Creating an Ecologically Modeled Performance Through the Remote Manipulation of Multiple Soundscapes

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Abstract. *This article presents and discusses the process of creation and development of a sonic art installation entitled "Firefly Destination"; a multimodal interactive artwork developed in PureData (Pd). This is a sonic artwork that aims to explore the remote interaction of distinct soundscapes manipulated in real-time by a single performer. This also focuses on the main goals of ubiquitous music by tackling the interaction of multiple soundscapes and their relations with the performer and listeners. This work uses Skype – a well-known VoIP (voice over internet protocol) – to allow the interaction of performer and soundscapes as agents of a complex open system. Together they create an interactive meta-soundscape, which is a sonic environment formed by sonic features of distant and distinct soundscapes modulated by the performer. This category of artwork may present aspects of self-organization by emerging aesthetical meaning through the ecological modeling of remote soundscapes linked in a computational networked multimodal performance.*

1. Introduction

Nowadays, with the technological resources that we have, it is possible to ponder on how much geographic distances still separate us. It is known that communication and informational digital technologies enable the interaction virtually immediate (perceptually unnoticeable) of audio and image between individuals located in different parts of the planet. This may create a perceptual dystonia from the senses of hearing and sight, as they become virtually immediate, in contrast to other senses such as touch, smell and taste, that are still bound to the limits imposed by the individual's spatial location. Nevertheless, it may seem feasible that audiovisual interactivity is enough to, at certain extent, provide the urgent needs and basic purposes of human remote communication. N the past decade, technology also enabled the mass production of miniaturized and low-cost sensors (equipments that convert physics quantities into electronic signals), such as microphones, video cameras, accelerometers, gyroscopes, compasses, GPS (global positioning system) and so forth. They allow the acquisition of human location, movement, and gestural data, which can be transmitted remotely in real-time, seemingly instantaneously. The interactivity of these new information and communication systems seems to converge so to enable the exploration of multiple medias, such as: sound, gestures and visual information; as building blocks of a large multimodal experience that may ultimately promote the creation of a sonic environment that is not bounded into a single geographic location but spaciously distributed.

The acquisition and virtually immediate transmission of multimodal data, allowed the creation of the project here presented, "Firefly Destination" or DP (from the Portuguese expression: "*Destino Pirilampo*"). DP explores acoustic possibilities that can be generated in the triadic interaction of sound, image and gesture. The advent of electronics in music contributed to the reduction of perceptual distance between its creation – given by the composer and performer – and its reception and interpretation – given by the end listeners. The immaterial registration of sound, through audio recording (being it analog or digital) made possible to indefinitely store an acoustic phenomenon which is intrinsically immaterial and fleeting. The advances of signal processing techniques enabled the manipulation, processing and reuse of recorded sound as well as to collect and transmit these sounds in real-time, which broadened the exploration of new aesthetics in previously unthinkable paths.

However, musical performances are still geographically limited by the imperative need of the members of a musical group to be located in the same physical spot and there remain during all the duration of a performance. Technological advances are still not fully capable of make sure that a formal performance, for example, a classical quartet, could be formed and carried on by a group of musicians spread in remote locations while they play together. There have been several attempts on this matter, as the ones of a weel-known series of videos available on www.youtube.com, titled "Virtual Choir", by Eric Whitacre. Yet, such attempts are still in their early stages of development. They still require a great deal of editing, post-production and still, have to abide by the inevitable delay of each and every online data communication.

As suggested, a major problem for remote computer interactivity in musical performances is the delay, also known by the name of latency. This is specially perceived in the interactions separated by large distances. Latency occurs due to the physical limit of the time interval that sound necessarily takes to travel between its acoustical source and reception. According to [Fornari 2010], this is one of the elements that may have contributed to the classical orchestra, during its evolution, to reach an specific limit in its physical size, in terms of the geographical spread of the musicians inside the orchestra, and consequently the size of stages specially built to fit such musical performances. This limit is approximately 34 meters. Sound takes about 1/10 of a second (100ms) to travel 34m. This interval is also the time lag where the auditory system begins to notice the delay in the sound communication, as reverb or even echo. This author named this concept as LIS (Limit of Interact Simultaneity). Any sound communication between musicians – who normally require a strong synchronization (as in the case of a classical music performance) – separated by a distance larger than LIS will tend to have synchronization problems due to the noticeable delay in their sonic cooperation.

Following the same principle, for the interactions between musicians through internet network, the occurrence of latency, disregarding the actual distance between parts, provides the same limit given by LIS. Consequently, similar problems of musical synchronization will be found even in remote interactions. According to [Barbosa 2010], even considering a hypothetical situation where someone had access to the highest possible speed of data processing, noticeable delay would still be observed. This author mentions that if someone consider the smallest possible length of a peer-to-peer connection between two individuals placed in the opposite sides of Earth, they would be separated by an distance of about 20,000 Km (corresponding to half of the distance of Earth circumference, which is about 40.000km). Even with the data transferred at the speed of light (around 300,000 Km/s) and counting with unrealistic unlimited bandwidth, bidirectional latency would still be present, which would last approximately 133.4ms, which is higher than LIS (100ms), as said before, the minimum tolerable threshold of sound synchronization. This points to the fact that there is no way to avoid the occurrence of latency in remote interactions. On that fact, there are recent researches in computer music of performances that support and take advantage of latency as another element of their artistic development and compositional exploration [Traub 2005]. Considering this context, the work here presented do not try to overcome latency but aims to minimize that, making sound communication dynamic and in real-time. DP creates an interactive sound model that incorporates the inexorable systemic latency of any remote communication. DP does not depend on the synchronization between their formant agents, once that the final result aimed y that is the creation of an interactive meta-soundscape; a soundscape made of multiple soundscapes, which is a form of sonic art that is not particularly dependent on agents synchronization, as normally happens in the case of formalized music.

The following sections will describe DP artwork installation and its relation with the concepts of eco-composition and soundscape.

2. The DP project

The main objective of DP project is to explore and promote the correlation and interactive manipulation of sound objects from remotely distant soundscapes through the transmission of its digital audio into a single centralizing and guiding performer. As mentioned before, its original name is in Portuguese language; "*Destino Pirilampo*" meaning: “Firefly Destination”. For this reason, this project is here also referred by the initials “DP”. The inspirational motif of DP is the comparison of a single centralizer performer in the rle of a light source that attracts revolving sound objects like flying insects. It also borrows inspirational motivation from Lorenz's “butterfly effect” (as explained in section 5) where sonic meaning may emerge out of chaos. The poetic license taken here is based on the assumption that if a flying insect, when attracted to a source of light, eventually finds its own death, then a firefly, which has its own source of light, as meeting with a bigger source of light, may find its own self. The performer represents this light source that attracts and manipulates sound objects from distant soundscapes (the fireflies). Altogether they create a meta-soundscape, representing the realization of its own self essence; a transcending soundscape not restricted by a physical location but inhabiting the cybespace; the immaterial landscape where this virtual soundscape takes place. The performer builds this new soundscape through multiple gestural content as exploring them in a ludic and intuitive manner, dynamically transforming the incoming sound content. This concept focuses on the correlation of remote audio together with visual aid that is created and mediated by digital audio from multiple agents.

Barreiro and Keller [2010] proposes that creative musical or sonic actions can fall into one of three categories: 1) individual activities without direct sonic results, 2) individual activities aiming for immediate audible results; 3) social interaction through the active participation of multiple users. This last category may imply that the interaction between individuals immersed in their soundscapes might foster a new type of action, the adjust or realization of themselves as agents in a new environment [Barreiro and Keller 2010]. In DP project, the environment can be appointed as a content originated from almost all possible sonic interactions. Much of the sound material essential for the construction of this soundscape comes from this interaction. This reciprocity occurs throughout cybespace, where participants (in the role of agents) send real-time audio content that are processed and controlled in a single station, where the performer and the audience are located, thus providing the possibility of creating a meta-soundscape. These characteristics are aligned with the the principles of ecological model, as defined by Keller [2004]. According to this author "Ecological models are the application of sound synthesis processes of interaction between agents and objects in the environment. Each iteration generates a sound event located in a location of space-time. The exchange between agents and objects changes the state of the organism and the material, adapting objects features to the needs of these agents, thus forcing them to change their behavior depending on the profile of its ecological niche. The sound is only one of the products of this interaction, which makes ecological modeling also multimodal [Keller 2004].

In the scope of ecological modelling, there are two types of related strategies for the interaction between composer and listener: 1) the application of artificial niches (the ones not found in nature) and 2) the exploration of natural affordances; natural channels of interaction common to humans in ecological niches [Barreiro and Keller 2010]. The concept of "sonic affordance" is characterized by relationships of sound interpretation between each sound object, each one having its own form of perception. Such forms of perception can arise from multiple factors, making this perceptual experience unique. The creational process of DP is related to the interaction between listener and composer allowing exchanges of information for the production of natural and artificial niches. In the brink of such exchanges the resulting sound may present original characteristics, while still being similar, which is a condition aligned to the fundamental principles of soundscapes and eco-composition, as following defined.

3. From Eco-composition to Soundscape

It might be possible to analyze electroacoustic music from three distinct perspectives: 1) the composer, 2) its sound material and 3) the creational process. Acousmatic music – which aims to seek and use fundamental aspects of sound, setting them apart from any reference or context other than sonic – is a direct descendant of Schaefferian thought and primarily focuses on the figure of the composer [Chion 2009]. This material is compiled and treated as the composer's aesthetics pleases. In a nutshell, acousmatic music can be defined by an aesthetic posture that is based on the composer understanding, in the role of a unquestionable designer of all compositional decisions [Barreiro and Keller 2010]. This sturdy posture of placing the composer in first place and so in absolute control of sonic creation contrasts with other approaches, such as the soundscape composition [Shafer 2001]. Unlike acousmatic music, soundscape composition focuses primarily on the sound material. This one began at Simon Frayser University, in Canada, where composer and educator Murray Schafer established the “World Soundscape Project”. Schafer coined the neologism “soundscape” following an analogy with a landscape of sounds, by mixing the words “sound” and "landscape", thus allowing the inclusion of extra-musical sound material in contemporary musical creation [Keller 2004], as well as the classification of virtually any physical environment as an element of spontaneous creation of soundscapes [Schafer 1997]. Natural soundscapes are generated by multiple sound sources which can be represented as external agents of an open and complex system. Through the process of self-organization, sonic meaning might emerge from this system, in the form of perceptual and cognitive features that undoubtedly characterizes and distinguishes each and every soundscape, where acoustic information is never repeated but its cognition is always similar. For this reason, generating a soundscape, or rather composing it (or even composing a piece of music with sonic elements of natural soundscapes) is not a trivial task. Soundscape are elusive sonic entities. As a matter of fact, once recorded, a soundscape actually ceases to exist. The recording of a soundscape is merely an immaterial registration of a sound phenomenon already over, that has occurred in the past, at the time when it was recorded, as a dynamic, cognitively similar and acoustically unique auditory phenomenon. However, the term “soundscape composition” usually refers to the type of composition using sound material recoded from actual soundscapes. One usual type of soundscape composition is named eco-composition. This is based on the organization of audio fragments of soundscapes in modular structures that form a musical piece. Thus eco-composition creates compositional structures using simple concepts such as modularity and the accumulation of sound material. By means of interactivity, the composer (or even the listeners) can also dynamically adapt the compositional structure of the piece, thereby creating a listening experience which is immersive for the listener that is also one of the composers of such sonic environment. These are definitive and essential characteristics of eco-composition, that focuses on the compositional process rather than in the sound material or the composer.

The work here introduced aims to extend the concept of eco-composition. This paper discusses the possibility of a dynamically intertwining soundscapes materials arriving simultaneously from different and remote locations. Instead of using recorded sounds, DP uses actual audio streaming straight from soundscapes dynamic generation. The DP project welcomes this contrasting mix of distinct soundscapes manipulated by a single performer that processes and blends all sound material to create a new soundscape which transcends the concept of "source bonding", as defined in [Smalley 1990]. This one deals with the cognitive bias, or gestaltic association, that automatically associates sound objects to their respective source contexts. This referential linkage can be understood as an informational flow between sound object and sound source. In DP, this flow is handled by the performer that sometimes makes this association clear, while at other times, such association seems to break apart, giving away the referential link from sound and source. In the meta-soundscape resulting from DP dynamic compositional process, this informational flow enables the emergence of sonic meaning and therefore the understanding and appreciation of this artwork. This is necessarily given by a set of cognitive concepts in common between composer and listener, which permeates the artwork and its audience. Just as in verbal language, where the meaning of words and structures can be understood (decoded), in a non-verbal sonic arts where it is essential that the listeners know the basics of the language in which the discourse is being developed [Denora 2000].

As seen, the interaction is part of the proposition of eco-composition, even collective interaction, where the figure of a single the centralizing composer becomes diffuse or less present. In such systems, materials, methods, format and audience are the integral parts of this compositional process, having the experience of this act as highly significant for the artistic endeavors [Keller 2004]. It is found in this method an open proposal, validating changes between agents and objects in a pre-determined space-time location. DP expands the concept of eco-composition, enabling communication between agents and physically separated objects, thus manipulating them and transcending the obstacle of a single space-time location. As said, DP aims to create a meta-soundscape through sound material acquired from distant and distinct natural soundscapes, where the performer, as the centralizing agent, is the handler of this new soundscape, created by the interactive modification of multiple dimensions of sonifications, thus approaching DP from the compositional processes of ubiquitous music.

4. Ubiquitous Music

In basic conceptual terms, ubiquitous music is made by the interaction of multiple users, handling a myriad of electronic informational technologies. This concept is related to the fusion between computing and natural environment, as proposed by Mark Weiser in late 1980s [Weiser 1991]. As a first condition, one can conceptualize ubiquitous music as coming from the previous context of ubiquitous computing, where the advent of mobile computing, independence and interconnection, devices heterogeneity, wireless infrastructure, pervasiveness, context-awareness, mobility and portability are complementary, at the end, all aiming to be incorporated to a cybernetic environment. These associations tend to allow a dynamic network of interactions between agents, objects and environments [Weiser and Radanovitsck 2011].

The term “ubiquitous”, as used in relation to computing, refers to the existence, availability and access of multiple individuals to a network of information integrated into their daily lives, as is the cyberspace. This same premise is applied in DP, where the sound information is sent in real time by several remote agents. This enables a huge range of sonic possibilities while keeping a reasonable dynamic handling. In order to establish a methodology for modeling ubiquitous music, Fornari [2010] mentions six possible categories: 1) the development of computational models for the acquisition of artistic gesture and its remote transmission, 2) the development of computational models of real-time sound synthesis, which are the core of virtual musical instruments; 3) the integration between these models of sound synthesis and gestural acquisition; 4) the real-time interactivity and intuitive exploration of sound material; 5) the experimentation of acousmatic extended musical techniques; 6) the application of ecological modeling.

In DP project, all areas mentioned above were met, as explained in section 6. Here, massive sonorities containing natural soundscapes are received, manipulated and synthesized by a single performer. These tend to be guided by a non-deterministic control, since such sound events often have a high degree of randomness and unpredictability. For example, if one of the agents is in a park, sending sound content for the DP performer, and suddenly a bird approaches and starts tweeting, this event will be unpredictable for the performer, as well as unlikely to be similarly repeated. The chaotic element that constantly permeates the production of DP refers to the concept of self-organization, which will be treated as follows.

5. From Butterfly Effect to Self-Organization

The butterfly effect is a famous term commonly used to refer to the theory developed by Edward Lorenz, in mid 1962, which is a mathematical model for a certain class of chaotic events. Lorenz, a meteorologist, found that in some circumstances very small variations in the parameters of certain mathematical models would turn to be impossible to forecast a predictable results, for instance, the provision of a particular climate state. The effects of these changes were both quantitative and qualitative. These observations prompted Lorenz to coin the following famous and nowadays memetic phrase: "the flapping of a butterfly's wings in one side of the planet can unleash a tornado on its other side"[1]

Chaotic systems have at their core the principle of taken into consideration both order and disorder, considering them as valid the aspects of uncertainty. Naveira [1998] proposed that chaos theory should be understood as an alternative for the determinism of mathematical formalization, where the results are perfectly predictable; and the uncertainty of stochastic models, where the occurrence of events can not be predicted. It should be noted that the use of the term "chaos", as commonly associated disorder, is here misleading. In science, this term does not necessarily refers to disorder, but to "order masqueraded as randomness" [Naveira 1998]. This concept is used in DP. All material sent via network is foremost taken as valid input, emphasizing them not as disorder or mere error but as masked order guided by randomness. As explained in section 2, the very title of DP ("Firefly Destination") is based on this aesthetical premise, associating the flapping of the wings and the interaction of an insect also with the butterfly effect.

The feature of spontaneously organizing a chaotic stream of data into some form of meaningful information is here seen as a process of self-organization. This concept, in a way, intertwines and formalizes several other concepts nowadays in use, such as "networked organizations", "self-managing teams" and "learning organization" [Naveira 1998]. Relating music and self-organization, Mazolli [1996] presents a proposal to create cycles of sound material occurring through reflexion and feedback. These are: 1) the manner in which the composer begins the work; 2) the number of cycles of sonic interaction; 3) the musical form that gradually arises. Manzolli points out that self-organization in a compositional process tends to become an advantageous tool once it allows spontaneity to be part of the process, as one of the parameters within a complex system. Such possibilities allow the adaptation of interactive models to be incorporated as a way of boosting the composer's creative autonomy. Compositional systems based on interactive models, as defined by Mazzolli [1996], particularly refer to the aspect of interactivity, disregarding the magnitude or the duration of sonic events. What that matters is the compositional dynamics of its temporal merging. This happens in the musical field where composer and performer become parts of a single compositional agent, which enables interactive and improvised structures to spontaneously occur [Mazzolli 1996].

1 http://blog.ap42.com/2011/08/03/the-butterfly-effect-variations-on-a-meme/

6. Method and Results

The computational model of DP was developed in the programming environment of Puredata, also known as Pd (www.puredata.info). Pd is an open-source visual programming platform for real-time data control, analysis, transformation an synthesis. Pd has an extended version named Pd-extended, that comes with several external libraries aggregating capacities other than the ones already present in Pd. Pd-extended, as it is called, can handles several types of data, such as: symbolic; numerical scalar and vectorial; MIDI and OSC; digital audio, image, animation, and video; text files; network protocols; among others [Fornari, 2010]. For the computing development of DP, it was initially used a version of Pd-extended running in Linux operating system. However, there were technical issues in the communication of digital audio data with the computational model of DP that seems to only be possible to solved by the migration of this model to another operating system, such as Windows. A computational model developed in Pd is called a "patch". For the DP project, 3 patches were built. As mentioned in section 4, this model covers all six areas of ubiquitous music, as further explained.

The first patch has visual characteristics which are modified dynamically in relation to their geometric shapes and colors of graphical objects, according to the received audio data and gestural data. This patch also contains the module of gestural data acquisition that acquire real-time data from the performer's gestures (see next figure). They are dynamically captured by the webcam of the machine (a common laptop) where this patch was running. The fact that this is a bodiless gestural interface, as described in [Fornari 2012], allowed the performer to explore intuitive control of the process while keeping the freedom of movements and gestural exploration. Next figure shows a detail of a typical performance of DP.

Figure 1: Detail of the performer gestures during a DP presentation, in front of the complex geometric structure (the green-yellow structure at the background) that is dynamically generated by the computer model (the first patch described above).

The second patch contains a subtractive sound synthesis model that emulates the typical sound of wind, by using a white-noise generator whose digital audio produced is processed by dynamic band-pass digital filters. This synthesis model aims to provide background sonification for the dynamically controlled digital audio streaming received from multiple soundscapes. This “wind-sound” synthesis is controlled by the intensity of gestures, captured by the bodiless interface of the first patch. Details of implementation of this gestural controlled synthesis can be found in [Fonari 2012]. The third patch is a model of digital audio acquisition that receives data from a VoIP (voice over internet protocol) software. In this experiment, the VoIP used was Skype (www.skype.com), a well-known cross-platform application software that allows real-time voice communication of multiple users connected throughout internet. The artistic proposal here presented uses audio data from multiple agents remotely located, realtime connected in conference-call through VoIP, where all audible information data comes as a single audio stream from this connection. This stream of audio, received by the third patch is mixed with the subtractive synthesis of the second patch, which is intuitively controlled in real time by the performer of DP, and also controls the realtime animation rendered on-the-fly by the first patch. Together these 3 patches create a multimedia experience that is immersive, dynamic and ubiquitous.

During the implementation of this project, it was found that digital audio communication between Skype and Pd was not the trivial task previously expected to be implement in Pd running on Linux. While researching and trying some freeware softwares applications, it was found a simple open-source application, developed only to run in Windows, that was able to successfully performed the required communication task. This is the application called Virtual Audio Cable (VAC); a free program able to transfer audio streams from one application to another. If there may be other available open-source applications with similar function, the authors tested only solutions for Linux and Windows, where they found only this one that were successfully able to recognize and to be recognized by Skype. In order to enable audio transfer from Skype to Pd through VAC, one should create two "virtual wires" in this softwares, which will feature input and output of multiple audio channels. Once these virtual cables are created, Skype and Pd will be instantaneously recognized and connected. The following figure shows a snapshot of the integration of these 3 pieces of software (Pd , Skype and VAC) running in Windows.

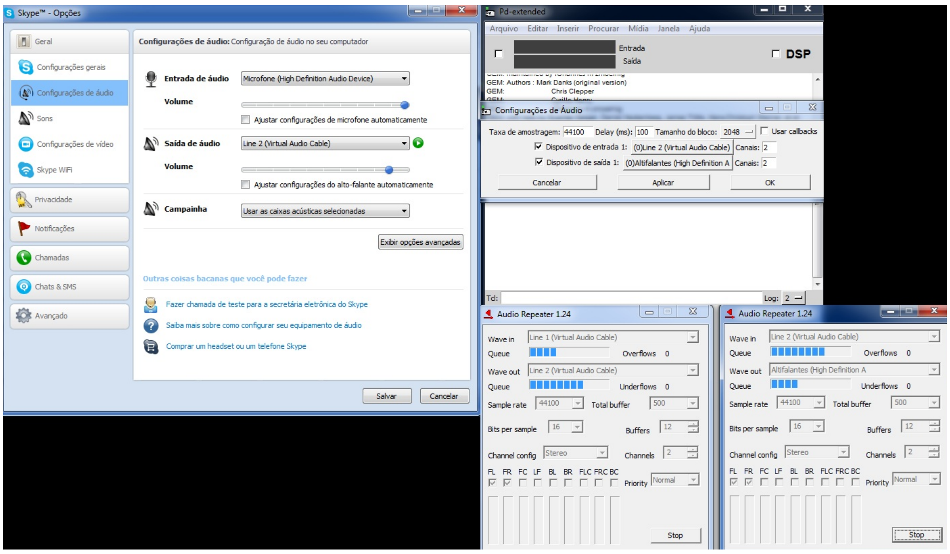

Figure 2: Software integration between: Pd, Skype and VAC; for the DP project.

7. Conclusions

This project aimed the artistic exploration of creating what is here referred by the coined name: “meta-soundscape”; a soundscape created by the audio data acquired and transformed in realtime from multiple soundscapes. This is done by overcoming physical limitations of locality throughout technological resources that allow the apparent reduction of distance between soundscapes remotely located by streaming audio realtime collected into a single location, where the artistic performance of DP takes place.

The fact that more and more individuals are connected through cyberspace, sharing so many types of data and forms of media with multiple users, makes artistic projects such as DP a “natural” consequence. This is a multimodal self-organized performance of social networks which is based in one interactive system that mediates several soundscapes remotely located. Audio data from multiple soundscapes are transmitted via VoIP, enabling the creation of a meta-soundscape that is dynamically manipulated by a single performer. As such, DP is not iconoclastic, but represents a continuation of artistic soundscape composition exploration. While preserving a centralized figure of a single performer, the compositional role is shared among all agents, acting as the producers of new sonic possibilities and meanings, expressed in the resulting meta-soundscape. One of this project premises is the advent of chaos as an enabler of a self-organizing process to generate meta-soundscapes. Through a simple association with the butterfly effect, this project also accepts and uses unpredictable sonic results while maintaining the typical soundscape self-similarity. Its computing development focused on the creation of a modular interface capable of taking multiple streams of sound patterns that can be controlled in real-time during the course of a single performance. This process was designed and implemented through an interconnection between the computational model of DP (compounded of 3 Pd patches), a VoIP (that handles audio data from the soundscapes to stream into Pd), and VAC (that transfer audio data, bridging the VoIP and Pd). This ensures that all initial goals of DP project were achieved and even surpassed. The concept of the concurrent handling of multiple soundscapes extends the premise initially settled by eco-composition, enabling ubiquitous exploration of multiple streams of sound material, which is here understood as a valuable contribution to future researches and artistic endeavors for contemporary computer music composers.

References

Barbosa, A. (2010) “Performance Musical em Rede”. In: Damián Keller e Rogério Budasz (ed.). Criação Musical e Tecnologias: Teoria e Prática Interdisciplinar. Goiânia: ANPPOM, p.97-126. http://anppom.com.br/editora/Pesquisa_em_Musica-02.pdf , Junho.

Barreiro, D. L. e Keller, D. (2010) “Composição com modelos sonoros: fundamentos e aplicações eletroacústicas”. In: Damián Keller e Rogério Budasz (ed.). Criação Musical e Tecnologias: Teoria e Prática Interdisciplinar. Goiânia: ANPPOM, p.97 -126. http://anppom.com.br/editora/Pesquisa_em_Musica-02.pdf , Junho.

Chion, M. (1982) “La musique électroacoustique”. Paris: PUF.

Keller, D. (2004) “Paititi: a multimodal journey to El Dorado”. Tese (Doutorado em Artes Musicais) Stanford University. Stanford, CA. http://portal.acm.org/citation.cfm?id=1048456 , Junho.

Fornari, J. (2010) “Percepção, Cognição e Afeto Musical”. Capitulo de livro da ANPPOM. Título do Livro: “Criação Musical e Tecnologias: Teoria e Prática Interdisciplinar”. ISBN:978-85-63046-01-7.

Manzolli, J. (1996) “Auto-organização um Paradigma Composicional”. In Auto-organização: Estudos Interdisciplinares, Campinas, CLE/Unicamp, ed. Debrun, M. Gonzales, M.E.Q. Pessoa Jr. O. p.417-435,

Naveira, R. B. (1997) “Caos e complexidade nas organizações”. Dissertação de Mestrado. São Paulo: FGV.

Radanovisck, E. A. A. (2011) “MixDroid: compondo através de dispositivos móveis”. Rio Grande do Sul: UFRGS. (Trabalho de Conclusão de Curso). http://www.lume.ufrgs.br/bitstream/handle/10183/31037/000782068.pdf?sequence=1, Junho.

Schafer, R. M. (2001) A afinação do mundo. São Paulo: Ed. UNESP.

Traub, P. "Sounding the Net: Recent Sonic Works for the Internet and Computer Networks". Contemporary Music Review. Vol. 24, No. 6, December 2005, pp. 459 – 481

Smalley, D. (1990) “Spectro-morphology and Structuring Processes In The Language of Electroacoustic Music”, ed. Emmerson, pg. 61-93.

Denora, T. (2003) “After Adorno: Rethinking Music Sociology”. Cambridge University Press. UK.

Weiser, M. (1991) “The Computer for the Twenty-First Century”. Scientific American, v. 265, n. 3, p. 94-101.

Fornari J. (2012) “Designing Bodiless Musical Instruments”. Anais da AES Brasil 2012. 8 - 10 maio. Expo Center Norte. São Paulo. Brasil.

Websites list

http://www.youtube.com/user/nicsunicamp

http://puredata.info/

http://www.skype.com/pt-br/

http://www.virtualaudiocable.net/