to further distinctions and observations; in other words, it observes *how* other observes the artwork. The concept of “intermedia song” embraces both kinds of observations: the arrangements of heterogeneous media that can be assembled by and observed in the artwork, and also the dynamic of observations – personal relationships, decisions, etc. – occurring in the creation process.

From the point of view of technology, the intermedia approach of *Canções dos Olhos* challenges the current understanding of “interactivity.” In opposition to the discourse of interactivity that glorifies the connection between bodies and digital interfaces, I define interactivity as the embodiment of the collaborative experience that materializes the creation process in the *form* of the work itself. Interactivity is a being-in-the-world, not an ensemble of devices and instructions. Following the theory of autopoietic systems, interactivity cannot exist between human beings and machines. They operate in different living domains, which are operationally closed to each other. The artwork accomplishes the structural coupling between those domains. By observing technology, art deliberately chooses a negative approach in order to observe what is impossible to be observed. As Luhmann claims, the negative version of which is habitually performed turns into a figure of reflection. “Blindness – not seeing – becomes the condition of possibility for seeing” (2000:83).

In the beginning of the 21<sup>st</sup> century, interactivity emerges as a model of dialogue communication in a broader sense. The paradigm of interactivity, according to Flusser is chamber music (1985: 173-181), which anticipates the model of dialogue of the telematic society. [4] The dialogue characterizes the exchange of information between man and machine in a network structure. Contemporary art deals with new perceptions, situations, and experiences resulting of the hybridization of physical and virtual spaces. This is actually not new. For example, the adoption of perspective in the early Renaissance permitted the experimentation with the “difference between reality and appearance” (Luhmann 2000: 85). However, in the post-human society, interactivity becomes a “politic” dimension because of its new role in technology. Are the network structures devoted to improve the dialogue or to reinforce hierarchical structures? This question becomes pertinent when we observe the existing uses of technology by society, particularly the use of digital objects in art. As personal computers, digital recorders, sensors, and all kinds of digital interfaces become available to musicians, dancers, visual, digital and media artists, etc., the art system assimilates these elements in its

structures as recursive operations. We observe people making sound and images with computer, dancing for cameras, tracking data with sensors and playing with interfaces. However, what we usually see is either the machine dominating the human being or the human being using the machine as a slave for her/his purpose. In fact, we tend to reproduce in our relationship with technology the same patterns of oppression and exploitation that inherently drive capitalist and imperialist systems.

The discourse of interactivity reveals the paradox of art: the system produces its own references by distinguishing between perception and communication and excludes the physical world. It doesn't matter how that particular sound in that particular music is generated, if by simple clapping of hands or by complex sound synthesis algorithms. The "materiality" of computers and other digital objects belong to the environment and can never become a "component of the system's operational sequences" (Luhmann 2000:99). Interactivity occurs only if it is embedded in the *forms* of the art system itself, distinguished either as first- or second-order observations. Solely as such it becomes an operation of the system and can be reproduced as communication. This point of view may be interpreted as a criticism of technology in the artistic domain. But it is not. In fact, such a conception of interactivity "resolutely embraces a perspective interested in 'how' things emerge, rather in 'what' they are" (Luhmann 2000:100). And this is quite optimistic.

#### 4. Conclusion

In this article, I showed how the idea of interdisciplinarity, conceived as an expansion of polyphony to the domain of intermedia composition, is developed in the pieces *Circular Roots* (2004) and *Canções dos Olhos (Augenlieder)* (2005). Both pieces explore topics of literary texts (Borges and Saramago) and were created in collaboration with other artists and engineers.

In the first section, I introduce the notion of "polyphonic subjectivity" and the "aesthetics of the machinic" as categories for understanding the changing relation of human subjectivity to the environment.

*Circular Roots* focuses on the visibility and invisibility of the musical gesture in an interactive live-performance composition. Physical gestures of the violinist are captured with different sensors and mapped to parameters of digital image processing algorithms. The relationship between physical gestures and mapping strategies generate different meanings for the intermedia composition. However, I argue that is necessary to adopt a more phenomenological approach of gestures in order to develop an extensive theory of the emergence and generalization of musical gestures (c.f. Hatten 2004). In other words, new musical instruments and interfaces need a new theory of musical gestures.

*Canções dos Olhos (Augenlieder)* focus on the visibility and invisibility of the body in a composition for electronic music, digital image and dance. It explores the topic of invisibility as a metaphor of the blindness generated by the technical apparatuses in our society. Related to the body, the question of interactivity occupies a central place in the aesthetics of this work. I claim that "interactivity" should not be restrained to the human-machine paradigm – a problem that can be observed in the way technology is used by many artists today – but rather should focus on the strategies necessary to make visible the multiple relationships that shape the creative process.



## Notes

[1] Wittgenstein compares musical chords with facial gestures as an example of how the context determines the meaning. He says, for example: “The reinterpretation of a facial expression can be compared to the reinterpretation of a chord in music, we hear it as a modulation first into this, then into that key” (1958: 144).

[2] A detailed description of *Canções dos Olhos (Augenlieder)* is found in Chagas (2006c). The present section elaborates and expands some topics of the former article.

[3] The term “intermedia” was first used by Dick Higgins in 1966, in the context of Fluxus. Higgins allegedly borrowed the idea from Samuel Coleridge (1812). See Higgins (2002: 91-93).

[4] For Flusser, the telematic society is one in which people are devoted to the creative exchange of information in a non-hierarchical network (1985: 177). According to Flusser, the universe of music is made of calculations and computations, which is the essence of digital thinking (1985: 179).

## References

- Ascott, Roy. (2003). *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness*. Berkeley, CA: University of California Press.
- Birringer, Johannes. (2005). *Interaktionslabor*. Retrieved June 30 2007, from <http://www.interaktionslabor.de/>
- Birringer, Johannes. (2005a). *FutureHouse, Blind Mine*. Retrieved June 30 2007, from <http://people.brunel.ac.uk/dap/futurehouse.html>
- Birringer, Johannes. (2005b). *Performing Art Performing Science*. Retrieved June 30 2007, from <http://people.brunel.ac.uk/dap/paps.html>
- Borges, Jorge Luis. (1970). *Fictions*. London: Penguin.
- Cavell, Stanley. (2000). *Excursus on Wittgenstein's Vision of Language*. In: *The New Wittgenstein*. Alice Crary and Rupert Read (eds.). 21–37. London; New York: Routledge.
- Chagas, Paulo C. (2003). *Polyphony, Form, Art Sonore*. Ph.D. Dissertation, Université de Liège [not published].
- Chagas, Paulo C. (2005). “Music and embodiment: a critical approach of the theory of autopoiesis.” *Trans – Revista Transcultural de Musica*: 9. URL: <http://www.sibetrans.com/trans/trans9/chagas.htm>
- Chagas, Paulo C. (2006a). “Virtuality and Metadesign: Sound Art in the Age of Connectivity”. In: Erkki Pekkilä et al (Ed.) *Music, Meaning, and Media*. *Acta Semiotica Fennica XXV (Approaches to Musical Semiotics 11)* (pp. 137-53). Helsinki: International Semiotics Institute.
- Chagas, Paulo C. (2006b). “Game and dialogue: Composing with machinery”. In: Eero Tarasti (Ed.) *Music and the Arts*. *Acta Semiotica Fennica XXIII (Approaches to Musical Semiotics 10)* (pp. 157-70). Helsinki: International Semiotics Institute.
- Chagas, Paulo C. (2006c). “The Blindness Paradigm: the Invisibility and Visibility of the Body.” *Contemporary Music Review* 25.1/2: 119-30.

- Deleuze, Gilles & Guattari, Félix. (1997). *A Thousand Plateaus: Capitalism and Schizophrenia*. Translated by Brian Massumi. Minneapolis: University of Minnesota Press.
- Eco, Umberto. (1997). *Art et Beauté dans l'Esthétique Médiévale*. Paris: Bernard Grasset.
- Flusser, Vilém. (1985). *Ins Universum der technischen Bilder*. Göttingen: European Photography.
- Flusser, Vilém. (1994). *Geste: Versuch einer Phänomenologie*. Frankfurt am Main: Fischer.
- Flusser, Vilém. (2000). *Towards a Philosophy of Photography*. Translated by Anthony Mathews. London: Reaktion Books.
- Guattari, Félix. (1992). *Chaosmose*. Paris: Galilée.
- Hansen, Mark B. N. (2004). *New Philosophy for New Media*. Cambridge, MA: The MIT Press.
- Hatten, Robert S. (2004) *Interpreting Musical Gestures, Topics, and Tropes. Mozart, Beethoven, Schubert*. Bloomington, IN: Indiana University Press.
- Hayles, N. Katherine. (1999). *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: The University of Chicago Press.
- Higgins, Hannah. (2002). *Fluxus Experience*. Berkeley, CA: University of California Press.
- Luhmann, Niklas. (1984). *Soziale Systeme. Grundriß einer allgemeinen Theorie*. Frankfurt am Main: Suhrkamp.
- Luhmann, Niklas. (1990). *The Autopoiesis of Social Systems*. In N. Luhmann. *Essays on Self-Reference* (pp. 1-20). New York: Columbia University Press.
- Luhmann, Niklas. (1995). *Social Systems*. Translated by John Bednarz, Jr., with Dirk Baecker. Stanford, CA: University of Stanford Press.
- Luhmann, Niklas. (1997). *Die Gesellschaft der Gesellschaft*. Frankfurt am Main: Suhrkamp.
- Luhmann, Niklas. (2000). *Art as Social System*. Translated by Eva M. Knodt. Stanford, CA: University of Stanford Press.
- Malt, Mikhail. (1994). *Patchwork Librairie Chaos. Référence*. Paris: Ircam.
- Maturana, Humberto R. & Varela, Francisco J. (1980). *Autopoiesis: The Realization of Living*. *Boston Studies in the Philosophy of Science*, vol. 42. Boston: D. Reidel.
- Miranda, Eduardo R. and Wanderley, Marcelo M. (2006). *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard*. Middleton, WI: A-R Editions.
- Saramago, José. (1997). *Blindness*. Translated by Giovanni Pontiero. San Diego: Harcourt.
- Varela, F. J. & Thompson, E., Rosch, E. (1991). *The Embodied Mind*. Cambridge, MA: The MIT Press.

Varela, Francisco J. (1999). The Specious Present: A Neurophenomenology of Time Consciousness. In J. Petitot & F. J. Varela, G. Pachoud, Jean-Michel Roy (Eds.) *Naturalizing Phenomenology: Issues in Contemporary Phenomenology and Cognitive Science* (pp. 265-314). Stanford, CA: Stanford University Press.

Wanderley, M. and Depalle, P. (2004). Gestural Control of Sound Synthesis. *Proceedings of the IEEE*, vol. 92, no. 4.

Wittgenstein, Ludwig. (1958). *Philosophical Investigations*. G. E. M. Anscombe, R. Rhees (eds.). Oxford: Basil Blackwell.

Wittgenstein, Ludwig. (1980). *Culture and Value*. Translated by Peter Winch. Chicago: The University of Chicago Press.

Wittgenstein, Ludwig. (2001). *Tractatus Logico-Philosophicus* [English translation by D. F. Pears and B. F. McGuinness]. London; New York: Routledge.

Wolek, Nathan. (2000). A Granular Toolkit for Cycling74's Max/MSP. Retrieved June 30 2007, from:

[http://www.nathanwolek.com/nathanwolek/papers/gtk\\_SEAMUS2002.pdf](http://www.nathanwolek.com/nathanwolek/papers/gtk_SEAMUS2002.pdf)